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Navigating AI Literacy: STEM Students' Perceptions of Generative AI

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ABSTRACT

CONTEXT

Generative AI (Gen-AI) tools are rapidly reshaping both professional practice and STEM education. As these technologies become embedded in learning, there is growing emphasis on AI literacy – the ability of students to understand, use, and critically assess the outputs and reliability of AI technologies. While frameworks such as UNESCO's Digital Literacy Global Framework (DLGF) outline relevant competencies, there is limited research connecting Gen-AI use in STEM education to the ethical and practical demands of professional roles. This study examines that connection by exploring how students' AI literacy aligns with industry expectations in an AI-driven world.

PURPOSE OR GOAL

This study investigates STEM students' perceptions of Gen-AI tools, focusing on their understanding of capabilities, limitations, and ethical implications. Using UNESCO's DLGF as a lens, it examines competencies such as critical thinking, digital citizenship, responsible technology use, and adaptability. While not AI-specific, the DLGF provides a useful lens for assessing key transferable skills relevant to Gen-AI use. The study aims to inform educational practices that balance technical proficiency with responsible and ethical practices in AI-enhanced learning environments.

APPROACH OR METHODOLOGY/METHODS

A convergent parallel mixed-methods design was employed, combining survey responses and semi-structured interviews to gather both quantitative and qualitative data from STEM students in engineering and IT disciplines (N=22). The study examined students' self-reported usage patterns, understanding of Gen-AI tools, and ethical awareness through the lens of key competencies from UNESCO's DLGF. Data were analysed using descriptive statistics and thematic coding, with attention to gender representation and its implications for inclusivity in AI and digital literacy.

ACTUAL OR ANTICIPATED OUTCOMES

The study findings show students widely recognise the productivity benefits of Gen-AI tools but express concerns regarding ethical issues such as bias, misuse, and overreliance. While they demonstrated emerging competencies in critical thinking and adaptability, gaps remained in ethical awareness and digital citizenship. These insights highlight the need for clearer guidance and suggest opportunities for more structured integration of AI literacy into STEM education and curriculum.

CONCLUSIONS/RECOMMENDATIONS/SUMMARY

This study highlights the need to embed AI literacy in STEM education to address the dual challenges of technological advancement and ethical complexity. Findings support pedagogical approaches that integrate digital fluency with ethical reasoning and human-centred skills to prepare students for responsible participation in generative AI-integrated work practices.

KEYWORDS

AI literacy, generative AI, STEM education, Digital competencies.

Introduction

The growing integration of digital technologies into all areas of life has made digital literacy an essential skill for full participation in contemporary society. In higher education, particularly within STEM (Science, Technology, Engineering, and Mathematics) disciplines, the emphasis has traditionally been on technical proficiency. However, there is increasing recognition that STEM graduates must also develop ethical awareness and critical thinking to navigate the broader societal impacts of emerging technologies (Tejedor et al., 2020). One such transformative technology is Generative Artificial Intelligence (Gen-AI), which is rapidly reshaping professional practices and learning environments. While Gen-AI tools offer significant productivity and creativity benefits, they also raise important concerns related to bias, misinformation, and ethical misuse. These concerns highlight the need for AI literacy - a set of competencies that enable individuals to understand, use, and critically evaluate AI technologies, including their societal implications (Zhao et al., 2022).

This study explores the perceptions of STEM students regarding Gen-AI tools to gain insights into their AI literacy. Although scholarly literature on generative AI is expanding – spanning technical architectures to pedagogical applications, there remains a significant gap in understanding what AI literacy looks like in practice. Here, AI literacy is framed as a specific subset of digital literacy that includes not only functional knowledge but also the ability to critically assess outputs, recognise limitations, and make ethically informed decisions. Despite growing institutional interest in responsible AI use, this literacy remains something of a black box: often assumed, rarely measured, and inconsistently taught. Educators may presume students possess the digital fluency to engage with Gen-AI, yet such assumptions can obscure real disparities in understanding and responsible use. To support more inclusive and pedagogically sound AI integration, we must examine how students engage with Gen-AI in relation to its capabilities, limitations, and ethical dimensions.

To guide this exploration, five competencies were selected from UNESCO's Digital Literacy Global Framework (DLGF) (Law et al., 2018), which, while not AI-specific (Almatrafi et al., 2024), provides a relevant foundation for assessing transferable digital skills. These include (1) information literacy, (2) technology literacy, (3) critical thinking and problem-solving, (4) adaptability and lifelong learning, and (5) digital citizenship. The research is guided by the following question: ***What are STEM students' perceptions of using Gen-AI tools, particularly in relation to their understanding of the tools' capabilities, limitations, and ethical implications?***

This research contributes to the growing scholarship on AI-enhanced education by examining how STEM students perceive and engage with Gen-AI tools. The findings aim to inform curriculum development by identifying areas needing support. As Gen-AI becomes embedded in professional workflows, graduates must demonstrate not only technical fluency but also critical and ethical competence. Aligning STEM education with these evolving demands is essential for responsible participation in AI-integrated careers.

Background

The rise of Gen-AI in higher education

Generative AI (Gen-AI), a branch of machine learning, creates original content across text, images, audio, and video (Gozalo-Brizuela & Garrido-Merchan, 2023). The emergence of large language models (LLMs) e.g., ChatGPT and image generators e.g., DALL-E has driven rapid adoption in education. Since its release in late 2022, ChatGPT has been widely used for tasks such as summarisation, translation, content generation, and coding support due to its accessibility and ease of use. However, issues such as factual inaccuracies, hallucinated content (e.g., false facts confidently presented), and embedded bias raise concerns around trust, transparency, and academic overreliance (Borji, 2023; Huang et al., 2025).

In higher education, Gen-AI offers potential to personalise learning, automate content creation, and streamline tasks like quiz or feedback generation (Pedro et al., 2019; Seo et al., 2021; Yan et al., 2024). Yet, its ability to simulate human writing challenges academic integrity, prompting educators

to reconsider traditional assessments and focus on higher-order thinking and ethical engagement with AI (Holmes et al., 2021; Cotton et al., 2023). In response, AI literacy frameworks have emerged to help learners develop skills to evaluate AI outputs, identify limitations, and manage ethical risks (Carolus et al., 2023; Wang et al., 2023). However, many remain broad, highlighting the need for discipline-specific adaptations, particularly in STEM.

Applications and impacts of Gen-AI in STEM education

Recent studies highlight both the pedagogical potential and emerging concerns surrounding Gen-AI use in STEM education. Cao et al. (2023) found that Gen-AI tools enhanced comprehension by translating abstract STEM concepts into visual formats. In programming contexts, Maher et al. (2023) showed that students' prior experience and attitudes influenced how they engaged with tools such as ChatGPT. Similarly, Kazemitabaar et al. (2023) reported that students using Codex completed tasks more efficiently without impairing manual coding skills. Prather et al. (2024) demonstrated that prompt engineering tasks fostered computational thinking, though challenges like overreliance on AI remained. Petrovska et al. (2024) noted that students displayed critical awareness of Gen-AI during assessments, balancing its strengths with scepticism.

These findings highlight the need to support both technical and ethical AI competencies in STEM learning. Despite growing Gen-AI adoption, students' capacity for responsible and reflective use remains underdeveloped. While frameworks such as UNESCO's DLGF offer relevant competencies (e.g., information literacy, critical thinking, digital citizenship), their application to AI-specific contexts is still limited. Further research is needed to explore how Gen-AI tools affect students' ethical reasoning, self-regulation, and readiness for AI-integrated professional environments.

Methodology

This study adopted a convergent parallel mixed-methods design (also known as Concurrent triangulation) (Creswell & Clark, 2017). Quantitative and qualitative data were collected concurrently, analysed independently, and then integrated to provide a comprehensive understanding of STEM students' perceptions of Gen-AI tools. This design allows for cross-validation and comparison of insights from different data sources, strengthening the interpretive depth of the findings. Figure 1 illustrates the research design, including the integration of survey data and interview findings in the interpretive stage.

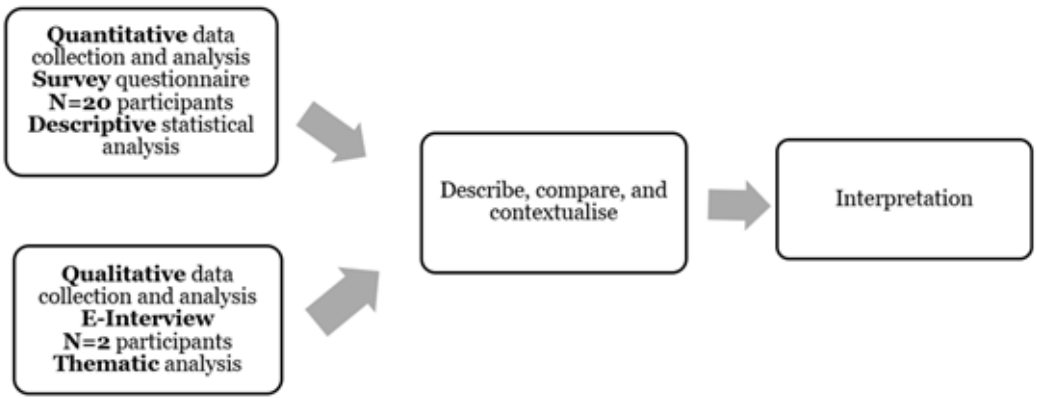

Figure 1: Research design

Ethics, data collection, and instrument development

This study received ethics approval from the university's Human Research Ethics Committee (Approval No. ETH23-8684). Data were gathered from four undergraduate STEM subjects in the Faculty of Engineering and IT during the Autumn 2024 semester. A volunteer/self-selection method allowed coordinators and students to opt in after a faculty-wide invitation. Though the sample was small and non-random, it yielded rich, reflective data from students with direct Gen-AI experience.

The open-ended responses and interviews provided valuable insights, prioritising depth over generalisability to inform evolving educational practice.

The study followed an interpretive approach and drew on UNESCO's DLGF to design survey and interview instruments. Five competencies were selected for their relevance to Gen-AI use: (1) information literacy, (2) technology literacy, (3) critical thinking and problem-solving, (4) adaptability and lifelong learning, and (5) digital citizenship (Bravo et al., 2021; Law et al., 2018; Miao & Holmes, 2021; UNESCO, 2021). Table 1 outlines how these were translated into question areas.

Table 1: Systematic mapping of survey and interview items to DLGF competencies

DLGF Element	Description
Information literacy	Understanding of the student's ability to navigate, critically evaluate, and interpret information responsibly/ethically using Gen-AI tools
Technology literacy	Understanding of the student's ability to interact with various Gen-AI tools effectively within their subjects
Critical thinking and problem-solving	Understanding of the student's ability to critically assess the impact, ethical considerations, and potential issues (biases or limitations) related to Gen-AI tools
Adaptability and lifelong learning	Understanding of the student's ability to recognise the need for continuous learning as Gen-AI tools evolve
Digital citizenship	Understanding the students' perceptions of the ethical use of Gen-AI tools, respecting intellectual property, and considering the societal impact

Survey, interview, and data analysis procedures

A custom online survey was distributed via university email to 307 students across four STEM subjects (T001, T002, T003, E004) at the end of Spring 2023. Delivered through Qualtrics, the survey included both closed- and open-ended questions covering: (1) demographics; (2) self-assessed AI literacy; (3) experiences and perceptions of Gen-AI use; and (4) ethical concerns.

Students could also opt in for a 30-minute follow-up interview. Two students participated, one female (IT, 01F) and one male (Engineering, 02M), both identifying as beginners in AI literacy. Interviews were conducted online, recorded with consent, and transcribed for analysis.

Quantitative survey data were analysed using descriptive statistics in SPSS (v28). Open-ended responses and interview transcripts were manually coded in Excel using deductive thematic analysis aligned to the five DLGF competencies, allowing for consistent interpretation of students' understanding and ethical engagement with Gen-AI tools.

Results and discussion

This section presents findings from both the survey and interviews, structured around the study's mixed-methods design. Results are interpreted through the lens of the five DLGF competencies, offering descriptive insights and contextual analysis.

Quantitative phase

The final sample comprised 20 participants, with a mean age of approximately 25 years (SD = 5.27). The demographic profile was predominantly male (75%, n = 15), with 95% (n = 19) reporting prior experience using Gen-AI tools such as ChatGPT, DALL-E, and GitHub Copilot. This suggests a high level of baseline familiarity with Gen-AI technologies among the participant group.

Self-reported proficiency

Participants were asked to rate their Gen-AI proficiency as beginner, intermediate, or advanced. The responses were distributed as follows: Beginner: 50% (n = 10), Intermediate: 25% (n = 5), and Advanced: 25% (n = 5). This distribution indicates a relatively balanced range of experience levels, which may reflect broader variability in exposure, confidence, or use cases across disciplines.

Ethical awareness

Participants were also asked whether they consider ethical implications when using Gen-AI in academic contexts. A significant majority (70%, n = 14) reported engaging in such ethical reflection. This finding points to a growing consciousness about responsible AI use, particularly in academic settings where concerns about plagiarism, bias, and overreliance are becoming more prominent. Interestingly, only one participant reported no prior experience with Gen-AI tools and indicated no ethical considerations related to their use. This response represents an outlier and may signal the need for further investigation into individual factors influencing ethical awareness, such as exposure, training, or disciplinary background.

Qualitative phase

Qualitative insights were drawn from open-ended survey responses and two follow-up interviews. The analysis was deductively coded using the five competencies of the DLGF as thematic categories. Not all participants responded to the open-ended items; response counts are reported alongside each theme. Participant narratives particularly centred around experiences with "ChatGPT", which emerged as the most frequently used Gen-AI tool (n = 9 of 12, 75%), followed by isolated mentions of "BingAI" and unnamed tools.

Information literacy

Students showed an emerging ability to critically evaluate the reliability of Gen-AI outputs, particularly in identifying inaccuracies or fabricated content. Both survey and interview responses reflected a growing awareness of the limitations of Gen-AI and the need for human oversight. Table 2 presents examples of how students assessed output quality, aligning with the information literacy competency in the DLGF.

Table 2: Student evaluation of Gen-AI reliability (information literacy)

Main theme	Sub-theme	Supporting evidence (Survey and Interviews)
Awareness of AI limitations	Recognition of inaccuracy	8 of 13 survey respondents (62%) noted that Gen-AI tools can produce false or misleading content: *"It often gives you the wrong answer… especially for complex or media-related questions."*
	Complexity increases error	*"The program [Gen-AI tool] fell short when it came to solving more complex or quantitative problems."*
Need for critical evaluation	Domain knowledge enables filtering	*"I know what good written content is… but I think if you didn't come in with that knowledge… you might just accept its answer as good when it isn't."* (01F)
	Cross-checking is essential	*When searching for [context-specific] figures, Bing AI generated fabricated stats and sources: "It just made up some random information… I couldn't find where it found it."* (01F)

While many recognised the risk of misinformation, the depth of critical evaluation often depended on students' prior domain knowledge. This suggests that AI literacy must be supported by disciplinary understanding to foster responsible and informed Gen-AI use.

Technological literacy

Students demonstrated varied levels of technological literacy through their use of Gen-AI tools in academic, creative, and practical tasks. Their functional understanding was shaped by both personal initiative and how the tools were introduced within the curriculum. Thirteen survey respondents and both interviewees (01F and 02M) discussed their experiences, particularly in group projects. Table 3 illustrates students' applications of Gen-AI in relation to this DLGF competency.

Students used Gen-AI across a range of learning contexts, from coding and writing support to creative ideation. The perceived effectiveness of Gen-AI, however, often depended on prior exposure and explicit instructional support highlighting the value of scaffolded integration into course design.

Table 3: Student use of Gen-AI tools (technological literacy)

Main theme	Sub-theme	Supporting evidence (Survey and Interviews)
Functional use of Gen-AI tools	Learning support	Asking questions, simplifying complex topics: "*It helps me gain a new perspective… simplifies things I don't get.*"
	Academic writing	Grammar checks, idea generation: "*Used for checking grammar… to get your brain moving.*"
	Information access	*"Used when finding appropriate resources online or offline was difficult."*
Creative engagement and iterative use	Ideation and brainstorming	*"I used it for simple ideas like team names or project ideas."*
	Creative co-design	*"We co-created the Dungeons and Dragons settings..." (01F)*; explored DALL-E via Bing AI for characters and settings.
	Writing refinement through iteration	*"A lot of back and forth… asking it to condense this sentence." (01F)*
Tool limitations and curriculum influence	Perceived limitations	*"If I tried to make it more specific, it would funnel itself into a corner." (02M)*
	Lack of guidance limits engagement	*"We were told we could use AI… and nothing much beyond that." (02M)*
	Scaffolding enhances exploration	*"Lecturers guided us through what the capabilities of these GenAI tools are." (01F)*
	Need for clearer usage boundaries	*"If we had time in class showing different ways… we'd better understand what was or wasn't allowed." (02M)*

Critical thinking and problem-solving

Students showed varied levels of critical thinking in how they reflected on the risks and consequences of Gen-AI use. Of the 11 survey respondents, 4 (36%) identified concerns such as plagiarism, overreliance, and reduced authorship, indicating emerging awareness of both academic and ethical implications. Table 4 summarises how students engaged with Gen-AI through a critical lens.

Table 4: Student reflections on Gen-AI use (critical thinking and problem-solving)

Main theme	Sub-theme	Supporting evidence (Survey and Interviews)
Awareness of cognitive and academic risks	Over-reliance reduces learning depth	*"Over-reliance on Generative AI may produce a lack of deep or meaningful understanding of a process."* (Survey)
	Plagiarism concerns	*"Used too liberally, it would probably make an assignment mostly done by the program itself instead of the student."* (Survey)
Critical reflection on Gen-AI output quality	Prior knowledge shapes critical use	*"I have four years in Literature… I know when it's giving me something that sounds terrible… other students might not come in with that."* (01F)
Awareness of ethical risks	Data privacy concerns	*"If you're putting in sensitive info… I hope students are having discussions before plugging in patient data or something."* (01F)
	Ownership and authenticity	*"The more I relied on AI, the less it felt like my own work… it felt like AI's work with my assistance."* (02M)
	Moral discomfort and shortcut thinking	*"It feels like a sort of cheat shortcut kind of way."* (02M)

The findings highlight the need to pair technical skills with opportunities for ethical reflection, with curricular support essential for deeper, discipline-informed engagement with Gen-AI.

Adaptability and lifelong learning

While not explicitly prompted, several student responses reflected adaptability and a mindset for lifelong learning. Many described experimenting with Gen-AI tools, refining their approaches, and reflecting on how these tools influenced their learning. These behaviours align with the DLGF's emphasis on adapting to new technologies and continuous learning (Table 5).

Table 5: Student adaptability and learning with Gen-AI tools (adaptability and lifelong learning)

Main theme	Insight	Supporting evidence (Survey and Interviews)
Openness to trying new tools and tasks	Students described first-time uses of Gen-AI for writing, coding, or design	*"I used it when trying to come up with simple ideas like team names or project ideas."* (Survey)
Iterative learning through prompt refinement	Students adjusted prompts to improve outcomes, showing learning-by-doing	*"I spent a lot of time going back and forth... condense this sentence... it was a lot of back and forth."* (01F)
Experimentation in creative contexts	One student explored text-to-image features in DALL-E to co-create story elements	*"I pretended it was our theoretical AI… we co-created the Dungeons and Dragons settings."* (01F)
Tool limitations sparked deeper learning strategies	When outputs were weak, students reflected on their own domain knowledge to evaluate	*"I know what good writing is... but someone without that knowledge might just accept it as good."* (01F)
Willingness to self-regulate usage based on learning goals	One student limited use due to discomfort and desire for personal ownership	*"I felt the more I used it, the less it felt like my own work… it felt like AI's work with my assistance."* (02M)

Students showed initiative in exploring Gen-AI tools, often through trial, feedback, and self-guided improvement. These patterns suggest that fostering a disposition for lifelong learning is essential for navigating evolving AI-enhanced learning environments.

Table 6: Student awareness of Gen-AI ethics and impact (digital citizenship)

Main theme	Sub-theme	Supporting evidence (Survey and Interviews)
Ethical engagement and responsible use	Students avoided direct AI-generated answers and checked outputs	*"I never directly ask AI to write a report… I usually explore the topic, write a draft, and then use AI to polish it."* (Survey)
	Class discussions fostered ethical awareness	*"We had lectures talking about the ethics of AI… the mental health chatbot example made us reflect on consequences."* (01F)
Respect for intellectual property	Awareness of proper attribution in written work	*"Even if there's no human author, it's still work you didn't do - so it must be sourced properly."* (Survey)
	Concern about data origin and creative ownership	*"I'm very aware of where it got this data from… artists and writers are speaking out about having their data stolen."* (01F)
Institutional influence and inconsistency	Ethical framing supported by curriculum	*"Ethics was an integral part of our design brief."* (01F)
	Limited or unclear guidance leads to discomfort	*"The guidelines were very broad and loose… I wasn't really comfortable using it."* (02M)
	Ethical topics surfaced only when raised by students	*"They only brought it up if a student asked something publicly."* (02M)

Digital citizenship

Students demonstrated increasing awareness of the societal and ethical dimensions of Gen-AI use. Of the 11 survey respondents, 7 (63%) noted broader human or societal concerns, and 6 described using Gen-AI in ethically conscious ways such as avoiding direct copying, validating outputs, and citing sources. Interviews revealed contrasting classroom experiences, with varying levels of guidance around ethical use. Table 6 summarises students' responses in relation to digital citizenship.

Findings show that even without structured instruction, many students made thoughtful, self-regulated choices around Gen-AI use. Their decisions reflected ethical reflection, respect for

authorship, and growing digital responsibility - key attributes of AI-era citizenship. To build on these strengths and address remaining gaps, an implementation plan is proposed to guide the integration of AI literacy into education, emphasizing teacher preparedness, student engagement, and ethical use. The phased approach includes awareness-building, professional development for staff, curriculum integration for students, and ongoing evaluation. Prioritising teacher training while embedding AI literacy across courses ensures sustainable and responsible adoption.

Conclusion and future directions

This study examined how STEM students engage with Gen-AI tools, offering insight into their AI literacy across five key digital competencies: information literacy, technological literacy, critical thinking and problem-solving, adaptability and lifelong learning, and digital citizenship. While most students were open to Gen-AI use, their engagement varied depending on prior experience, ethical awareness, and the presence of curricular scaffolding.

Technological literacy emerged most strongly, particularly where Gen-AI use was guided through assessment or classroom activities. Information literacy was evident in students' recognition of issues like hallucinated content, though shaped by disciplinary knowledge. Ethical reflection linked to digital citizenship and critical thinking surfaced in concerns around plagiarism, authorship, and data privacy. Where educators facilitated ethical discussions, students navigated Gen-AI use more confidently. Evidence of adaptability and lifelong learning appeared through prompt iteration, self-directed exploration, and critical tool use. These findings reinforce what prior studies have indicated: AI literacy cannot be assumed. Despite institutional focus on responsible AI use, students' competencies remain uneven and context-dependent. STEM curricula must integrate AI literacy through not only technical instruction but also structured opportunities for ethical reflection (e.g., class debates on data ownership), critical evaluation (e.g., assessing AI reliability), and scaffolded experimentation (e.g., guided prompt design). Reflective tasks already common in many subjects offer a strong starting point for this integration.

Looking ahead, further research should examine how factors such as gender, discipline, and prior digital experience shape Gen-AI engagement. Longitudinal and comparative studies could track literacy development over time, alongside efforts to develop methods for quantifying AI literacy. Drawing on models from digital and information literacy, survey instruments, performance tasks, or rubric-based measures could provide comparable benchmarks across disciplines and institutions. Educator perspectives also warrant attention, as teacher preparedness strongly shapes classroom adoption. Generational gaps highlight the need for targeted professional development to build technical and ethical competencies that amplify student learning (Ding et al., 2024; Sperling et al., 2024). Future work should also explore the link between AI literacy and academic integrity: while Gen-AI can be a powerful tutor, it equally raises risks of plagiarism and misuse, highlighting the need for ethical literacy and clear institutional policies. Ultimately, embedding AI literacy into STEM education must extend beyond technical skills to foster informed, ethical, and adaptive digital citizens.

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