

Fostering AI literacy in education: Insights from a targeted teacher training program

Promuovere l'alfabetizzazione all'intelligenza artificiale nell'istruzione: evidenze da una formazione per docenti

JESSICA NIEWINT-GORI*, FRANCESCA STORAI, SARA MORI

INDIRE, Florence, Italy, j.niewint@indire.it*, f.storai@indire.it, s.mori@indire.it

* Corresponding author

HOW TO CITE Niewint-Gori, J., Storai, F., & Mori, S. (2026). Fostering AI literacy in education: Insights from a targeted teacher training program. *Italian Journal of Educational Technology*. Accepted Manuscript Online. <https://doi.org/10.17471/2499-4324/1447>

ABSTRACT This study examines the impact of targeted professional development on teachers' AI knowledge and confidence. 60 secondary school teachers participated in training on AI principles, applications, and classroom integration, using hands-on and collaborative approaches. The study uses a counterfactual design with pre-post measurements and a control and experimental group. The research measured changes in knowledge of AI concepts and affective responses to AI tools. Results show statistically significant improvements in the intervention group across multiple dimensions: general AI knowledge, familiarity with AI technologies and techniques, ability to distinguish AI from non-AI tools, and perceived ease of use. Teachers also reported increased engagement and reduced anxiety about AI integration, despite greater awareness of implementation complexity. Findings demonstrate that structured professional development combining conceptual understanding with practical application effectively builds foundational AI literacy. The results underscore the need for continuous professional development to address the rapid evolution of AI technologies.

KEYWORDS Artificial Intelligence; In-Service Teacher Training; Teaching Practices; Teachers' Perception; AI Literacy.

SOMMARIO Lo studio esamina l'impatto dello sviluppo professionale mirato sulle conoscenze e la fiducia degli insegnanti nell'intelligenza artificiale (IA). 60 insegnanti della scuola secondaria hanno partecipato a una formazione sui principi, le applicazioni e l'integrazione in classe di IA. Utilizzando questionari pre-post, la ricerca ha misurato i cambiamenti nella conoscenza dei concetti di IA e le risposte affettive agli strumenti IA. I

risultati mostrano miglioramenti nel gruppo di intervento su più dimensioni: conoscenza generale dell'IA, familiarità con le tecnologie, capacità di distinguere gli strumenti di IA da quelli non di IA e facilità d'uso percepita. Gli insegnanti hanno segnalato un maggiore coinvolgimento e una minore ansia riguardo all'integrazione dell'IA. I risultati dimostrano che uno sviluppo professionale strutturato che combina la comprensione concettuale con l'applicazione pratica costruisce efficacemente una competenza di base nell'IA. I risultati sottolineano la necessità di uno sviluppo professionale continuo per affrontare la rapida evoluzione delle tecnologie di IA.

PAROLE CHIAVE Intelligenza Artificiale; Formazione Insegnanti; Pratiche Didattiche; Percezione degli Insegnanti; Alfabetizzazione all'Intelligenza Artificiale.

1. Introduction

Artificial intelligence (AI) is reshaping many sectors, and education is no exception. Incorporating AI into educational contexts and teaching its informed use is an indispensable skill for future generations (World Economic Forum, 2024). Unlike earlier information and communication technology (ICT) tools that were also user-responsive (Bonaiuti et al., 2017), the generative power of AI not only has the potential to enhance and make learning experiences more inclusive, but also to be a versatile tool to support the teacher in a broad variety of tasks in their teaching activities (OECD, 2023).

To integrate AI effectively, teachers must develop foundational technical competencies to understand AI's operational mechanisms and build confidence in their ability to use AI tools in educational contexts (U.S. Department of Education, 2023). While ethical considerations surrounding AI integration are critical, they represent complex dimensions requiring dedicated research beyond technical literacy. The complexity of AI integration highlights the need for structured, research-based competence frameworks to guide educators (Ning et al., 2024). Existing frameworks advocate for progressive development of teacher competencies, enabling educators to acquire, deepen, and apply knowledge in ways that align with evolving technological contexts (MIAO & CUKUROVA, 2024).

Projects like the Erasmus+ initiative AI4T¹ (Artificial Intelligence for and by Teachers) exemplify efforts to prepare educators for AI integration. AI4T involved developing professional learning pathways, including a Massive Open Online Course (MOOC) and an open textbook (AI4T), to familiarize teachers with AI's principles, applications, and ethical considerations. Piloted across five countries, the project shows the importance of collaborative, adaptable approaches to teacher training, emphasising critical reflection and practical application of AI in diverse educational settings.

¹ AI4T Project. Artificial Intelligence for and by Teachers - <https://www.ai4t.eu/> Retrieved October 1, 2025

2. Background and Context of the research

Integrating AI tools in educational practice that are accessible and responsive to the diverse needs of learners is critical in fostering inclusive educational environments (European Commission, 2023). To achieve this, teachers require not only digital literacy, but also the capacity to combine this knowledge with pedagogical approaches and content expertise to integrate AI effectively into classroom practices (Ning et al., 2024). A key focus is developing AI and data literacy to foster a clear understanding of these technologies' capabilities and constraints (Markauskaite et al., 2022). This demand for new skills presents both opportunities and challenges for teacher professional development (MIAO & CUKUROVA, 2024) and calls for engagement of teachers in continuous professional development to assure the integration of AI effectively into educational practices (Mori & Niewint, 2024).

2.1. Integrating AI in Education: Dimensions, Challenges, and the Role of Teacher Competencies

The impact of AI in education could be described in three primary areas (see Figure 1): Education for AI, Education with AI, and Education about AI. (Niewint, 2023). Education for AI highlights the cultivation of teacher and learner competencies that enable confident, critical, and safe engagement with AI, without the need for advanced mathematical or programming skills (Council of Europe, 2022). Education with AI explores the integration of AI technologies to enhance teaching and learning by tailoring methods and tools to specific contexts, supporting differentiation (Tomlinson, 2014) and personalisation (Shemshack & Spector, 2020). Finally, Education about AI focuses on foundational concepts such as programming and machine learning, preparing students for workforce demands and shaping curricula to reflect emerging industry trends (Markauskaite et al., 2022).

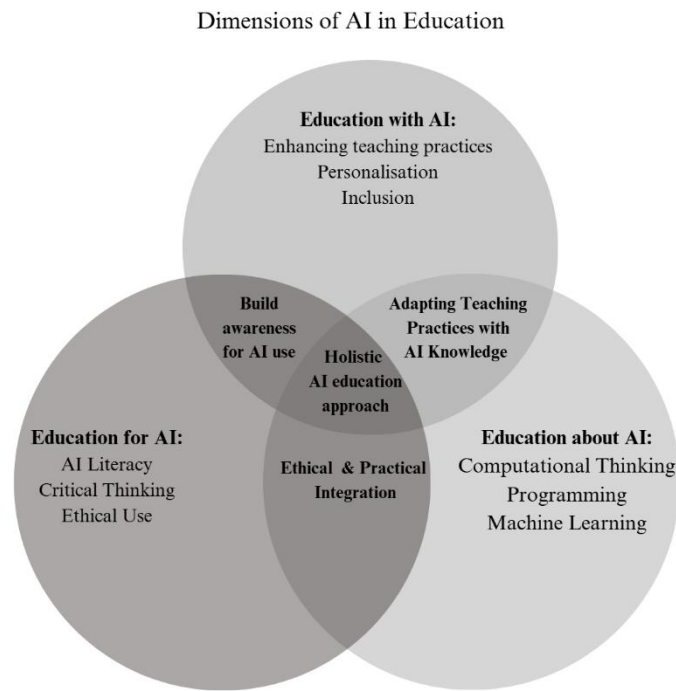


Figure 1: Three dimensions of AI in education.

The current debate about AI in education mostly investigates applications that could be seen at the intersection of the fields “for AI” and “with AI.” (Fu et al., 2024). This highlights the importance of aligning its use with established, research-based frameworks, such as Technological Pedagogical Content Knowledge (TPACK) (Mishra & Koehler, 2006). This framework (see Figure 1), which consists of three key components, provides a foundation for engaging with the unique capabilities of AI. With the emergence of technologies like generative AI (GenAI) technologies, teachers must not only update their knowledge and skills but also develop an understanding of the systemic factors that influence their practices. GenAI tools such as ChatGPT, CoPilot, and Gemini provide educators with on-demand support, instant feedback, and resources to create and differentiate instructional activities. By enhancing classroom practices and fostering meaningful interactions, AI could be a further tool for teachers to meet the diverse and unique learning needs of students more effectively (Goldman et al., 2024).

Beyond learning how GenAI functions and adapting it to meet pedagogical needs, educators must be aware that their actions are shaped also by external constraints over which they have only limited control (Mishra & Warr, 2021). For instance, a teacher proficient in using GenAI to teach topics like Newton’s Laws or literary analysis may meet barriers if district-level policies restrict the use of such tools in classrooms. In this context, the dimension of Contextual Knowledge (CK) (Mishra, 2019) becomes a critical factor in determining the success or failure of technological integration, particularly given the potential of technologies like GenAI to challenge established systems and practices (Mishra et al., 2023).

2.2. *New demands on teachers' skills*

To realise the educational benefits of AI and the digital data, teachers need to actively engage with these technologies and develop AI and data literacy skills, to understand their potential while recognising their limitations. For example, teachers not only must select age-appropriate, pedagogy-driven AI tools aligned with educational goals, but also ideally continuously evaluate their effectiveness and decide whether to adapt existing pedagogies or develop new ones to preserve the human elements of teaching. To do so, teachers need not only to require sufficient knowledge of AI to use and explain tools effectively, but need to stay updated on technological advances, as well as maintain ethical responsibility, including protecting student data and addressing issues like transparency and accountability.

Frameworks such as UNESCO's AI Competency Framework (2024) and the European Commission's Digital Competence Framework for Educators (DigiComp 2.0) (VUORIKARI ET AL., 2022) identify multiple dimensions of AI literacy, including technical knowledge, pedagogical integration, and ethical awareness. While comprehensive AI literacy encompasses all these dimensions, empirical research must carefully delineate which competencies are being measured and developed through specific interventions.

The Council of Europe (2022) highlights AI literacy as essential for all citizens, including knowledge of how AI works and its impact on privacy, cognitive abilities, and personal agency. Teaching about AI needs to address not only its functionality but also fostering a comprehensive understanding of its influence. Frameworks such as AI4K12² Five Big Ideas for AI Education provide a structured approach to teaching about AI, focusing on concepts such as perception, reasoning, machine learning, natural interaction, and societal impact, allowing students to engage as both users and developers of AI systems.

Teacher self-efficacy emerges as a critical mediator between AI knowledge and classroom implementation, making confidence-building a central objective of effective professional development, to enhance teachers' perceived preparedness to integrate AI into daily practice (MacDowell et al., 2024). Beyond technical skill acquisition, professional development can fundamentally reorganise teachers' mental models of AI, demystifying AI's operational logic and establishing cognitive foundations for responsible integration (Kurz et al., 2022). Also, teachers' initial attitudes toward AI predict their willingness to adopt and sustain innovative practices (Kaplan-Rakowski et al., 2023). Given that AI's complexity resembles a broad ecosystem rather than a single tool, teacher preparation must cultivate both competence and confidence simultaneously, positioning educators not merely as AI users, but as informed mediators capable of addressing benefits and risks with students (Fissore et al., 2024).

2.3. *The AI4T Project*

The AI4T Project was a 36-month Erasmus+ initiative (2021–2024), as part of the Digital Education Action Plan (DEAP, 2021–2027). The project aimed to prepare educators to effectively integrate AI into their educational practices. It focused on developing professional learning pathways using two main resources: the “AI4T MOOC”³. and “AI for Teachers: An

² AI4K12 Five Big Ideas for AI Education <https://ai4k12.org/> Retrieved October 1, 2025

³ AI4T Mooc <https://www.ai4t.eu/teacher-training/> Retrieved October 1, 2025

Open Textbook⁴ These resources introduced teachers to the basic principles of AI, educational applications, ethical and legal considerations, and tools for teaching and assessment. The structured training pathway for the teachers emphasized approaches such as collaborative learning, problem-solving, and project-based learning, and the co-design of educational resources focused on critical reflection on AI's broader implications, such as data governance and General Data Protection Regulation (GDPR) compliance. The 'collaborative' dimension took shape through forums and synchronous discussions that allowed for the exchange of experiences and a comparison of teaching practices. The 'adaptable' approach was evident in the possibility of following the modules asynchronously or synchronously, with flexibility in the choice of tools, based on the needs of different national contexts.

The project was piloted in the 2021-2022 school year and extended in 2022-2023. It targeted teachers of mathematics, languages, and other subjects for students aged 15-17. Participants engaged in a variety of formats, including face-to-face, online, sessions, and self-paced learning, with approaches varying by country. Learning outcomes included understanding AI systems, critically evaluating AI tools, and promoting ethical awareness in educational settings.

Evaluation methods combined surveys, interviews, and analysis of teachers' learning trajectories to assess the impact of the programme. Key findings related to teachers' learning, perceptions, and behavioural changes regarding the use of AI in education. Differences in implementation, such as the inclusion of specific AI tools such as ChatGPT⁵ and Kwyk⁶, highlighted the project's adaptability to different educational contexts. The initiative offered valuable insights into promoting AI literacy among educators.

The project explored the knowledge, skills, and tools needed to integrate AI into education ethically and effectively, focusing on teacher training and pedagogical innovation. Collaborating with 17 partners from France, Slovenia, Italy, Ireland, and Luxembourg, AI4T engaged 320 secondary schools and around 1,000 teachers in English and STEM disciplines, working with students aged 15–17. The project aimed to create a validated framework for AI in teaching, enhancing teacher development and student readiness for a digital future. Its five objectives were to build AI understanding, provide AI tools for education, integrate AI into educational software, examine AI's indirect effects, like adaptive learning and data bias, and address AI ethics and data privacy. This article focuses on the results of the experiment conducted in Italy. For a comparison of results between countries, please refer to the Comparative European Evaluation Report (Paris et al, 2024).

⁴ AI for Teachers: An Open Textbook <https://www.ai4t.eu/textbook/> Retrieved October 1, 2025

⁵ OpenAI -ChatGPT [Large language model]. <https://chatgpt.com/> Retrieved October 1, 2025

⁶ Kwyk. [Mathematics learning platform]. <https://www.kwyk.fr/> Retrieved October 1, 2025

3. Methodology

3.1. Aims and hypothesis of this contribution

This study forms part of the broader impact evaluation of the AI4T project and aims to investigate whether there are significant differences between the experimental and control groups. Specifically, the analysis focuses on the general scales of the questionnaires, which are designed to capture the main constructs related to teachers' knowledge of, and emotions towards, artificial intelligence. The theoretical framework is based on the recent UNESCO AI Competency Framework (2024), which identifies five key competencies for sustainable and responsible development: a human-centred mindset; the ethics of AI; the foundations and applications of AI; AI pedagogy; and AI for professional learning. Meanwhile, Fullan's (2007) perspective highlights three fundamental areas for fostering effective change in the classroom: curricular materials, teaching practices, and beliefs or understandings about the curriculum and learning.

The professional training pathway developed within the AI4T project was designed with these frameworks in mind, aiming to provide teachers with technical knowledge and opportunities for reflection and practical experimentation. The primary purpose of this study is therefore to examine whether and to what extent specific training can influence teachers' attitudes and their level of familiarity with AI.

The research questions are as follows:

- 1) Has the training improved teachers' knowledge of AI tools and their use?
- 2) Can training foster more positive perceptions of using innovative tools in the classroom (e.g. ChatGPT, Copilot, Gemini and Kwyk)?

The initial hypothesis is that a professional development pathway involving direct experimentation with tools and practices in a school setting can strengthen knowledge and nurture positive attitudes towards innovation. From this perspective, it is essential to systematically measure the impact of AI-focused teacher training programmes, ensuring that educators are adequately prepared to meet the challenges of innovative education.

3.2. Sample

The recruitment process took place through a public call for applications launched by the Ministry of Education and Merit in January 2023 to select volunteer mathematics and modern languages teachers, working with students aged 15 to 17. Following a review of the responses to the call, 91 secondary schools were selected in line with the project criteria. Schools were chosen based on their institution type, geographical region, and socio-economic background. While the samples were not considered representative of the general teaching population, ministries were encouraged to select socio-economically diverse schools located in different areas.

The Italian AI4T sample initially involved 275 teachers and 1,589 students who completed the questionnaire from 91 schools at the baseline assessment. Participants were randomised at school level. Following the recommendations of Duflo and Banerjee (2017), stratification was chosen as the method of randomisation. The stratification criteria were adapted from country to country, depending on the sample size and their relevance within the national context. Participants were informed of their group, either the intervention or the control group, after the administration of the baseline questionnaire for teachers.

In the first phase of data refinement, students whose teachers were not among the 275 identified in the baseline were excluded, reducing the sample to 1,448 students. The analysis then focused on the subset of 110 teachers corresponding to these students, revealing that 165 of the original 275 teachers had no students who completed the questionnaire. For the statistical analysis, the final sample was structured as follows: 60 teachers in the intervention group, representing 904 students from 28 schools, and 50 teachers in the control group, representing 544 students from 26 schools. Before conducting the impact analysis, the randomisation was verified to have generated comparable groups within each country. To achieve this, a student's t-test was performed on teacher characteristics and the primary outcomes measured at baseline. Significant differences between the two groups are likely in small samples like this. While these differences do not invalidate the randomisation process, they do reinforce the importance of including control variables in the regression analyses. The comparability of the two groups also depends on attrition throughout the experiment. Differences in response rates between the two groups could lead to observable and unobservable differences.

In the final experimental group of 110 teachers, an estimated 73 (66.3%) are women, and 33 (33.7%) are men. The majority have over 20 years of teaching experience, totalling 51 teachers or 46.36% of the sample, indicating that half of the group possesses significant professional experience. Among the subject areas, language teachers constitute 34.5% of the total (38 teachers), followed by mathematics teachers at 32.7% (36 teachers). Science teachers account for 12.3% (14 teachers), computer science teachers for 14.1% (16 teachers), and the "other" category for 6.4% (7 teachers). The distribution across categories is relatively balanced, with a slight predominance of language and mathematics teachers. It is important to note that the selected schools, and so the teachers, have previously taken part in other training projects. This indicates that the sample consists of individuals who already have digital competence or, at the very least, familiarity with certain relevant topics, this may have an impact on the study's results. This aspect is considered in the development of the final guidelines for policies for the implementation of AI in the classroom. Furthermore, as will be highlighted in the results, this aspect emphasises the importance of digital literacy for teachers.

3.3. Research and dataset analysis procedure

The evaluation of the AI4T intervention adopts a mixed-methods approach, combining both quantitative and qualitative data. Questionnaires and interviews were the primary tools for data collection, complemented by additional sources such as learning analytics derived from teachers' activity on the MOOC and produced by Loria. The evaluation protocol, along with all instruments, was reviewed by an ethics committee in each participating country, and full approval was granted to the evaluators to carry out the study. Teachers, School Principals, and selected student classes were invited to complete online questionnaires. To assess the impact of the AI4T professional learning pathway, teachers were asked to complete the questionnaire twice: once at the start of the intervention and again at its conclusion. In contrast, school leaders and students responded only once, at the end of the project, providing contextual insights. Teachers and school leaders accessed the questionnaire via generic links and were assigned individual evaluation codes. Students filled in the questionnaire during class time under the supervision of school staff, using their teacher's evaluation code to log their responses.

The teacher questionnaires focused on the key outcomes of the study: teachers' knowledge, perceptions, and use of AI. In the baseline version, teachers were asked to report basic demographic and professional information (e.g., gender, teaching experience). In the endline version, teachers who had taken part in the intervention were invited to reflect on their level of

engagement and satisfaction with the training. In this study, the analysis draws on scales derived from the teacher questionnaire. The data were collected for all participating countries. Initially, the databases were cleaned to minimize missing data. When a participant submitted more than one response, the most complete entry was retained. If multiple responses had the same level of completeness, the first submission was preserved. Incomplete responses were included only if the participant had completed at least the initial result form. The pre- and post-test results from the Italian sample were analysed using R software. R was chosen because it offers a wide range of statistical packages, enables analyses to be reproduced through scripting and allows complex datasets to be handled flexibly (Field et al., 2012). Furthermore, its open-source nature makes it a transparent and widely recognised tool in academic research.

Analysis of Variance (ANOVA) was employed. ANOVA is a statistical technique used to test whether the means of two or more groups differ significantly by partitioning the total variance into components associated with different sources of variation. Within the counterfactual design, this method is particularly useful as it enables a rigorous comparison between experimental and control groups, allowing researchers to determine whether the observed effects can be attributed to the intervention rather than to random variation (Montgomery, 2019).

3.4. Tools

For the administration of the questionnaires, the Ministry of Education distributed generic links to teachers and school managers via their official email addresses. To access the questionnaires, individual evaluation numbers were assigned to each participant. The teachers' questionnaires addressed key aspects of their knowledge, perceptions, and use of AI. During the baseline phase, teachers were also asked to provide contextual information, such as gender and teaching experience. At the conclusion of the study, teachers who participated in the intervention were additionally surveyed regarding their commitment to and satisfaction with the intervention.

This study uses data from both the pre-training and post-training questionnaires to explore the following areas: Tools used in the classroom; Knowledge of generative AI tools; Emotions experienced when integrating AI into classroom activities. The questionnaires employed Likert scales with 5-, 6-, or 7-point response ranges, depending on the specific items. To assess the impact of training, five key dimensions of AI literacy were measured, each represented by a validated scale: general AI knowledge (K4), which evaluates conceptual understanding of AI capabilities and limitations; familiarity with AI technologies (K5), assessing recognition of specific AI techniques and approaches; ability to distinguish AI from non-AI tools (K6AI), measuring discrimination between AI-enabled and conventional technologies; perceived ease of use (E1), examining confidence in operating AI tools; and affective responses to AI (F2A), capturing emotional engagement, anxiety, and enjoyment related to AI integration. Below is the structure of the scales and response ranges for each dimension (see Tables 1-5). For transparency and replication, the complete item wording and response options are provided, enabling reuse and benchmarking across studies.

Table 1. Evaluation of participants' general knowledge of AI: this scale asked the degree of agreement with respect to the following statements.

K4. For each statement, indicate how confident you are that they are true or false for current AI-based systems	Response options	
AI tries to mimic human cognitive functions	1-6	I am very confident it is false I am pretty confident it is false I am not confident, but I think it is false I am not confident, but I think it is true I am pretty confident it is true I am very confident it is true
A single AI product can perform many different tasks in a wide variety of areas.		
AI can be trained using datasets		
AI can display racial or sexist prejudice		
AI always takes the form of a robot		
AI is conscious of what it does		
AI can analyse learner's answers		
AI can analyse learner's behaviours		
AI can model a learner		
AI can model a content that will be taught		

Table 2. Participants' familiarity with AI technology: investigated the degree of familiarity with respect to some AI technologies.

K5. How familiar are you with these AI technologies	Response options	
Machine learning	1-5	Totally unfamiliar Rather unfamiliar Rather familiar Familiar Very familiar
Neural network		
Deep learning		
Supervised learning		
Reinforcement learning		
NAL v-coding		
Clustering		

Note: 'NAL v-coding' is a fictitious term included as an attention check to detect inattentive responding among genuine AI concepts.

Table 3. Evaluation of participants' ability to distinguish between AI tools and non-AI tools: investigated the degree of confidence with AI tools.

K6AI. Would you say that the following technologies fall under the umbrella of AI?	Range answer	
Automatic translator (e.g. Deepl, Google translate, etc.)	1-6	I am very confident it doesn't I am pretty confident it doesn't I am not confident, but I think it doesn't
Recommender system (e.g. products recommendations on Amazon)		

Slideshow software (e.g. Microsoft PowerPoint, Prezi, Google slides, etc.)		I am not confident, but I think it does I am pretty confident it does I am very confident it does
Intelligent tutoring system		
Spreadsheet (e.g. Excel, Google sheets, etc.)		
Automated essay grading software		
Digital workspace		
Interactive quiz software (e.g. Kahoot, Quizizz, etc.)		

Table 4. Teachers' perceived ease of use of AI: measured the degree of agreement on the usability of AI.

E1. Do you agree with the following statements? In my work as a teacher...	Response options	
Learning to operate AI tools is/would be easy for me	1-7	Strongly agree Agree Generally, agree Neither agree nor disagree Somewhat disagree Disagree Strongly disagree
I (would) find AI tools easy to use.		
It is/would be easy for me to become skilful at using AI tools.		
I (would) find it easy to get AI tools to do what I want them to do.		

Table 5. Teacher's enjoyment (Christensen & Knezek, 2009; Noiwan et al., 2005) of AI , measured the degree of agreement on emotions with AI.

F2A. Do you agree with the following statements? In my work as a teacher...	Response options	
The challenge of learning about AI is exciting	1-7	Strongly Agree Agree Generally agree Neither agree nor disagree Somewhat disagree Disagree Strongly disagree
Learning to use AI tools makes/would make me anxious		
I (would) enjoy using AI tools		
Using AI tools is/would be stimulating		
Using AI tools makes/would make me anxious		
I am afraid of making mistakes if I use an AI tool.		
I am afraid that AI tools will malfunction when I or my students use them.		
I (would) enjoy conducting class sessions in which my students use AI tools		
Conducting class sessions in which my students use AI tools makes/would make me anxious		

The scales are designed to measure teachers' confidence and familiarity with AI, as well as their knowledge of and attitudes towards using it in education. By measuring these aspects both before and after the training, the design allows assessment of the extent to which the intervention may have enhanced them among participating teachers compared to those who did not take part in the programme.

4. Results

Pre-intervention assessment confirmed no statistically significant differences between the intervention group (T) and control group (C) across all measured scales, establishing baseline equivalence. Post-intervention analysis of the endline questionnaire revealed significant between-group differences across five dimensions of AI literacy and affective response. Table 6 presents the descriptive statistics and significance tests for scales showing statistically significant differences ($\alpha = 0.01$).

Table 6. Average and significance control and intervention group.

	avg control C	avg intervention T	p-value	
K4. scale	4.70	5.23	1.30E-04	Significance $\alpha = 0.01$
K5. scale	2.27	3.31	1.79E-07	Significance $\alpha = 0.01$
K6AI.scale	4.47	5.41	2.40E-06	Significance $\alpha = 0.01$
E1. scale	4.76	5.42	5.50E-03	Significance $\alpha = 0.01$
F2A.scale	3.27	2.64	9.82E-03	Significance $\alpha = 0.01$

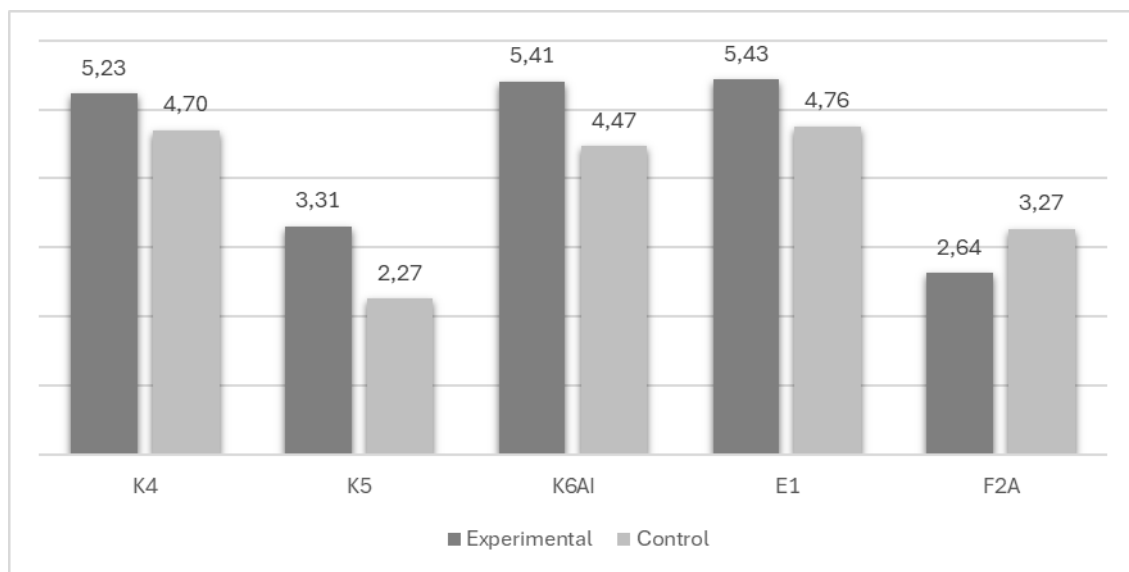


Figure 2. Graphic display of the averages of the two groups.

4.1. Knowledge and Familiarity Domains

Three scales measuring cognitive dimensions of AI literacy show substantial intervention effects. The K4 scale (general AI knowledge) showed the intervention group (T) achieved significantly higher scores ($M = 5.23$) compared to the control group (C) ($M = 4.70$, $p < 0.001$),

indicating strengthened conceptual understanding of AI capabilities, limitations, and operational principles.

The K5 scale (AI technology familiarity) revealed the largest between-group difference, with intervention participants (T) reporting markedly greater familiarity with fundamental AI techniques ($M = 3.31$) versus controls (C) ($M = 2.27$, $p < 0.001$). This substantial gain suggests the training effectively enhanced participants' technical vocabulary and recognition of core AI methodologies including machine learning, neural networks, and deep learning approaches.

The K6AI scale (AI tool discrimination) demonstrated that trained teachers (T) developed superior ability to distinguish AI-enabled technologies from conventional digital tools ($M = 5.41$ vs. C: $M = 4.47$, $p < 0.001$). This critical competency enables informed pedagogical decisions about technology selection and integration.

4.2. Usability Perceptions and Affective Responses

The E1 scale (perceived ease of use) presented the following findings: intervention participants (T) reported lower perceived ease ($M = 5.42$) compared to controls (C) ($M = 4.76$, $p = 0.006$). This apparent paradox could indicate an increased awareness. Trained teachers recognized AI's operational complexity more accurately than untrained peers who may have held overly simplistic assumptions about implementation demands.

Conversely, the F2A scale (affective responses) showed intervention participants (T) reported significantly more positive emotional orientations toward AI integration ($M = 2.64$ vs. C: $M = 3.27$, $p = 0.010$). Lower scores on this scale indicate reduced anxiety and greater enjoyment, suggesting the training successfully built confidence and engagement despite participants' heightened awareness of implementation challenges.

5. Discussion

The results of this study support the transformative potential of AI in education, while highlighting the opportunities and challenges associated with its integration. The training interventions significantly improved teachers' general knowledge and familiarity with AI, equipping them with a clearer understanding of its capabilities. Indeed, about the degree of teachers' knowledge and familiarity with AI tools, evidence shows that the group of teachers who participated in the training (T) gained more knowledge than the control group (C) who did not receive the training. These findings are in line with existing research that emphasizes the importance of targeted professional development to fill gaps in AI literacy (Brandão et al., 2024) and much of the literature in recent years (Chen et al., 2020; Jamal, 2023; Salas-Pilco et al., 2022). The training the participants received appears to have boosted both confidence in AI functionality and familiarity with specific tools such as Machine Learning, Neural Network, Deep Learning, Supervised Learning and Clustering (understood here not as individual tools, but as fundamental AI techniques and approaches introduced at a conceptual level). These findings underline the importance of training courses to enable teachers to effectively use advanced AI tools through a hands-on approach that can enhance understanding of functionality and improve teachers' skills (Ahmad et al., 2021). In addition, data suggest that those who received the training gained greater awareness in the use of AI tools, better understanding the level of complexity and difficulties that can arise from using such technologies (Familoni, & Onyebuchi, 2024; Pedro et al., 2019) and that it takes time to achieve mastery of such tools. In addition, the treated teachers show greater engagement on the beliefs they experienced when

using artificial intelligence in teaching. This could be explained by the fact that having increased awareness and familiarity with such tools, self-efficacy, and emotions in using them have also increased (Kim et al., 2022; Polak et al., 2022). Training, based on sharing and a hands-on approach to AI tools, was important in the AI4T project, as it enabled teachers to have a more positive attitude towards technology.

However, there are some limitations to consider: the data collected mainly concerned teachers' perceptions and did not measure actual behavior, The absence of classroom observations, analysis of lesson artifacts, or longitudinal follow-up limits evidence about the training's impact on pedagogical practice. The sample involved was made up of teachers with an already elevated level of digital competence that allowed them to approach the new AI tools in a more open manner. This self-selected sample of early adopters may have been predisposed toward positive responses to AI training, potentially inflating effect sizes. The studies single-country context and focus on secondary mathematics and language teachers limits transferability to other educational levels, subject areas, or cultural contexts where AI integration challenges may differ substantially. The control group design, while strengthening causal inference, could not account for potential contamination effects if control teachers accessed AI information through other channels during the study period. Also, the relatively short intervention period (one academic year) precludes assessment of whether observed changes persist over time. Research on effective professional development shows that sustained, ongoing support beyond initial training is essential for lasting teacher change (Desimone, 2009), a dimension this study did not evaluate. These results underline the need to expand these interventions and further deepen the understanding of the potential and risks associated with the use of digital tools.

6. Conclusions

The findings of this study support the transformative potential of AI in education, while highlighting both the opportunities and challenges associated with its integration. Training interventions significantly enhanced teachers' general knowledge and familiarity with AI, equipping them with a clearer understanding of its capabilities. These outcomes align with existing research that emphasizes the importance of targeted professional development to bridge gaps in AI literacy (Brandão et al., 2024). Teachers who took part in the training showed improved confidence in distinguishing AI tools from non-AI technologies. This ability is crucial for navigating the increasingly complex landscape of educational technology and ensuring that tools are selected and applied in ways that align with pedagogical goals. The training improved knowledge, familiarity, tool discrimination, and affect readiness precursors most applicable to planning/design and in-class orchestration. Because phase-specific empowerment was not measured, effects on student task design or assessment will be claimed. Future evaluations should add short, phase-specific performance checks so that “empowerment in AI integration” is reported unambiguously by a pedagogical phase. The study also revealed a dual perspective among trained teachers, who recognized the complexities inherent in mastering AI tools, while reporting increased enjoyment and engagement in their use. This suggests that, although challenges remain, structured and hands-on training programs, such as those offered by the AI4T project, are fostering both confidence and motivation among educators. Collaborative and reflective approaches within these programs proved particularly valuable in preparing teachers to integrate AI into diverse educational contexts (Yousef, 2024).

Structured, professional development can build foundational technical knowledge and positive affective orientations toward AI tools among secondary educators. However, comprehensive AI literacy extends beyond these dimensions to encompass ethical reasoning, data governance competencies, and critical evaluation of AI's societal implications. Future research should develop and validate instruments specifically measuring teachers' ethical awareness and decision-making capabilities regarding AI integration. Subsequent studies should investigate on how professional development combining technical training with explicit ethical frameworks influences teachers' capacity to navigate complex issues, such as algorithmic bias, student data privacy, and equitable access to AI-enhanced learning opportunities. Only through research that pairs technical skill development with measurable ethics and governance competencies can the field develop evidence-based approaches to preparing educators for responsible AI integration in diverse educational contexts.

7. Author contributions

Jessica Niewint-Gori authored Section 1 (Introduction) and Section 2 (Background and Context of the Research). Sara Mori authored Section 3 (Methodology) and Section 6 (Conclusion). Francesca Storai authored Section 4 (Results) and Section 5 (Discussion). All authors contributed to the conceptual development of the manuscript, reviewed its content, and approved the final version.

8. Acknowledgements

Part of the research activities presented in this article were conducted within the project Artificial Intelligence for and by Teachers (AI4T), funded by the Erasmus+ Programme for European policy experimentations in the fields of education and training (Project No. 626154-EPP-1-2020-2-FR-EPPKA3-PI-POLICY).

9. References

- Ahmad, S. F., Rahmat, M. K., Mubarik, M. S., Alam, M. M., & Hyder, S. I. (2021). Artificial intelligence and its role in education. *Sustainability*, *13*(22), 12902. <https://doi.org/10.3390/su132212902>
- Bonaiuti, G., Calvani, A., Menichetti, L., & Vivanet, G. (2017). *Le tecnologie educative*. Carocci.
- Brandão, A., Pedro, L., & Nelson Zagalo, N. (2024). Teacher professional development for a future with generative artificial intelligence: An integrative literature review. *Digital Education Review*, *45*, 151–157. <https://doi.org/10.1344/der.2024.45.151-157>
- Chen, L., Chen, P., & Lin, Z. (2020). Artificial intelligence in education: A review. *IEEE Access*, *8*, 75264–75278. <https://doi.org/10.1109/ACCESS.2020.2988510>
- Christensen, R. W., & Knezek, G. A. (2009). Construct validity for the teachers' attitudes toward computers questionnaire. *Journal of Computing in Teacher Education*, *25*(4), 143–155.

- Council of Europe. (2022). *Artificial intelligence and education: A critical view through the lens of human rights, democracy, and the rule of law*. Council of Europe. <https://rm.coe.int/artificial-intelligence-and-education-a-critical-view-through-the-lens/1680a886bd>
- Desimone, L. M. (2009). Improving impact studies of teachers' professional development: Toward better conceptualizations and measures. *Educational Researcher*, 38(3), 181–199. <https://doi.org/10.3102/0013189X08331140>
- Duflo, E., & Banerjee, A. (Eds.). (2017). *Handbook of field experiments* (Vol. 1). North-Holland.
- European Commission, European Education and Culture Executive Agency. (2023). *AI report: By the European Digital Education Hub's squad on artificial intelligence in education*. Publications Office of the European Union. <https://doi.org/10.2797/828281>
- Familoni, B. T., & Onyebuchi, N. C. (2024). Advancements and challenges in AI integration for technical literacy: A systematic review. *Engineering Science & Technology Journal*, 5(4), 1415–1430. <https://doi.org/10.51594/estj.v5i4.1042>
- Field, A., Miles, J., & Field, Z. (2012). *Discovering statistics using R*. Sage.
- Fissore, C., Floris, F., Fradiante, V., Marchisio Conte, M., & Sacchet, M. (2024). From theory to training: Exploring teachers' attitudes towards artificial intelligence in education. In *Proceedings of the 16th International Conference on Computer Supported Education* (pp. 118–127). <https://doi.org/10.5220/0012734700003693>
- Fu, Y., Weng, Z., & Wang, J. (2024). Examining AI use in educational contexts: A scoping meta-review and bibliometric analysis. *International Journal of Artificial Intelligence in Education*, 35(3). <https://doi.org/10.1007/s40593-024-00442-w>
- Fullan, M. (2007). *The new meaning of educational change* (4th ed.). Teachers College Press.
- Goldman, S. R., Taylor, J., Carreon, A., & Smith, S. J. (2024). Using AI to support special education teacher workload. *Journal of Special Education Technology*, 39(3), 434–447. <https://doi.org/10.1177/01626434241257240>
- Jamal, A. (2023). The role of artificial intelligence in teacher education: Opportunities and challenges. *International Journal of Research and Analytical Reviews*, 10(1), 140–146. <https://www.ijrar.org>
- Kaplan-Rakowski, R., Grotewold, K., Hartwick, P., & Papin, K. (2023). Generative AI and teachers' perspectives on its implementation in education. *Journal of Interactive Learning Research*, 34(2), 313–338. <https://www.learntechlib.org/primary/p/222363/>
- Kim, J., Lee, H., & Cho, Y. H. (2022). Learning design to support student-AI collaboration: Perspectives of leading teachers for AI in education. *Education and Information Technologies*, 27(5), 6069–6104. <https://doi.org/10.1007/s10639-021-10831-6>

- Kurz, T., Jayasuriya, S., Swisher, K., Mativo, J., Pidaparti, R., & Robinson, D. T. (2022). Investigating changes in teachers' perceptions about artificial intelligence after virtual professional development. *Journal of Interactive Learning Research*, 33(4), 225–241. <https://www.learntechlib.org/primary/p/221764/>
- MacDowell, P., Moskalyk, K., Korchinski, K., & Morrison, D. (2024). Preparing educators to teach and create with generative artificial intelligence. *Canadian Journal of Learning and Technology / Revue canadienne de l'apprentissage et de la technologie*, 50(4), 1–23. <https://doi.org/10.21432/cjlt28606>
- Markauskaite, L., Marrone, R., Poquet, O., Knight, S., Martinez-Maldonado, R., Howard, S., Tondeur, J., De Laat, M., Buckingham Shum, S., Gašević, D., & Siemens, G. (2022). Rethinking the entwinement between artificial intelligence and human learning: What capabilities do learners need for a world with AI? *Computers and Education: Artificial Intelligence*, 3, 100056. <https://doi.org/10.1016/j.caeai.2022.100056>
- Miao, F., & Cukurova, M. (2024). *AI competency framework for teachers*. UNESCO. <https://doi.org/10.54675/ZJTE2084>
- Mishra, P. (2019). Considering contextual knowledge: The TPACK diagram gets an upgrade. *Journal of Digital Learning in Teacher Education*, 35(2), 76–78. <https://doi.org/10.1080/21532974.2019.1588611>
- Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record*, 108(6), 1017–1054. <https://doi.org/10.1111/j.1467-9620.2006.00684.x>
- Mishra, P., & Warr, M. (2021). Contextualizing TPACK within systems and cultures of practice. *Computers in Human Behavior*, 117, 106673. <https://doi.org/10.1016/j.chb.2020.106673>
- Mishra, P., Warr, M., & Islam, R. (2023). TPACK in the age of ChatGPT and generative AI. *Journal of Digital Learning in Teacher Education*, 39(4), 235–251. <https://doi.org/10.1080/21532974.2023.2247480>
- Montgomery, D. C. (2019). *Design and analysis of experiments* (10th ed.). Wiley.
- Mori, S., & Niewint, J. (2024). Personalization and teaching: Cognitive processes and digital technologies for the development of everyone's potential. *QWERTY: Interdisciplinary Journal of Technology, Culture and Education*, 19(2), 59–80. <https://doi.org/10.30557/QW000086>
- Niewint-Gori, J. (2023). A snapshot of the evolving landscape of artificial intelligence in education. In *Proceedings of Ital-IA 2023 Thematic Workshops* (pp. 455–460). <https://ceur-ws.org/Vol-3486/92.pdf>
- Ning, Y., Zhang, C., Xu, B., Zhou, Y., & Wijaya, T. T. (2024). Teachers' AI-TPACK: Exploring the relationship between knowledge elements. *Sustainability*, 16(3), 978. <https://doi.org/10.3390/su16030978>

- Noiwan, J., Piyawat, T., & Norcio, A. F. (2005). Computer attitude and computer self-efficacy: A case study of Thai undergraduate students. In *Proceedings of the Human-Computer Interaction International Conference (HCII 2005)*.
- OECD. (2023). *OECD digital education outlook 2023: Towards an effective digital education ecosystem*. OECD Publishing. <https://doi.org/10.1787/c74f03de-en>
- Paris, A., Labetoulle, A., Bezjak, S., Butler, D., Cardoso-Leite, P., Chesné, J.-F., Kirsch, C., Mori, S., Nardi, A., Nencioni, P., Niewint, J., Rivera, L., Rossi, F., Toci, V., & Mirazchiyski, P. V. (2024). *AI4T: Comparative European evaluation report*. Laboratoire Formation et Apprentissages Professionnels and Cnesco. <https://hal.science/hal-04557981v1>
- Pedro, F., Subosa, M., Rivas, A., & Valverde, P. (2019). *Artificial intelligence in education: Challenges and opportunities for sustainable development*. UNESCO. <https://hdl.handle.net/20.500.12799/6533>
- Polak, S., Schiavo, G., & Zancanaro, M. (2022). Teachers' perspectives on artificial intelligence education: An initial investigation. In *CHI Conference on Human Factors in Computing Systems Extended Abstracts* (pp. 1–7). Association for Computing Machinery. <https://doi.org/10.1145/3491101.3519866>
- Salas-Pilco, S. Z., Xiao, K., & Hu, X. (2022). Artificial intelligence and learning analytics in teacher education: A systematic review. *Education Sciences*, 12(8), 569. <https://doi.org/10.3390/educsci12080569>
- Shemshack, A., & Spector, J. M. (2020). A systematic literature review of personalized learning terms. *Smart Learning Environments*, 7, 33. <https://doi.org/10.1186/s40561-020-00132-4>
- Tomlinson, C. A. (2014). *The differentiated classroom: Responding to the needs of all learners* (2nd ed.). Association for Supervision and Curriculum Development.
- U.S. Department of Education, Office of Educational Technology. (2023). *Artificial intelligence and the future of teaching and learning: Insights and recommendations*. <https://tech.ed.gov/files/2023/05/ai-future-of-teaching-and-learning-report.pdf>
- Vuorikari, R., Kluzer, S., & Punie, Y. (2022). *DigComp 2.2: The digital competence framework for citizens: With new examples of knowledge, skills and attitudes*. Publications Office of the European Union. <https://doi.org/10.2760/115376>
- World Economic Forum. (2024). *Shaping the future of learning: The role of AI in education 4.0*. <https://www.weforum.org/publications/shaping-the-future-of-learning-the-role-of-ai-in-education-4-0/>
- Yousef, A. (2024). Challenges and best practices in training teachers to utilize artificial intelligence: A systematic review. *Frontiers in Education*, 9, 1470853. <https://doi.org/10.3389/feduc.2024.1470853>