Computers and Education Open 6 (2024) 100184

Contents lists available at ScienceDirect

Computers and Education Open

journal homepage: www.sciencedirect.com/journal/computers-and-education-open

Combining human and artificial intelligence for enhanced AI literacy in higher education

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ARTICLE INFO

Keywords:
Adult learning
Cooperative learning
Collaborative learning
Human-computer interface
Post-Secondary Education
Teaching/Learning Strategies

ABSTRACT

This paper seeks to contribute to the emergent literature on Artificial Intelligence (AI) literacy in higher education. Specifically, this convergent, mixed methods case study explores the impact of employing Generative AI (GenAI) tools and cyber-social teaching methods on the development of higher education students' AI literacy. Three 8-week courses on advanced digital technologies for education in a graduate program in the College of Education at a mid-western US university served as the study sites. Data were based on 37 participants' experiences with two different types of GenAI tools–a GenAI reviewer and GenAI image generator platforms. The application of the GenAI review tool relied on precision fine-tuning and transparency in AI-human interactions, while the AI image generation tools facilitated the participants' reflection on their learning experiences and AI's role in education. Students' interaction with both tools was designed to foster their learning regarding GenAI's strengths and limitations, and their responsible application in educational contexts. The findings revealed that the participants appeared to feel more comfortable using GenAI tools after their course experiences. The results also point to the students' enhanced ability to understand and critically assess the value of AI applications in education. This study contributes to existing work on AI in higher education by introducing a novel pedagogical approach for AI literacy development showcasing the synergy between humans and artificial intelligence.

1. Introduction

Artificial intelligence (AI) has experienced several advancements since its inception and publicization in the 1950s [1]. This was seen most recently in November 2022 with the emergence of large language model (LLM) chatbots, such as *ChatGPT, Gemini,* and *Meta.ai*. AI has become a pervasive part of everyday life in various domains through the massive popularity and use of personal devices. Education is a primary area of implementation due to its immense potential to transform student learning experiences [2].

The incorporation of AI into education has been occurring for approximately sixty years and has been changing how we interact with the world—first with expert programmed learning systems [3], then with systems based on hand-annotated machine learning [4], and more recently, with self-supervised, reinforcement learning [3,5]. Broadly, AI in education can be categorized into three main areas: learning "for," "about," and "with" AI [6]. While there is a substantial body of research focused on learning "*about*" and "*for*" AI, fewer empirical studies have explored applications [7], especially since the emergence of Generative AI (GenAI). GenAI promises to revolutionize pedagogical approaches through personalized and adaptive learning, aiming to enhance educational outcomes [2,8,9]. Consequently, it is important to investigate issues of teaching methodologies, institutional frameworks, access, ethics, equity, bias, and sustainability [10,11] for successful implementation and adaptation. The use of GenAI by both teachers and students also highlights the need for a new type of literacy - AI literacy - crucial for the effective and responsible utilization of these emerging technologies.

AI literacy is a multifaceted concept that encompasses not only the understanding of AI technologies but also their responsible and effective

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https://doi.org/10.1016/j.caeo.2024.100184
Received 14 February 2024; Received in revised form 9 May 2024; Accepted 13 May 2024
Available online 14 May 2024

use, along with the application of critical thinking to their design and implementation [12–15]. Laupichler et al. [7] and Ng et al. [16] describe this type of literacy as the capacity to critically understand, evaluate, and apply AI technologies, without the prerequisite of creating AI models independently. This also involves a spectrum of skills that enable individuals to effectively communicate and cooperate with AI systems and employ AI tools in various aspects of life, including online spaces, domestic environments, and the workplace [17]. These skills have become particularly relevant when GenAI technologies are considered. In light of this, scholars such as Steinbauer et al. [18] and Ng et al. [16] contend that the development of AI literacy should be an integral aspect of K-12 education. Indeed, this type of literacy has become vital for navigating life, academic content, and employment in an evolving, AI-dependent society. Based on this need, recent scholarly work has delved into the field of AI literacy in higher education, uncovering a nuanced landscape of both opportunity and necessity.

For example, Laupichler et al. [7] carried out a scoping literature review on the topic of AI literacy in higher and adult education. Specifically, the scholars aimed to evaluate the current state of the literature, identify thematic foci and recent research trends, and provide recommendations for research and practice. The review focused on 30 articles published since 2021 that explicitly dealt with theoretical or practical aspects of AI literacy, particularly teaching AI skills to non-experts. The analysis undertaken showed that the scope and selected methods reported in the chosen papers were broad, with most works reporting on program assessment and only seven studies (23 %) based on empirical work. Consequently, Laupichler and colleagues emphasized the need for further research in the area, as well as the clarification of relevant terminology and the identification of suitable content for all students, regardless of their backgrounds.

More recently, Sperling et al. [19] conducted a similar review, but the focus this time was on the literature that conceptualizes AI literacy in relation to teachers' diverse forms of professional knowledge, specifically in the context of teacher education. The scholars identified 34 papers that met their inclusion criteria and analyzed them using a combination of quantitative and qualitative methods. The analysis showed that existing studies covered a wide range of topics and used different methodological approaches, but they did not broadly address important aspects of teachers' professional knowledge. For instance, Sperling and colleagues uncovered research gaps in connection with educators' practical and ethical knowledge, suggesting that addressing these gaps could contribute to a more comprehensive understanding of AI literacy in teaching as well as inform AI literacy education in teacher programs.

Cardon et al.'s work [20] also focused on teachers and AI technologies, investigating the challenges and opportunities of AI-assisted writing in business communication as viewed by university instructors. The study involved the participation of 343 communication instructors to understand their opinions on AI-assisted writing and its impact on instruction. The results revealed that the participants believed AI-assisted writing would be widely adopted in the workplace and would require significant changes to instruction, identifying also challenges and benefits. Similarly to Sperling et al. [19], based on their findings, Cardon and colleagues highlighted the importance of developing AI literacy both in connection with educators and students, which would entail the need for a focus on application, authenticity, accountability, and agency.

AI literacy has also been investigated in connection with educational programs or curricula. Specifically, research in this area has examined instructional practices that might result in the development of students' AI literacy. For instance, Kong et al. [21] describe the design, implementation, and evaluation of an AI literacy course for university students with diverse backgrounds, the objective of which was to promote AI literacy and empower participants to understand and work with AI concepts. The course employed a flipped classroom learning approach and focused on conveying AI concepts, rather than technical details, through self-directed reading materials and hands-on experiences. The participants were 82 women and 38 men, who were assessed on their progress in understanding AI concepts. Data were gathered through pre- and post-course surveys and tests, as well as focus group interviews. The findings showed significant improvements in students' understanding of AI concepts, AI literacy, and empowerment, indicating that such educational interventions can bridge gaps in AI knowledge across genders and disciplines. This study also highlights the potential for AI literacy courses to empower a broader range of students as well as foster inclusive education with AI technologies.

Fathahillah et al. (2023) have also investigated AI literacy in connection with university students, examining the opinions of 156 students enrolled in web programming courses relying on blended learning during the COVID-19 pandemic in a department of informatics and computer engineering. The study used a proportional sampling method to distribute a Google survey that probed the participants' views on various aspects of AI literacy. The results showed that the students had a moderate level of understanding of AI concepts and applications. Additionally, Fathahillah and colleagues posited that understanding the advantages and disadvantages of AI, the implications of AI use, and the ethical and legal aspects of AI might have a significant impact on data security and privacy in blended learning instruction. The scholars also believe that further research is needed to explore the complex relationships between AI literacy, ethics, law, and data security and privacy in blended learning models.

AI literacy development has also been explored in connection with language learning in higher education contexts. For example, Hwang et al. [15] applied Oppenlaender's [22] taxonomy of GenAI prompt modifiers in the examination of the role of prompt literacy in second language (L2) university classes. This study involved the participation of 30 L2 English students in Korea, who worked on a GenAI-powered project to create visual representations of English words. Learners showed their understanding of new L2 words through prompts they developed to visually represent the meaning conveyed by the chosen terms. The analysis of the prompts resulting from learners' work showed that they exhibited the same iterative nature reported by Oppenlaender, which entailed exerting various changes to prompts until the desired results were achieved. The findings in Hwang et al.'s study also pointed to noticeable improvements in the participants' vocabulary learning strategies. Additionally, participation in this work appears to have enhanced the students' understanding of human-AI collaboration. This study highlighted the possible contributions of GenAI to L2 education, and it also showed the importance of prompt literacy in the AI era.

In their reflection on the role of GenAI in L2 writing education, Kang and Yi [23] also identified "fine-tuned prompt literacy" as a critical competency for students' growth as effective AI users and multimodal communicators. For example, the researchers described ways in which GenAI can aid in developing multimodal and fine-tuned prompt literacy in L2 writers, and they emphasized the need to offer learners opportunities to critically assess and create AI prompts effectively. Both Hwang et al.'s [15] study and Kang and Yi's [23] reflection underscore the potential of AI in fostering a more dynamic literacy landscape, enabling university students to create more nuanced and contextually appropriate outputs.

The studies discussed in the previous paragraphs have offered information on important aspects related to AI literacy in connection with both educators and students in higher education. Much, however, is still needed, particularly within fields such as social arts and history, media, and education, which have not been widely examined. The purpose of this work is to contribute to the existing body of work on AI literacy in higher education by addressing calls for more empirical work (e.g., [7, 19]) as well as by bridging existing gaps. To do so, we investigate what students in a postgraduate education program believe are effective ways of developing their AI literacy. Specifically, this study focuses on graduate university students' perspectives, with the objective of answering the following **research question:** *How do university students' exposure to*

and work with AI review mechanisms and AI-image generation tools influence their perceived AI literacy development? Through this exploration, this research aims to set the stage for a future where AI literacy is not only technical expertise but rather a holistic understanding that aligns with humanistic values and ethical considerations.

To achieve this goal, the study explores machine and human collaboration through review mechanisms within the context of student AI literacy. This investigation is grounded in the notion of cognitive prostheses, which views digital technologies as learning process enrichment. That is, technological developments, such as computers, smartphones, and AI tools, are able to not only increase the accessibility and capabilities of cognitive tools and can shape how individuals interact but can also complement and augment human cognition and the capacity to convey meaning [24]. Grigsby [25] believes that the human cognitive system is limited in its capacity to perform tasks such as memory retention, attention span, sensory processing, comprehension, and visualization. Therefore, by harnessing the power of AI, we can augment human cognitive skills and create a symbiotic relationship between humans and AI. As a result, AI can be leveraged as a cognitive prosthesis to create engaging experiences that seamlessly enhance our understanding and capabilities.

This study was conducted at a public university in the US, and it involved the participation of students from three 8-week post-graduate courses. The focus of these classes was the use of advanced digital technologies in education. Two key applications were involved in this work: (1) the use of a specialized AI review tool in conjunction with human peer reviews for assessing complex essays, and (2) the employment of AI-based image generation tools for obtaining reflections on student learning experiences. In the next sections of this paper, we introduce the study and discuss its results. This is followed by the presentation of pedagogical suggestions and the limitations of this work.

2. Methods

2.1. Participants

This study was conducted across three 8-week online courses within the College of Education at a midwestern university in the United States. The recruitment of participants for this work was carried out through course announcements. Even though the study was based on curricular content and activities, participation in it was voluntary and not a requirement for course enrolment. Sixty-one students were enrolled in the courses; however, only 37 volunteered to participate in the study, completed all parts of the data collection process, and were considered in the analysis.

These participants were of mixed demographics, with the majority of them being white females between 25 and 45 years old (Table 1). All of them were pursuing graduate academic degrees ranging from certificates (5 %) and master's (65 %) to doctoral degrees (30 %). Their main academic backgrounds were 'Education' (37.8 %) and 'Humanities' (16.2 %) (Table 2), and they were all concurrently maintaining professional careers as education professionals, either as instructors, administrators in educational institutions, instructional designers, or consultants.

The participants reported varied levels of exposure to AI technologies prior to the study. While 22 % stated they were 'Very familiar' with AI and machine learning concepts, 54 % claimed moderate familiarity. These levels of familiarity are also reflected in the fact that 57 % of participants reported that they had used an AI tool, such as ChatGPT, Bing, etc., for assessment purposes in academic or professional settings. Notably, 22 % admitted to being 'Not at all familiar' with AI and machine learning concepts. This lack of familiarity aligns with the 73 % of participants who had no prior experience using AI image generation tools. Furthermore, 43 % of participants reported never using AI tools in their daily or professional lives, while 27 % reported usage at a cadence of 'Once a week.'

Table 1
Participants' Demographics.

Age	Percentage	Race/Ethnicity	Percentage	Gender	Percentage
18–24	11 %	*White*	67.6 %	*Male*	30 %
25–35	38 %	*Hispanic/Latino*	16.2 %	*Female*	70 %
35–45	30 %	*Asian*	8.1 %		
45–55	16 %	*Multiracial*	2.7 %		
55+	5 %	*N/A*	2.7 %		

Table 2
Participants' Academic Backgrounds.

Academic Background	Percentage
Education	37.8 %
Humanities (English, Literature, International Studies)	16.2 %
Science (Biology, Chemistry, Mathematics)	10.8 %
Business/Administration (Economics, Human Resources Management)	8.1 %
Engineering (Mechanical Engineering)	2.7 %
Other (Industrial Design, Psychology, Actuarial Science)	10.8 %
N/A	13.5 %

2.2. Educational context

This study focused on students' experience and exposure to AI concepts and tools through graduate-level education courses and their required activities. The study targeted three courses taught during one semester through a joint weekly live session and various asynchronous activities. Collectively, these three classes offered a comprehensive exploration of the dynamics between learning, technology, and pedagogy. Course A contrasted machine and human learning, delving into AI's capabilities and implications in education, while Course B bridged learning theories and educational technology, critically exploring paradigm shifts in psychology and their practical application in digital learning environments. Course C examined diverse pedagogical approaches and the knowledge acquisition process across various educational contexts, highlighting the role of literacy and critical engagement with learning materials. These courses were pre-existing curriculum components and not designed specifically for research purposes. The research opportunity presented itself when students enrolled in these classes, allowing for the observation and analysis of their engagement with AI tools and concepts. Jointly, these classes offered students a complex view of the multifaceted intersection connecting technological advancement and educational practice.

In order to explore students' perceived development of their AI literacy in these classes, a holistic, cyber-social approach was followed, entailing the use of various digital tools and the implementation of diverse collaborative learning practices. These included the following: (a) the application of a social learning platform's GenAI review tool designed and developed by our research lab, accompanied with tutorial videos to facilitate student comprehension of AI tools and their functionality (see also Section 2.3.); (b) the employment of GenAI image generation tools for students' reflections on their experience with AI and peer reviews; and (c) students' critical exposure to topics related to educational technologies and AI through course resources, live discussions, peer lightning presentations, and project creation.

The projects that students were expected to complete in the courses in which they were enrolled (i.e., the three classes of focus) consisted of multimodal critical pieces examining technology, educational theory, and practice. Students chose their topics and then incrementally worked on their projects throughout the semester, receiving both GenAI and peer feedback at different points of the development process. Both

learners' work and the AI and human reviews were based on a rubric[1] drawn from a schema grounded in an epistemological approach to learning (Fig. 1), not solely focusing on cognition but more broadly on knowledge-making activities additionally involving material practices, embodied activity, and socio-emotional engagement [26,27]. Upon submission of a complete draft, students generated an AI review based on this elaborated rubric. Then, they revised their work based on the AI feedback received. Once revisions were finalized, they submitted their work for peer review. Each student further reviewed the work of two other students against the same rubric used by the GenAI tool. Students finally compared the human and machine feedback and then reflected on the review process before their final revision and submission. Fig. 2 showcases the steps followed in the project creation process.

2.3. AI review tool

To design and develop the AI review tool used in this study, a novel approach was implemented, termed "cyber-social research" ([3], p. 88). This methodology, inspired by modern software development practices, synergizes "agile research" approaches [28], with educational design research techniques [29]. The unique approach of this present study involves collaboration between higher education students and research team members in the iterative development of the tool. The development process is dynamic, with software updates being deployed nightly, influenced by user interactions from the preceding day leveraging agile, cyber-social research methods and practices [3].

The AI review tool (Fig. 3), a novel addition to the social learning platform used in this work, interfaces with OpenAI's GPT through an application programming interface (API). This integration enables the provision of automated feedback on the multimodal texts developed by students in their courses, complementing peer and instructor feedback based on the criteria of the course project (see rubric[1]). The tool is designed to accommodate instructors' input of various assessment rubrics, offering AI-generated evaluations of student submissions.

The instructional scaffolding for this tool was augmented with a comprehensive video tutorial, depicted in Fig. 4, which detailed the use of the AI review tool. The video provided step-by-step instructions, demonstrating the entire process—from signing into the platform to obtaining the AI-generated review. Furthermore, the tutorial explained the underlying mechanics of the tool, such as the use as prompts of the same rubric criteria students employ to construct their works. It also referred to the tool's calibration for providing targeted feedback based on a knowledge base pertinent to the courses. The tutorial underlined the necessity for a critical stance towards the AI-generated reviews, recommending their use in conjunction with peer assessments to optimize feedback for student projects.

The AI review tool we designed distinguishes itself through strategic enhancements to the large language model (LLM) it employs. This includes prompt engineering, precision fine-tuning, insistence on transparency, human moderation, and the integration of high-level disciplinary ontologies as supplementary knowledge processes. These modifications were considered vital for the effective application of GenAI in educational environments.

Central to this effort is prompt engineering which is the art of crafting queries for the chatbot to interact with the LLM, emphasizing academic literacies and the structure of knowledge representation. Generative AI excels at automating genre-specific responses [30], and the tool created and used in this research exploits this by guiding the AI to analyze student submissions based on genre characteristics defined in a rubric, thereby providing targeted feedback. Fine-tuning the process then involves curating the LLM with academically valuable texts [31], enhancing its output by prioritizing these over the vast array of less reliable internet sources. This implementation enriches the LLM with extensive scholarly writings, created by the research team and graduate students, aiming to significantly improve the quality of its outputs.

Another key aspect is that transparency and human moderation allow the LLM interactions to be visible to users and, furthermore, to subject AI suggestions to human review. The researchers' AI tool operates with a pedagogically explicit rubric, mirroring the one provided to students. This ensures that human evaluators always cross-check AI-generated advice—whether peers, the students themselves, or instructors. In addition, ontology supplements introduce machine-understandable domain expertise, shaping the LLM's analysis with structured human knowledge. Drawing on the knowledge processes schema outlined in Fig. 1 [32], the suite of pedagogical strategies presented in Fig. 2 was implemented. These strategies, which emphasize collaborative and reflective learning practices, were applied through the designed AI tool aiming to enhance the pedagogical repertoire of educators and support learners in achieving specific educational outcomes. The effectiveness of these strategies is expected to vary depending on their application and adaptation across various disciplinary and educational contexts.

Through all these recalibrations, the aim is to make the AI not just a tool but a collaborator in the educational process, one that respects the nuances of discipline-specific teaching and learning and one that supports the expansion of pedagogical and knowledge repertoires within academic settings.

2.4. Procedures

This investigation employed case study methodology [33,34] using a convergent, mixed-methods approach [35,36] to explore students' perceptions of their AI literacy development in higher education. The mixed-methods approach, integrating quantitative Likert scale data with qualitative insights from open-ended questions and student reflections, effectively addresses the limitations of Likert scales by providing deeper insights into the evolving perceptions and experiences of participants. Since our aim was only to investigate students' views, no other methods were employed to assess AI literacy growth. That is, in this work, our focus was mostly pedagogical, as we sought to unveil technical and methodological strategies to enhance graduate students' AI literacy based on their own experiences as well as suggest ways in which artificial and human intelligence can be leveraged to effectively achieve this goal.

The first source of data in this study consisted of pre- and post-course surveys that probed into participants' perceived AI literacy development in the courses of focus. The surveys were designed and distributed through *Qualtrics* [37], and they were administered at the onset of the semester (pre-course survey) and during its concluding phase (post--course survey).

The pre-course survey (see Appendix A, Table A.1) included five questions aiming to gage participants' experience with AI. Students were first asked to rate their familiarity with AI and machine learning concepts through a single-select Likert scale ranging from 1 (not at all familiar) to 5 (extremely familiar), aiming to ascertain their baseline knowledge. Subsequent questions inquired whether participants had previously employed GenAI tools, like *ChatGPT, Bard*, or *Bing*, for reviewing academic or professional work and, similarly, if they had experience using GenAI image generation tools such as *DALL-E, Midjourney*, or *Stable Diffusion* for educational or work purposes. These single-select, closed questions—with response options of "No," "Maybe," or "Yes"—aimed to shed light on the participants' hands-on experience with AI applications prior to the study. The pre-course survey also sought to measure participants' self-assessed confidence in using AI tools to improve learning outcomes, as well as their confidence in crafting prompts for AI image generation tools. These two questions utilized a single-select Likert scale with options from 1 (not at all

[1] For a schematic view of the rubric, check the following link: https://drive.google.com/file/d/1AeAXykz5uZ8pAXEkT6oJ-q_JLDrvHxLV/view?usp=sharing.

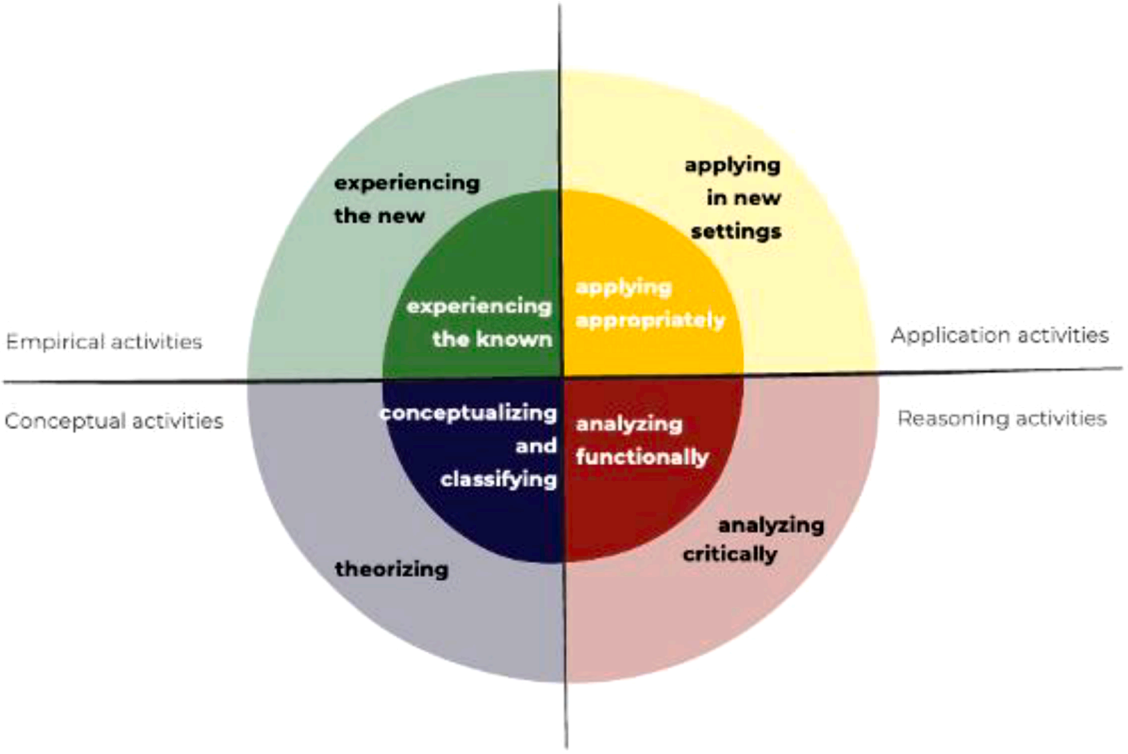

Fig. 1. Knowledge Processes Schema.

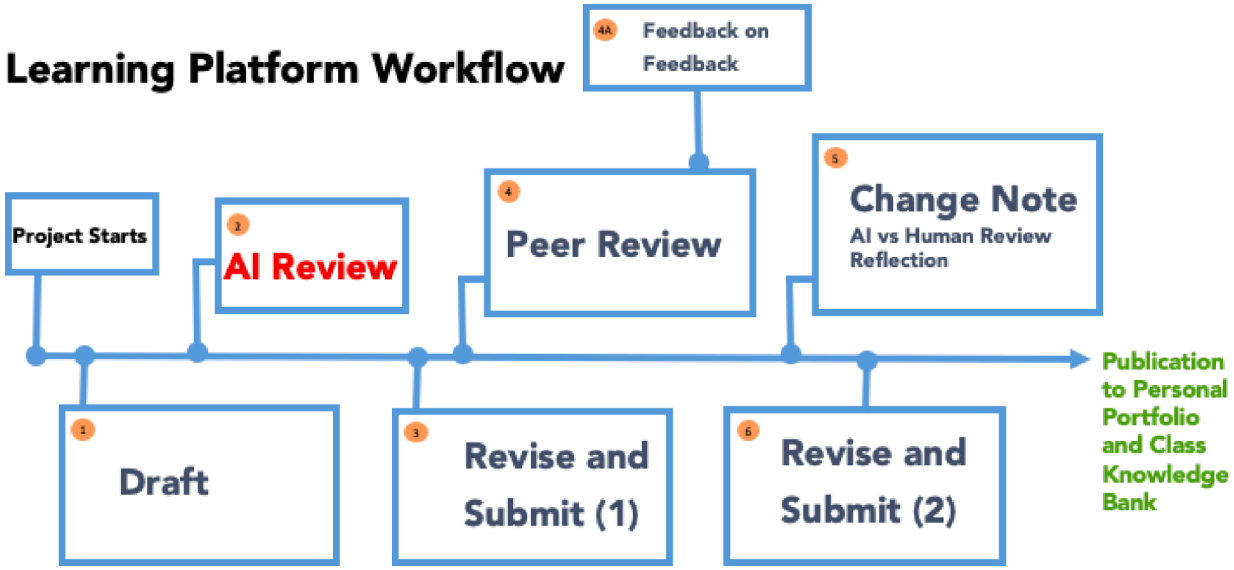

Fig. 2. Project Workflow with Human and AI Reviews.

confident) to 5 (extremely confident), targeting the participants' self-perceived proficiency and comfort level with AI tools.

The post-course survey (see Appendix A, Table A.2) comprised ten questions and targeted participants' views and perceived learning outcomes concerning AI and machine learning concepts after completing the course. Specifically, the survey included four single-select Likert scale questions, which were closed questions allowing students to reflect on their level of familiarity, confidence, and perceived usefulness of AI tools on a scale from 1 (not at all) to 5 (extremely). These questions addressed the participants' familiarity with AI and machine learning concepts, confidence in utilizing AI tools to enhance learning outcomes, confidence in creating prompts for AI image generation, and the usefulness of AI image generation tools for their learning experience. Complementing these, there were six open-ended questions that provided participants with the opportunity to express in their own words their comprehension of AI, explain their confidence levels of using AI tools for learning, describe their knowledge gains about using AI in course processes, articulate their thoughts on combining human and artificial intelligence in pedagogical activities, identify any skills they enhanced related to using AI in the course, and explain why they felt a certain level of confidence in creating prompts for AI image generation.

These surveys provided a framework for assessing shifts in students' perceptions and competency with AI tools before and after their course exposure and use, contributing to the understanding of AI literacy

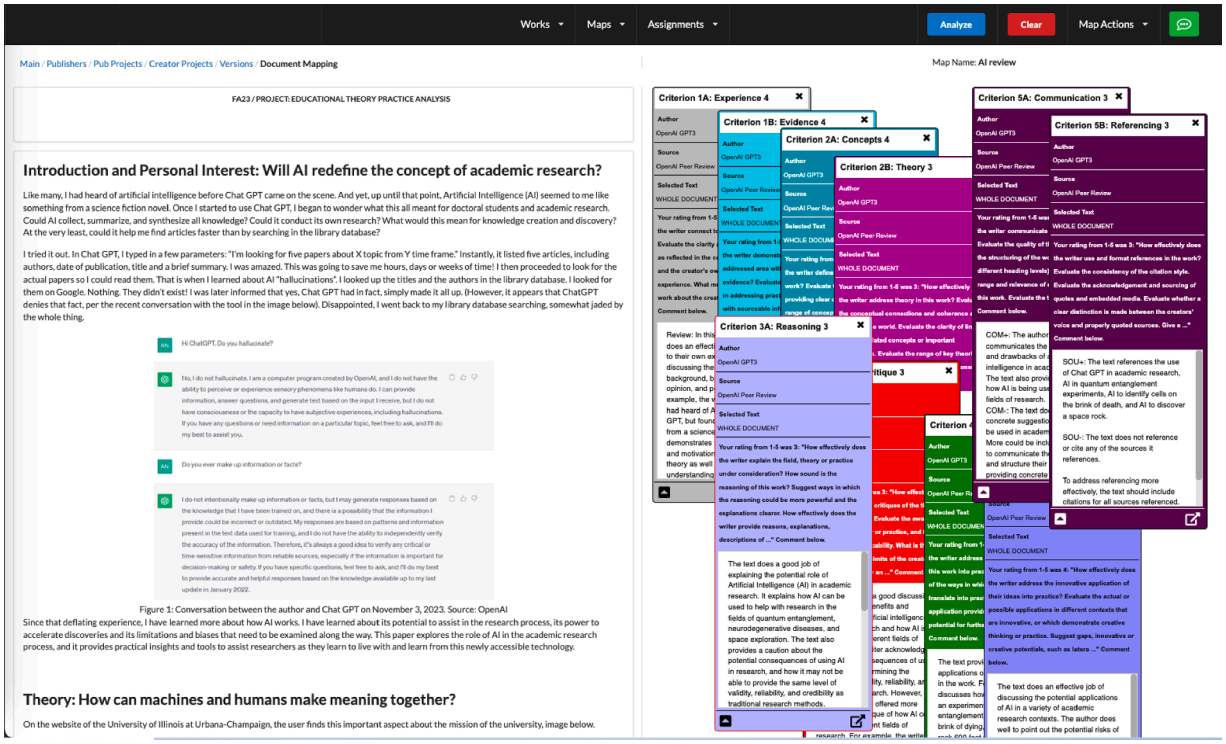

Fig. 3. AI Review of a Course Participant's Work in the AI Review Tool.

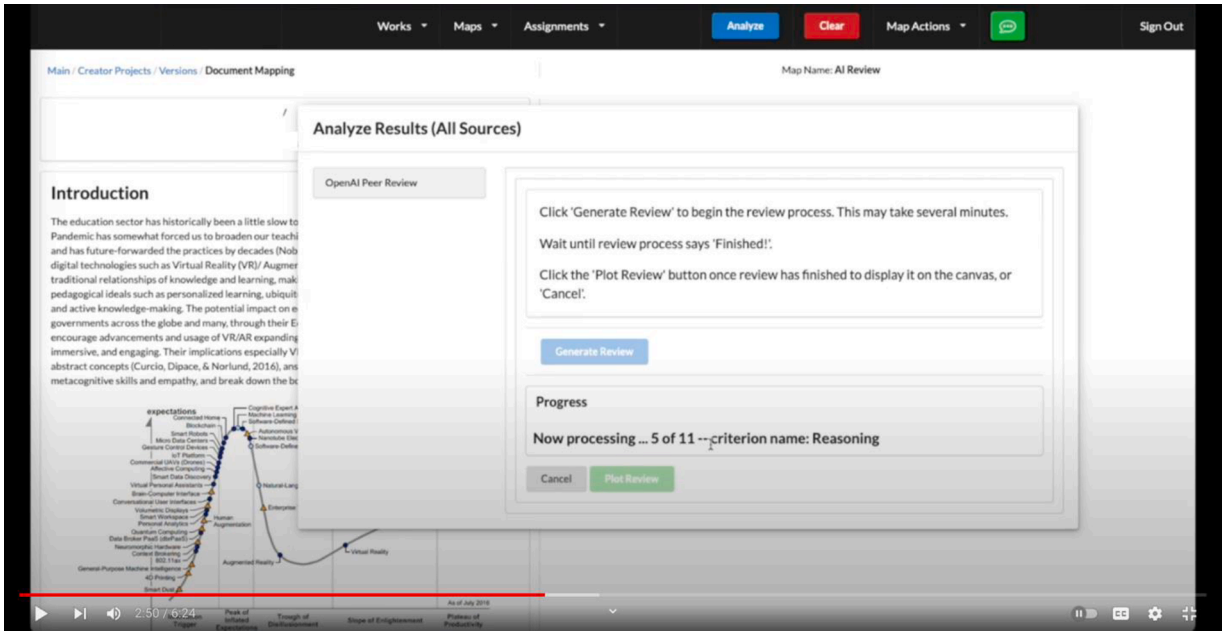

Fig. 4. Screenshot of the video tutorial about the AI review tool.

development in higher education settings. Tables A.1 and A.2 in Appendix A present the specific questions in the pre- and post-course surveys, the response options, and each question's type and goal.

The third source of data for this paper was the participants' written reflections on their AI literacy progress. After students had finalized the post-graduate courses of focus, they were invited to express their perceptions of the ways in which the study's holistic approach might have influenced their AI competence. These reflections were multimodal, and they were guided by two different prompts.

The first prompt offered students the opportunity to employ Generative AI tools to create digital images to convey their experiences with both review types (human and AI) multimodally (i.e., through the combination of visual, gestural, and spatial semiotic resources). Students were provided with a set of recommendations on possible tools they could use, but they were encouraged to employ any that would suit better their needs and preferences. The resulting artifacts were accompanied by textual reflections in which the students assessed the AI tools they had used and described the process they had followed to develop their multimodal works.

The second prompt guided participants to describe, linguistically,

their experiences with the peer and AI review processes. These written descriptions provided insights into their views of the effectiveness of both review types in relation to their work in the courses of focus, as well as the lessons learned for future peer collaboration. These reflections also involved a self-assessment of their AI competence, considering their confidence when using AI tools, their trust in AI outcomes, the impact of the course on their future use of AI in personal and professional contexts, and how they envisioned preparing for the evolving landscape of AI tools.

2.5. Data analysis

The data from the 37 participants who completed both the pre- and post-surveys were subjected to both descriptive and inferential statistical analyses to determine differences between their responses after they had been exposed to AI in the courses. The first step of the analysis consisted of destringing the non-numerical variables into a numerical format for mathematical operations. This resulted in the generation of several dummy variables, primarily focusing on converting Likert-scale responses into numerical values ranging from 1 to 5, where 1 represents the lowest rating and 5 signifies the highest rating. Later, to determine whether there were significant changes in participants' reported familiarity with AI concepts, confidence in using AI tools, and prompt creation skills for image generation, a paired samples *t*-test was employed. This statistical analysis was chosen because it is suitable for comparing the means of two related groups, i.e., in this case, the same participants' pre- and post-survey scores.

The survey's open-ended responses and participants' written reflections on their AI literacy progress were subjected to thematic analysis. This type of analysis has been employed in a large number of studies that have focused on participants' opinions and have relied on similar instruments for data collection [38]. Therefore, it was deemed appropriate for this study. The first step of the analysis consisted of the careful reading of the students' responses and the recording of aspects common to their experiences with AI. In the next stage, themes and exemplifying statements were identified and recorded.

3. Results

This section presents the findings of our study. Our discussion is organized in three different sub-sections. The first one focuses on the pre- and post-course survey data on AI literacy progression. This is followed by the results from the qualitative analysis of students' reflections accompanying the AI image generation artifacts, and textual comments on their overall experience with AI tools.

3.1. Pre- and post-course survey self-reported data on AI literacy progression

In the pre-course survey, the participants disclosed their prior use of AI tools, distinguishing between general applications and AI image generation tools. Even though the majority (57 %) had previous experience with general AI tools such as *ChatGPT, Bard*, and *Bing*, a significant 73 % had not used AI image generation tools, suggesting potential for educational development in this domain. After course exposure to these types of tools, 5 % regarded them as 'Extremely Useful,' 32 % found them 'Moderately Useful,' and 30 % considered them 'Very Useful.' These results suggest that those students with no previous experience with AI image generation appeared to recognize its practical application in an academic setting after their direct interaction and experience with it. Despite these overall positive attitudes, it is important to note that some participants seemed to find little use for this type of AI use, as 22 % characterized it as 'Slightly Useful', and 11 % responded 'Not useful at all.' This result could be related to the participants' area of education, as some students might not have been able to see a use for this type of tool in connection with the subjects they teach or will be expected to teach in the future or their current professional role/responsibilities. This finding could also point to the need for customized educational strategies to maximize AI tool adoption and literacy development based on varied student needs and levels of AI literacy.

The statistical analysis of the pre- and post-course surveys reflects an increase in students' perceived familiarity with AI and machine learning concepts. The data presented in Table 3 suggests growth in the participants' reported understanding of AI and machine learning concepts, as evidenced by the higher mean value in the post-survey as compared to the pre-survey values (3.22 vs. 2.62 in the pre-course survey). This might be indicative of AI literacy development. Additionally, the standard deviation and variance values in the post-survey point to more consistent responses among the participants after their courses. The decrease in these measures of dispersion suggests that the intervention's holistic approach might have led to more consistent comprehension and understanding of the concepts among the participants. Furthermore, the inferential statistical analysis yielded a t-statistic of −3.48, which, combined with the low p-value ($p < .01$) rendered these results significant. These findings appear to complement the change registered in the percentage of students who initially lacked experience with AI image generation tools but, post-course, acknowledged at least a moderate utility for these tools in their learning.

The statistical analysis of the pre- and post-survey data also indicates a reported benefit in students' ability to use AI tools for educational purposes (Table 4). For example, an increase in mean scores in the statements probing into the participants' perceived AI confidence is noted in the post-course survey in comparison with pre-survey values (3.27 vs. 2.41 in the pre-course survey). Specifically, post-course, 55 % of the students indicated that they felt 'Moderately confident' in utilizing AI tools to enhance their learning outcomes, while 30 % chose 'Very' or 'Extremely confident' to characterize their level of confidence with this technology. Additionally, lower standard deviation and variance values post-course (see Table 4) suggest a more consistent reported confidence level among participants, indicating that the study's approach might have not only increased overall confidence, but could also have contributed to a more uniform AI literacy growth across the participant group. The t-statistic and p-value resulting from the inferential analysis suggest statistically significant differences between pre- and post-survey values. These findings, aligned with the previous data suggesting increased perceived usefulness of AI image generation tools, point to the study's possible positive influence on participants' reported confidence and competency in utilizing AI tools for learning, which might have resulted in AI literacy development.

The analysis of the pre- and post-survey statements examining participants' perception of their abilities to craft prompts for AI image generation also suggests positive changes (Table 5). For instance, the mean score in the post-survey was higher than in the pre-survey (3.35 vs. 2.16 in the pre-course survey). This change appears to be supported by the standard deviation and variance values, which point to higher reported AI abilities and more consistency of opinions among the participants (see Table 5). Inferential statistics values offer support for these results, as differences between pre- and post-survey findings are statistically significant. These data highlight the possible positive influence of

Table 3
Statistical Insights into Participants' Evolving Perceived Familiarity of AI and Machine Learning Concepts.

	Mean	Standard Deviation	Variance	t-statistic	p-value	Cohen's d
Pre-course survey	2.62	1.06	1.13	−3.48	0.0013	0.66
Post-course survey	3.22	0.71	0.51			

Table 4
Statistical Insights into Participants' Evolving Perceived Competency in AI Tool Utilization for Learning Outcomes.

	Mean	Standard Deviation	Variance	t-statistic	p-value	Cohen's d
Pre-course survey	2.41	0.96	0.91	−4.64	0.000045	0.95
Post-course survey	3.27	0.87	0.76			

Table 5
Statistical Insights into Participants' Evolving Perceived Proficiency When Generating Prompts for Image Creation.

	Mean	Standard Deviation	Variance	t-statistic	p-value	Cohen's d
Pre-course survey	2.16	1.04	1.08	−6.42	0.00000019	1.23
Post-course survey	3.35	0.89	0.79			

the adopted practices on the participants' development of their AI skills, particularly in connection with prompt generation for AI image creation. This also complements earlier findings showing most participating students' post-course appreciation for AI image generation tools' utility in their learning process.

3.2. Students' reflections expressed with AI image generation tools

The thematic analysis of the participants' reflections showed that the development of their multimodal artifacts had involved an iterative process characterized by trial and error and ad-hoc strategies, both in connection with the generative platforms employed and the creation of textual prompts. For example, most participants first resorted to Open AI's *DALL-E*; however, when the images generated proved to be "very bland and plastic looking" (Participant 1), they moved on to other popular options such as *Lexica, Leonardo AI*, and *Wepik*. The findings also revealed that platform choice had been primarily guided by the ease of use and the creative affordances offered. For instance, Participant 28 chose *Wepik* because it "proved more efficient [than *DALL-E*]. Its flexibility with longer prompts and customization options opened up new avenues for creativity." Nevertheless, the participants' overall impression was that none of the platforms could really reflect the vision they had wanted to convey. While some students found this frustrating, as evinced in the following sample statements, most viewed imperfect AI versions as a source of inspiration, creativity, and learning:

> *"I wasn't getting anything I liked. However, some images were popping up that gave me new ideas for prompts."* (Participant 12)

> *"In the end, I thought this was extremely entertaining. I can see how you might become entranced with becoming a prompt-whisperer and work to refine these generated images."* (Participant 1)

> *"This was such an interesting learning experience. I had no idea what I was doing, but on my second try I found an image [to express] how I felt."* (Participant 22)

Clearly, the participants' image generation entailed several prompt revisions, particularly because all of them sought to convey their meaning metaphorically, employing a variety of semiotic resources. For example, emotions towards and experiences with peer and AI reviews were expressed through facial expressions, body gestures, and size and spatial saliency as well as the use of different colors (e.g., Participant 27 chose blue to represent confusion and yellow for excitement). Some artifacts also relied on figurative tools such as personification or the establishment of analogies between AI and characters from films. Two such instances can be seen in the images developed by Participant 17, who endowed a computer with a human-face mask and also used color symbolically, and Participant 6, who compared the AI with the No-Face character from the animated movie Spirited Away. In the following quotes, these students offer more information on the meaning they attempted to embed in their AI generated artifacts, presented respectively in Figs. 5 and 6:

Fig. 5. Representation of AI Feedback Created by Participant 17.

Fig. 6. Representation of AI Feedback Created by Participant 6.

"The masked computer shows AI posing as intelligent and human-like, but just a fake, hollow representation of one. The melting portrays the 'melting down' I have observed in the process, each AI review being less useful, accurate, and complete than the previous one. The jumbled wires are a mess surrounding the computer - like lifelines, but in a maze of disorganization showing generative AI as a prototype in the infancy of its development. The blank background illustrates the empty promises of AI, yet to be realized." (Participant 17)

"No-Face eats people, and, once he's eaten them, can speak in their voice. That's sort of what AI is like, or how it works: it needs a database of training materials to be able to fluently 'speak.' No-Face also hides behind a mask, a mask that temporarily gives it an expressionless face. This is how I felt reading my AI feedback: it was convincingly written, but off-putting, because of the fact that I know it comes from nowhere: it has no perspective, no subjectivity (or at least I don't think it does, it's not clear to me how it could)." (Participant 6; emphasis in original comment)

The positive effects of prompt development resulting from the AI-generated image activity were also highlighted in the post-course survey results. Specifically, when asked to reflect on their confidence in creating prompts for AI image generation, 82 % of the participants characterized it as 'Moderate' to 'Extremely high,' praising the opportunity to develop the skill of crafting targeted prompts that this task had offered them.

3.3. Students' reflections on AI tools

The thematic analysis of the open-ended questions in the post-survey and students' textual reflections on the significance of AI in their classes suggest that they valued AI feedback, and they considered AI useful for the generation of ideas, content, and the overall support offered throughout the completion of their class projects. For example, participants described AI as a powerful, intelligent, and collaborative tool that enhances productivity and helps develop cognition. This is clearly seen in the opinions expressed by Participant 10, who regarded AI as "a collaboration tool that makes human work more efficient and productive, allowing it to analyze high volumes of information and provide valuable information to improve work." Additionally, students who had first been exposed to AI reviews in the study's classes felt that this experience had served as an introduction to the capabilities of AI tools and had prompted a heightened interest in exploring potential AI applications in their future academic study and work areas. The reflections below offer evidence for these opinions:

"This class has definitely opened the AI door for me. I now know the capabilities of my AI knowledge and will keep developing them as I move forward." (Participant 12)

"I have been using chat GPT for only a few months now. I do feel more confident now. I also think I understand it better." (Participant 14)

"I hope to leverage AI more in my day-to-day life. I already have some experience in prompt generation, but I am not certain how to actually use AI in a specific program. Seeing the innovative uses of AI in this class, such as an AI feedback tool, inspires me to further my personal reach on what I can accomplish with AI." (Participant 19)

Similar views were offered by students who had experienced the study's AI review tool three or more times in previous courses and reported feeling more confident and comfortable incorporating AI reviews into their reviewing process. Furthermore, due to their exposure to AI reviews, these students had begun to integrate AI tools, such as *ChatGPT*, more extensively into their pedagogical practices and personal studies beyond the scope of their post-graduate courses. For example, these participants felt the incorporation of AI into their classes had motivated them to recognize the positive impact that AI could have on their personal and professional lives, which had encouraged them to enhance their skills and abilities in engaging with GenAI tools, such as *ChatGPT*, *Bard*, and more.

The participants' experience with AI feedback also appears to have developed their ability to identify its advantages and disadvantages in comparison with human reviews. These quotes evince the critical assessment resulting from the students' exposure to both types of feedback:

"Comparing AI and peer reviews revealed distinct differences in their approaches and benefits. AI excelled in adhering strictly to rubric criteria, offering an objective evaluation. However, it lacked the personalized, contextually rich feedback that peers provided. On the other hand, peer reviews, despite potential biases and occasional challenges, offered a more informal, content-specific, and empathetic critique. One instance stood out when a peer prompted me to consider what might be lost in the classroom due to the incorporation of AI technology." (Participant 25)

"AI reviews offer rapid feedback but occasionally need help with contextual understanding, as exemplified by my paper's misinterpretation of source titles. On the other hand, peer reviews can provide more depth and more contextually accurate feedback. I adopted AI for initial feedback, especially for identifying fundamental issues. I then used peer feedback for deeper, more contextual insights. This combined approach allowed me to benefit from the rapidity of AI while leveraging the depth of peer insights." (Participant 20)

Overall, the majority of students in this work seem to have regarded both AI and human reviews as invaluable tools in knowledge acquisition. In their view, both types of feedback assisted them in reflecting on their written work, prompting further research to address issues identified by both machine and human peers.

Despite most participants' welcoming attitudes towards AI, there were also recorded concerns associated with privacy, security, and inaccuracies found in some of the comments originating from machine feedback. For example, Participant 30 felt that the AI output "is not 100 % accurate and cannot be considered a source of truth, so it could cause harm in giving false information." This quote points to a vital aspect of AI literacy involving the responsible utilization of AI, including the verification of information produced by GenAI. Participant 28 also made reference to another area of concern connected to AI—its potential biases, pondering on the "ethical considerations [that] should be taken into account when using AI for assessments, especially considering its limitations and potential biases."

4. Discussion

The results from the three sources of data in this work suggest that the participants regarded their exposure to and work with AI tools as significant for the development of their AI literacy. Both the quantitative and qualitative responses recorded in the post-survey and textual reflections point to various reported benefits that mirror previous discussions on AI literacy development (e.g., [12,13]), including skill acquisition, critical thinking, and ethical engagement. Clearly, the participants' engagement with AI reviews offered the opportunity to contemplate broader applications of AI and explore additional AI technologies applicable to both their professional and personal lives. Additionally, the findings offer evidence for a spectrum of student experiences, from those inspired by the imperfect outputs to others who viewed AI as a collaborative partner that augmented their cognitive processes. Most participants, however, highlighted the advantages of the combination of AI and human feedback, which can be considered as a reflection of their maturing AI literacy—one that appreciates AI's strengths as a welcomed addition to human intelligence, but also critically assesses its limitations, including ethical issues connected with its lack of accuracy and possible biases. Also, both the quantitative data and the students' narratives suggest an educational experience that moved beyond traditional learning paradigms, embracing the complexity and

potential of AI as a multifaceted tool in the landscape of higher education.

The analysis of the linguistic reflections that accompanied the AI-generated image submitted by the participants to convey their experiences with AI reviews also appears to support the growth of participants' AI knowledge, and, in turn, the development of their AI literacy. For example, the findings from the recorded reflections mirror those reported in previous studies on prompt generation and university students' AI literacy development. The data show that the participants' work with prompts exhibited the same non-intuitive, trial-and-error characteristics reported by Oppenlaender [22] in his analysis of prompt generation, which he described as a process entailing "iterative experimentation akin to brute force trial and error…[and as] an acquired skill that is associated with a learning curve" (pp. 5–6). The students' comments clearly point to experimentation involving ad-hoc strategies and several attempts, characterized at times by frustration and struggle, before results matching expectations could be achieved. These results were similar to those highlighted by Hwang et al. [15] in their study on AI image generation by university students in Korea.

The complex, multimodal conceptualizations dissected by the participants in their reflections and embedded in their artifacts also underscore the opportunity that AI image generation offered them to develop both their AI and multimodal literacy. That is, tasks like the one included in this study can now be deemed essential in higher education to facilitate students' "understanding and capability to interact with, utilize, and critically evaluate AI systems and their implications" ([15], p. 2) and thus function effectively in the era of AI literacy [7,16]. Clearly, in this work, the participating students need to find the most effective platform and way to visually represent their ideas, resulting in a journey of discovery that strengthens their knowledge of both AI tools and prompt generation. Additionally, the learners' assessment of the generated AI images as well as the changes they made to them to reflect their vision allowed them "to engage in multimodal literacy by considering the relationships among different modes of communication, deciphering intended meanings, and critically evaluating the effectiveness of multimodal presentations" ([23], p. 1). This, in turn, might have resulted in their growth as multimodal communicators and effective AI users.

The overall results of this work suggest that a pedagogical integration of AI tools within human-centric, cyber-social teaching strategies can foster students' abilities to both critically assess and effectively employ AI technologies. The study's data also seem to point to students' growing proficiency and ethical awareness when using AI tools, mirroring the comprehensive educational approach advocated by Laupichler et al. [7]. This work, therefore, not only mirrors calls by Long and Magerko [17] and Steinbauer et al. [18] for comprehensive AI education, but also offers possible actionable insights into the transformative potential of AI in nurturing a society adept at coexisting with advanced technologies.

Considering the implications of these findings, it is important to acknowledge the benefits and challenges of cyber-social teaching. Cyber-social teaching, as described by Cope & Kalantzis [5], offers several benefits, including enhanced cognitive and social learning, balanced learning agency, and productive diversity. It leverages digital tools and social learning strategies to create engaging and collaborative educational experiences. However, it also has limitations, including dependence on technology, risk of surface learning, challenges in assessment integrity, and epistemic provenance issues. Recognizing these limitations is crucial for developing effective and sustainable cyber-social teaching practices. Building on the experiences and insights presented in this paper, we offer pedagogical suggestions in the next section, aimed at harnessing the potential of AI in education and contributing to ongoing conversations about the future of teaching and learning in the age of AI.

5. Pedagogical recommendations

Drawing from the findings presented in this paper, we offer pedagogical suggestions for educators and educational professionals in higher education looking to promote AI literacy in their curricula. We have divided our recommendations into three groups, based on the different aspects of AI literacy highlighted in the literature (e.g., [16]). The three groups–*Instructional Strategies, Reflective Learning*, and *Ethical and Critical Engagement*—are presented separately in the next three sub-sections.

5.1. Instructional strategies

This group of suggestions includes recommended strategies for embedding AI tools into teaching practices, highlighting the value of multimodal tools that align with diverse learning preferences and foster a dynamic, experimental learning environment. These suggestions aim to provide students with opportunities to experiment with AI technologies and develop their critical thinking skills about AI.

- ***Incorporation of multimodal AI tools*:** Educators should consider integrating a range of AI tools that enable multimodal learning. This study showed that students appear to benefit from engaging with various AI platforms, which can cater to different learning styles and encourage creativity. Tools that facilitate visual, gestural, and spatial learning, such as AI image generation tools, can be particularly effective.
- ***Fostering an agile environment*:** Given the iterative nature of working with AI, as evidenced by students' trial-and-error approaches, educators should embrace an agile pedagogical approach that encourages an experimental mindset. Creating assignments that allow for revisions and exploration of different AI functionalities can enhance students' understanding and confidence in using these technologies.
- ***Provision of diverse AI exposure:*** This entails the development of tasks that can introduce students to a range of AI technologies early in their educational journey. This work revealed a gap in experience with AI image generation tools; thus, educators should ensure that students are not only familiar with general AI tools but also with specific applications relevant to their field.

5.2. Reflective learning

In this section, we focus on the role of self-reflection in developing AI literacy, emphasizing the importance of metacognitive activities and peer collaboration in deepening students' critical understanding of AI.

- ***Encouragement of reflective practice:*** The use of metacognitive reflections is crucial for developing AI literacy. Students should be prompted to regularly reflect on their experiences with AI tools, both in written form and through creative expressions like image generation. This reflective practice helps students articulate their understanding and critically assess the role of AI in their learning. This reflection also needs to allow for connections with students' lifeworld, particularly in the case of programs for teachers, such as the ones on which this work is based. This implies that, as part of their critical assessment, student teachers need to consider which technologies would be appropriate in their specific fields and how they could support their practice as well as their own students' learning process and AI literacy development.
- ***Focus on collaborative intelligence:*** Activities that promote collaborative intelligence, where students share knowledge and feedback with peers, can be augmented with AI tools. This approach was shown in the study to enhance students' ability to critically evaluate AI-generated content against human feedback, leading to the development of a critical stance towards AI con in general.

5.3. Ethical and critical engagement

These recommendations address the need for an ethical framework and critical thinking skills in AI education, advocating for a curriculum that balances technological proficiency with an understanding of AI's broader societal impacts.

- ***Reinforcement of critical evaluation skills:*** Educators should guide students in evaluating the strengths and weaknesses of AI tools, fostering an analytical mindset. This includes assessing the quality of AI-generated feedback, understanding the limitations of AI systems, and recognizing the importance of human insights with AI analyses.
- ***Balance of AI with human intelligence:*** This study highlighted the importance of balancing AI tools with human insights. While AI can provide rapid, objective responses, human insights offer depth and context. Educators should design assignments that utilize both types of intelligence to prepare students for the hybrid AI-human interactions they will likely encounter professionally.
- ***Emphasis on ethical considerations***: AI literacy involves understanding the implications of AI; thus, it is important to discuss the ethical aspects of AI use. Topics such as data privacy, bias in AI algorithms, reliability of AI outputs, and steps to mitigate the risks from these implications should be integrated into the curriculum to ensure responsible use of AI.

The findings of this study suggest that a multifaceted approach that leverages the strengths of both AI and human intelligence, while also fostering a collaborative learning environment, can be effective in fostering AI literacy in higher education. These recommendations are aimed at helping educators create a learning environment that not only develops and/or improves AI literacy but also prepares students to navigate the complexities of AI in their future academic and professional endeavors.

6. Study limitations

While this research provides some insights into the impact of interventions on AI-related skills, it exhibits the limitations often found in teaching and learning scholarship, such as the description of a short instructional intervention in a specific educational context with a small number of student participants and the lack of longitudinal data and control group. Also, the study relies solely on self-reported data, which introduces the possibility of response bias. Participants might provide socially desirable responses, impacting the accuracy of their reported familiarity with AI concepts and utilization of AI tools. Furthermore, the small sample size may have affected the statistical power of the analysis, limiting the precision and generalizability of the observed effects. The results are further constrained by the fact that data were collected during one specific academic term. This temporal limitation restricts the generalizability of findings beyond this specific time frame. Seasonal variations, academic workload, rapid developments, including those of our study's software, or other temporal factors may influence participants' responses differently in other terms. Additionally, the targeted courses were graduate-level online courses which might influence the study outcomes compared to undergraduate-level courses of different formats (e.g., in-person or hybrid). Finally, the study focuses on short-term outcomes based only on related responses collected after the courses of focus had been finalized. Long-term sustainability and retention of the reported benefits on students' ongoing academic practices as well as the development of their AI literacy warrant further investigation.

7. Conclusions

The study presented in this paper explores the emerging landscape of AI in higher education, examining the possible dynamic interactions between human and artificial intelligence. This investigation harnessed the synergy of AI tools and human-centric pedagogical strategies to foster a comprehensive understanding of AI among higher education students. The integration of an AI review tool, tailored to course rubrics and complemented by human peer reviews, alongside the utilization of AI image generation tools, not only offered the participating students the opportunity to be exposed to and utilize AI tools, but it might have also contributed to the development of their AI literacy, including the critical assessment of AI's capabilities and its educational value both for their postgraduate learning experiences and their professional educational practice. In our work, the participating students have emerged not just as passive recipients but as active and critical users and evaluators of AI, reporting also the advancement in their AI literacy.

As we move forward, it is crucial that educators, policymakers, and institutions recognize the urgency and depth that AI literacy commands. This study serves as an example of AI's possible impact and the indispensable role it might play in shaping the future of education. Our participants' views invite us to embrace AI not simply as a tool but as an integral, multifaceted partner in the educational journey, paving the way for a society adept at thriving alongside advanced technologies. The insights garnered from this investigation thus underscore the necessity to integrate comprehensive AI education into curricula, ensuring that the next generation of learners is equipped with the knowledge, skills, and ethical framework to harness AI responsibly and innovatively.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the authors used Grammarly in order to improve the text's spelling and grammar. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

CRediT authorship contribution statement

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A

Survey Questions

Table A.1
Pre-course Survey Questions.

Questions	Response options	Goal	Type
On a scale from 1 to 5, how familiar or not are you now with AI and machine learning concepts?	1. Not at all familiar 2. Slightly familiar 3. Moderately familiar 4. Very familiar 5. Extremely familiar	Familiarity with AI concepts	Single-select Likert scale
Have you previously used an AI tool (e.g. ChatGPT, Bard, Bing) for **review** of any academic or professional work?	- No - Maybe - Yes	Previous experience with AI tools for review process	Single-select
Have you previously used an AI image generation tool (e.g. DALL-E, Midjourney, Stable Diffusion) for any academic or professional work?	- No - Maybe - Yes	Previous experience with AI-image generation tools	Single-select
How confident are you in utilizing AI tools to enhance your learning outcomes, e.g. your course project?	1. Not at all confident 2. Slightly confident 3. Moderately confident 4. Very confident 5. Extremely confident	Confidence level	Single-select Likert scale
How confident or not are you in creating prompts for AI image generation?	1. Not at all confident 2. Slightly confident 3. Moderately confident 4. Very confident 5. Extremely confident	Confidence level	Single-select Likert scale

Table A.2
Post-course Survey Questions.

Questions	Response options	Goal	Type
On a scale from 1 to 5, how familiar or not are you now with AI and machine learning concepts after completing this course?	1. Not at all familiar 2. Slightly familiar 3. Moderately familiar 4. Very familiar 5. Extremely familiar	Familiarity level with AI concepts	Single-select Likert scale
Based on your experience through the course, describe in your own words what AI means to you.		Comprehension of AI	Open-ended
After taking this course, how confident are you in utilizing AI tools to enhance your learning outcomes, e.g. your course project?	1. Not at all confident 2. Slightly confident 3. Moderately confident 4. Very confident 5. Extremely confident	Confidence level	Single-select Likert scale
Please explain why you feel confident or not.		Confidence level explanation	Open-ended
After taking this course, how confident or not are you in creating prompts for AI image generation?	1. Not at all confident 2. Slightly confident 3. Moderately confident 4. Very confident 5. Extremely confident	Confidence level	Single-select Likert scale
Please explain why you are confident or not in creating prompts for AI image generation.		Confidence level explanation	Open-ended
How useful or not did you find the AI image generation tool for your learning experience during the course?	1. Not at all useful 2. Slightly useful 3. Moderately useful 4. Very useful	Usefulness of AI image generation tools	Single-select Likert scale

(*continued on next page*)

Table A.2 (*continued*)

Questions	Response options	Goal	Type
	5. Extremely useful		
What do you think about combining human and artificial intelligence as a support for learning? Why?		Feedback on human and artificial collaborative intelligence	Open-ended
What did you learn about using AI in your learning processes from this course?		Discovery of takeaways of using AI in the learning process	Open-ended
What skills did you enhance, if any, after completing this course that are relevant to using AI in learning?		Discovery of perceived skill development related to AI	Open-ended

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