Embedding AI Literacy in Education: A Multidimensional Approach to Fostering Cognitive Liberation

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I. Introduction

Over the past few years, the fast evolution of Generative Artificial Intelligence (GenAI) has essentially transformed the technology field, particularly in education. Generative AI pertains to those machine learning models that can generate original contents in the form of texts, images, audio, or even codes by means of deep learning algorithms. Su and Yang (2023) conceptualized Generative AI as a type of AI that employs algorithms to create new text in a way that is similar to what people write, highlighting the feature of engaging with users in natural language, provoking human-like dialogue and creative responses through conversational interfaces. This ability has spurred the adoption of GenAI in classrooms globally. According to the 2025 HEPI report, nearly all undergrads (92%) reported using AI in some form, and about 88% had used generative AI for coursework alone (Freeman, 2025). GenAI is now showing a disruptive impact in formal learning.

However, this trend of growing reliance is a double-edged sword as there are some consequences. Recent research signals the danger of cognitive degeneration and decreased autonomy of students who heavily rely on GenAI. In an experimental study by Ju (2023), learners showed a 25% drop in accuracy when composing text entirely with AI assistance compared to their independent work. This empirical result signifies potential harm of losing the ability to execute critical thinking outsourced to AI. Moreover, Hou et al. (2025) argue that the overuse of GenAI can undermine peer learning and social interaction, leading to fragmented learning communities with students' reduced autonomy. One peer reviewed study examined adolescents (15-19 years old) and found that students who possess lower executive function (EF) abilities perceive ChatGPT as helpful for completing assignments. However, there was no significant association between AI usage and academic achievement - this implies that there is a high chance that students rely on AI as a cognitive comfort rather than actually using it as a learning aid (Klarin et al., 2025).

Responding to these concerns, the call for comprehensive AI literacy education has risen rapidly. Under this circumstance, AI literacy is no more confined to operational fluency; rather, its concept encompasses technical understanding, ethical reasoning, emotional readiness, and social awareness. AI literacy is defined as a broad competency that includes understanding AI technologies, critically evaluating AI outputs, recognizing bias, and making critical decisions when using AI in real life (Laupichler, Aster, Schirch, & Raupach, 2022). TIn their scoping review, the importance of effective AI education is emphasized as it has the duty of empowering learners to learn how AI functions, and to apply these insights wisely in real-life situations.

In this paper, I argue that effective AI literacy education serves as a form of cognitive liberation, equipping students with mental tools of critical thinking skills, self-efficacy, autonomy, and ethical awareness. To support this thesis, the next following section examines core competency dimensions of AI literacy, and pedagogical approaches.

II. Building Blocks of AI Literacy

The development of AI literacy requires more than a superficial understanding about how AI works. Thus, it must be rooted through a multidimensional framework that addresses various

aspects of learning with and about AI. Research about developing an AI literacy framework, Kong et al. (2024) propose a robust model consisting four dimensions: cognitive, metacognitive, affective, and social.

A. Core Competencies of AI Literacy

The cognitive dimension encompasses students' conceptual understanding of fundamental concepts and principles of AI, including supervised and unsupervised learning, neural networks, and "how these algorithms can be adapted as solutions to real-life problems" (Kong et al., 2024). This dimension also emphasizes the logic and function of AI algorithms as tools for solving real-word problems - the goal is to build a solid conceptual foundation that allows citizens to apply AI responsibly, evaluate their feelings and perceptions toward AI, and understanding the values and limitations of AI at the same time (Kong et al., 2024). However, simply conceptual understanding of AI alone is insufficient to navigate AI in the real-world. One study emphasizes that Gen AI can diminish users' true understanding of what it generates as "models still show basic errors in understanding that would not be expected even in non-expert humans" (West et al., 2023). This confusion underscores the importance of demystifying AI mechanisms.

To complement this insufficiency, the metacognitive dimension focuses on the developing strategies for self-regulation, reflection, and problem-solving in AI contexts (Kong et al., 2024). Through metacognitive strategies, students learn to monitor their own learning processes, critically view outputs that AI provides, and revise their approaches appropriately. According to the research by Kong et al. (2024), Project-based learning (PBL) has shown to enhance these capacities – improving students' metacognitive strategies for problem solving AI and even strengthened their conceptual understanding of AI. It also encourages students to apply AI knowledge to authentic problem-solving tasks while fostering reflection and iteration (Kong et al., 2024). The same study reports that students who experienced PBL scored significantly higher on post-evaluation tests than those who received only lecture-based instruction.

The affective dimension is about students' "physical readiness to interact with AI" - it addresses the emotional and ethical aspects of interacting with AI, including ethical awareness and responsible use (Kong et al., 2024). It emphasizes the significance for learners to perceive the personal and societal consequences of AI applications. This includes educating students to possess a sense of responsibility for the potential harms and benefits generated by the usage of AI. In fact, according to McKinney et al. (2023), learners' emotional states such as anxiety or overconfidence can shape how they trust or misuse AI, which underscores the necessity to integrate emotion-sensitive approaches into AI curricula.

The social dimension of AI literacy enhances students' collaborative skills and understanding the societal impacts of AI technologies. Students must learn to control individual usage of AI with collective ethics, perceiving tensions between technological convenience and social paybacks. This dimension provides an opportunity to students to consider issues such as algorithmic bias, surveillance, and loss of critical thinking skills due to their heavy reliance. Gu and Ericson (2025) refer to this form of "critical literacy" as essential to developing learners in systems which are increasingly shaped by opaque and automated decision-making.

The same empirical research supports the efficacy of its AI literacy framework as 128 secondary students who participated in this AI literacy course demonstrated significant gains in both conceptual understanding and problem-solving performance. The course's PBL design enabled students not only to learn about AI but also to apply it in multiple contexts in their daily lives. The findings of this research address the importance of a well-structured curriculum which indicates multiple dimensions of AI literacy, producing wise citizens in their AI use.

B. Pedagogical Approaches for Fostering AI Literacy

AI literacy can be cultivated through a variety of instructional designs. Project-Based Learning (PBL) improves conceptual understanding and metacognition. As studied by Ng et al. (2024), game-based learning boosts emotional engagement and long-term retention through its interactive mechanism. Tseng and Yadav (2023) propose a scenario-based approach with their *ActiveAI* framework, which engages students through goal-driven situations to foster reflection, critical thinking, and practical experience with AI.

III. Cognitive Liberation

The significance of AI literacy in education truly emerges when it's acknowledged from the aspect of cognitive liberation. To know the concept of cognitive liberation, the concept of critical pedagogy should be accompanied. In the book called *Pedagogy of the Oppressed* (1970), Paulo Freire began to suggest the concept of critical pedagogy. His key concepts for the critical pedagogy was conscientization, and liberatory education. Conscientization refers to the process in which students perceive the social conditions that they belong to. Liberatory education is a type of education which empowers learners to transform their realities through reflection and action. Overall, Paulo Freire's theory argues that the traditional education (so-called the "banking model") treats students as passive agents who merely receive knowledge from instructors. Therefore, he argues that the education should be dialogical - based on continuous interaction between teachers and students. His ideas soon transformed to critical pedagogy. In the context of AI literacy education, critical pedagogy is an educational philosophy which makes students into active participants who are capable of understanding how technologies work, what social impacts they might cause, and what power structures they reinforce or weaken. Rather than merely knowing how to use technologies efficiently, it truly improves their capacity to understand why those technologies exist, who benefits or gets harm from them, and what ethical and social challenges that they may generate.

To briefly conclude, cognitive liberation in AI education refers to both mental and intellectual attainment which leads students to move beyond learning how to use artificial intelligence tools efficiently. Ultimately, cognitive liberation allows students to be equipped with autonomy, self-efficacy, critical thinking skills, and ethical awareness.

A. Autonomy

AI literacy education improves students' autonomy throughout the process of independent decision-making and self-regulation in learning environments influenced by AI systems. In an experimental study by Sengul et al. (2025), they used corss-sectional, descriptive, and correlation design with a quasi experiment to investigate the impact of generative artificial intelligence literacy (GAIL) on self-directed learning skills (SDL) among

undergraduate nursing students in Turkiye. For measurements, they used generative AI literacy scale (GAILS), general attitudes toward AI scale (GAAIS), and self-directed learning scale (SDLS). Among these scales, SDLS is a great proxy of autonomy as it evaluates learners' self-planning ability, goal setting, and independent decision-making. All these three measures are hallmarks of autonomy as it evaluates learners' capacity to initiate, regulate, and reflect their learnings. Particularly, independent decision-making enables learners to make choices about pacing, tools, and problem-solving approaches. This measure shows cognitive control over their own journey. In this experiment, nursing students experienced the AI Literacy Training Program over several weeks. As a result of this intervention, there was a significant increase in self-directed learning. Mediation analysis thus confirmed that AI literacy fosters autonomy both directly and indirectly through improved attitudes. This demonstrates that AI literacy is not merely a tool to improve technical competence, but it's deeply integrated into students' ability to construct their own learning, question the system that they interact with, and improve decision-making skills. These qualities are all components of cognitive liberation. Particularly, the AI literacy intervention applied to nursing students refers to the GAIL (Generative Artificial Intelligence Literacy). As GAIL doesn't mean merely an ability and knowledge about using AI but a complex form which includes related attitudes and competencies to wisely use AI, the measure of SDLS strongly supports the aspect of cognitive liberation.

B. Self-Efficacy

AI literacy education also reinforces students' self-efficacy with the confidence, motivation, and belief that they are able to actively engage with artificial intelligence systems. The relevance of self-efficacy as cognitive liberation in AI literacy education is demonstrated by an experimental study of Ng *et al*. (2023). In this research, they constructed an AILQ (AI Literacy Questionnaire) for middle school students to assess their AI literacy. In those self-report questionnaires, four key dimensions were suggested, which are affective, behavioral, cognitive, and ethical (Ng et al., 2023). Throughout the affective dimension, AILQ measures students' confidence and motivation in interacting with artificial intelligence systems. This study shows that this affective dimension is strongly correlated with self-efficacy, as AI literacy education can develop students' positive feelings, confidence, and motivation toward AI. According to Kong & Yang, 224 secondary school and university students completed an 18-hour AI literacy program. This intervention was established to improve students' AI empowerment, which possesses four core components of AI self-efficacy, creative self-efficacy, perceived impact, and meaningfulness (Kong & Yang, 2025).With the completion of the program, there was significant increase in AI self-efficacy, creative self-efficacy, and meaningfulness. AI self-efficacy refers to the belief in one's ability to successfully understand, use, and navigate AI tools, which reflects personal confidence toward utilizing AI systems. Creative self-efficacy is also a great measurement that reflects self-efficacy as it demonstrates students' belief that they can use AI to generate original ideas or creative solutions. Lastly, meaningfulness is directly tied into self-efficacy – it shows the degree to which students find AI learning socially or personally valuable. Most importantly, these empowerments were not influenced by students' prior knowledge and experiences with AI or gender, suggesting that the cognitive liberation that the program is widely applicable. Ultimately, AI literacy education improves students' self-efficacy by enabling them to understand and evaluate the AI systems, not only learning how to use it. These findings indicate that AI literacy education goes beyond technical acquisition, toward

self-efficacy by cultivating one's capacity to engage with AI technologies with creativity and motivation, which is an essential component of cognitive empowerment.

C. Critical Thinking Skills

AI literacy education facilitates students to cultivate critical thinking skills by guiding them to evaluate AI-generated responses by themselves, and detect bias and misinformation. Vasconcelos and dos Santos (2023) analyzed how Chat GPT and Bing Chat could serve not only as tools for delivering answers to students, but as objects-to-think-with, which refers to the platforms that facilitate reflection, comprehension, and problem-solving skills in students. The researchers analyzed students' interaction with those AI tools and logged these followings: whether students questioned or challenged AI explanations and responses, whether they reorganized their understanding based on the conversation, whether they provided post questions which demonstrate their critical engagement (Vasconcelos & dos Santos, 2023). As a result of using AI tools, there was improvement in reflective thinking, critical thinking, and problem-solving skills. Based on the logs of dialogue, students didn't obediently accept the responses that AI provided. Rather, there was an observed pattern that reinterpreted those responses and coordinated their understandings. Based on the experiment by Promma et al. (2025), the researchers posed the central question as follows: "Can AI literacy (AIL) improve students' complex problem-solving (CPS) skills?" With 420 accounting students in Thailand, they observed whether students could think critically about AI-generated information, and apply both systematic thinking (STS) and intuitive thinking (ITS) in solving complex problems. In this work, they found a positive correlation between AI literacy and STS/ITS (Promma et al., 2025). This correlation demonstrates that experiencing AI literacy can increase STS, ITS, and also complex problem-solving skills. By cultivating the ability to critically evaluate AI-generated outputs and spot out underlying biases, AI literacy education equips students with cognitive liberation which is a state in which they continuously think and judge critically in a technological-driven world.

D. Ethics

By positioning students as reflective moral users rather than passive users of technology, AI education provokes ethical awareness, the process which learners recognize, question, and transform moral implications of AI in their own societies through a critical perspective. Empirical studies underscore how AI literacy programs can improve students' ethical reasoning and awareness. In the study by Usher and Barak (2024), science and engineering students participated in an online explicit-reflective learning module on AI ethics designed to foster their ethical knowledge and awareness. The module integrated case-based learning with ethical frameworks of OECD and IEEE. For instance, this framework encapsulates reflection on real-world dilemmas such as privacy breaches and biased data. To evaluate its effective impacts on students, Usher and Barak employed three indicators, which are ethical knowledge of AI ethics, awareness (subdivided into perceived awareness and actual awareness), and problem-solving skills in AI ethics using pre- and post-intervention questionnaires. The results of this empirical study demonstrated marked improvement across all domains. First of all, there was a striking increase in students' ethical knowledge in AI post-intervention, with an increase in the average score. Among sub-categories, the most significant gain happened in "Possible Solutions to AI Ethical Concerns" which increased from M=2.56 to M=4.56. These increased results indicate that students didn't merely demonstrate an action of identifying ethical problems,

but also envisioned corrective action. Perceived ethical awareness also was strengthened significantly with the sharp improvements on students' confidence to identify and resolve AI-related dilemmas. Their actual ethical awareness measured through open-ended responses almost doubled including average issues recognized and mean awareness score. Mentions of critical components such as biased data, privacy risks, and disclosure ambiguity all increased with the statistical significance ($p<.001$). Altogether, these statistical and quantitative findings demonstrate that AI ethics education can lead to a measurable shift from shallow surface of awareness to deep ethical reasoning, enabling students to equip the ability to exercise moral autonomy and reflective considerations while using AI. These quantitative data do not merely represent the mere increase in scores, rather, they represent the transformation of knowledge about AI from information into ethical awareness which can be applied to the real-world usage of AI empowering individuals to judge and act independently away from the over-trust and heavy reliance toward AI.

IV. Practical Implications of AI Literacy

AI literacy has emerged as a critical education priority - contemporary researchers argue for a systematic and broad integration of AI literacy into education. This idea emphasizes the need to equip students with the ability to question, interpret, and actively engage with artificial intelligence systems. Furthermore, AI literacy is being viewed as a multidisciplinary competency, crucial to students' social and cognitive development.

In recent years, a growing number of literature has highlighted the necessity and importance of escaping from the conventional education which isolates AI-related classes as electives and enrichment programs. For example, scholars such as Gu and Ericson (2025) have underscored the importance of embedding AI literacy education across core subjects to facilitate interdisciplinary learning. At the same time, calls for equity and early access demand that AI literacy education should be universal - considering and including students from all backgrounds, especially for students who are marginalized from technology education.

This section will explore the practical implications of AI literacy in education, focusing on three major areas: curriculum integration, professional development, and equitable access for students. These creative implications will fix AI literacy as foundational to 21st-century education.

A. Curriculum Integration

AI literacy should not be confined to computer science or coding classes; instead, it must be integrated and embedded to core academic subjects. According to Gu and Ericson (2025), they argue the importance of treating AI literacy as an interdisciplinary literacy which includes AI literacy in subjects such as language arts, social studies, and science. This application can enhance the effects of AI literacy in education by providing social readiness, not mere technological skills learning. For instance, students might compare AI-generated texts in their English classes to detect bias and misinformation. Gu and Ericson (2025) also suggested " a curriculum that teaches both machine learning fundamentals and how they can cause algorithmic biases", which provides students a dual lens with both technical and sociocultural

aspects. By embedding AI literacy in various core subject areas, students will be able to develop diverse abilities which ultimately nurture cognitive liberation.

B. Assessment and Evaluation Practices

While AI literacy education is widely adapted to the current educational field, its long-term and stable application heavily relies on how effectively students' growth through AI literacy education is assessed and interpreted. According to this expectation, recent measurement tools emerged in several studies. Among those studies, Kong, Cheung, and Tsang (2024) developed a four-dimensional AI Literacy Framework (AILF) through cognitive, metacognitive, affective, and social dimension, to assess students' ability to deal with AI-related problem-solving through a project-based learning (PBL). Their mixed-method study involving 128 secondary school students demonstrated a significant increase in conceptual understanding, metacognitive strategies, ethical awareness, etc. The accurate interpretation of impacts of AI literacy education on those students were made possible with the support of validated quantitative instruments such as the *AI Concepts for Problem-Solving Test* and *the AI Ethics Survey*. The importance of assessment and evaluation practices is portrayed through Kong et al. (2023) study as these assessment tools not only measured secondary students' improvement in information acquisition, but also reflected students' empowerment, self-efficacy, confidence, and creativity in applying AI to real-world problems. The study also underscores the effective assessment frameworks for AI literacy in education as the impacts of AI literacy often accompanies both cognitive and socio-ethical transformation in students. Practically, this implies that when AI literacy is integrated in future educational curricula, that education should include validated and multidimensional tools to monitor various aspects of learner's transformation through its education as the PBL did by focusing on four dimensions suggested by AILF. To strengthen this view, a recent research by Ng et al. (2023) from British Journal of Educational Technology (BJET) argues that the true effectiveness of AI literacy education lies in interpretation from the results of those measurements. Thus, it emphasizes teachers' role in understanding and translating results into meaningful feedback that enhance students' learning experiences. This perspective is indicated in Ng et al. (2023)'s study, who developed and validated the AI Literacy Questionnaire (AILQ) through repetitive stages and collaboration, as they mentioned "qualitative feedback from five teachers and ten students was collected to evaluate the face validity of the instrument (Ng et al, 2023). Altogether, for the long-term integration of effectiveness of AI literacy in education, it is essential to establish assessment systems that not only measure students' improvement throughout the certain framework, but also facilitates teachers to interpret, adapt, and reflect on results of evaluations to foster students' continuous cognitive liberation in AI-mediated learning environments.

V. Conclusion

This paper argues that effective AI literacy education facilitates cognitive liberation, equipping students with mental tools of critical thinking skills, self-efficacy, autonomy, and ethical awareness. AI literacy is not a mere tool to develop students' competency when engaging with AI-mediated environments, but it's a tool which contributes to students' multidimensional developments which are vital for using AI systems in their daily lives. AI literacy education

allows students to transform into active and critical thinkers capable of studying independently in a technology-driven world. As research by Kong et al. (2024) and Gu & Ericson (2025) represent, interdisciplinary integration is needed for AI literary education through the multidimensional framework encompassing cognitive, metacognitive, affective, and social aspects. Grounded in Freire's critical pedagogy, AI literacy education nurtures students with autonomy, self-efficacy, critical thinking, and ethical awareness, facilitating students to act as reflective agents rather than as passive agents which receive changes that AI suggests obediently. Lastly, AI literacy has its bright future with its practical implications. The significance of AI literacy education is highlighted through various societal sectors and its practical implications can be realized through curriculum integration and multidimensional assessment tools that fosters long-term application of AI literacy through deep reflection and interpretation.

While this study argues that AI literacy education provides cognitive liberation for students, there are still some limitations that the field of education has to resolve for its better application and development. The first assignment is about accessibility and equity. Although AI literacy is universally beneficial once it's applied, its positive effect preassumes that students have equal access to AI technology, digital literacy, and qualified teachers. Since there are disparities in school infrastructures and teachers' readiness to adapt AI literary education, equal access should be considered as one of the factors. The second consideration comes from the debate whether AI literacy education is instrumental or transformative. Developing an AI literacy framework that evenly highlights several dimensions from technical comprehension to ethics modules is sometimes realistically hard. Thus, the result can be ended up in surface-level awareness rather than genuine cognitive liberation. Lastly, another factor that can hinder the true quality of cognitive liberation is pedagogical overloads for educators. Without sufficient instructors training and time investment, the realization of integrating cognitive, metacognitive, affective, and ethical dimensions can be limited.

Despite these limitations, the emergent truth is that AI literacy education has the potential to become an indispensable foundation that cultivates responsible and ideal citizens in the AI era. Through continuous improvement and practice of interpretation and reflection, students can learn how to establish their own balance between dependence on AI technology with independent attitudes, possessing the true meaning of cognitive liberation.

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