

Preparing Students for an AI-Driven World: Generative AI and Curriculum Reform in Higher Education

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Abstract Generative AI (GenAI) is rapidly transforming higher education. This study explores the imperative for curriculum reform to effectively integrate these powerful tools of GenAI into education and prepare students for an AI-driven world. It also proposes a comprehensive framework encompassing three key strategies: (1) fostering AI literacy across disciplines through tiered courses that address fundamental concepts, applied uses, and advanced techniques; (2) shifting pedagogical approaches from rote memorization to problem-solving, emphasizing active learning strategies such as problem-oriented and project-based learning, and encouraging interdisciplinary collaboration; and (3) establishing dynamic updating mechanisms of curriculum, including partnerships with industry and research institutions, modular curriculum design, and cultivating students' self-learning abilities. Moreover, this study addresses critical considerations for successful implementation, such as faculty training, resource allocation, ethical implications, assessment strategies, and the maintenance of academic integrity in the face of AI-generated content. Furthermore, this study provides a roadmap for educators and institutions to navigate the opportunities and challenges of GenAI, empowering students to thrive in a rapidly evolving technological landscape.

Keywords Generative AI (GenAI), higher education, curriculum reform, AI literacy, problem-solving, interdisciplinary collaboration, dynamic updating mechanisms of curriculum, faculty development

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1 Introduction

Generative AI (GenAI), a subfield of AI focused on creating novel content using sophisticated deep learning models, such as generative adversarial networks (GANs) and large language models (LLMs) (Chakraborty et al., 2024), has rapidly emerged as a transformative force across society. These models and algorithms, unlike traditional AI systems that primarily analyze existing data, produce diverse outputs ranging from texts and images to music and code (Bandi et al., 2023; El Ardelyia et al., 2024; Fui-Hoon Nah et al., 2023; Sengar et al., 2024). Accessible AI-powered tools have rapidly proliferated and achieved widespread adoption, consistent with projections. For instance, 80% of software development companies will use these technologies by 2026 (El Ardelyia et al., 2024; Epstein et al., 2023; Liu et al., 2023; Sengar et al., 2024). Such increases in expansion and application disrupt the established workflows in fields such as design, journalism, and research (El Ardelyia et al., 2024; Epstein et al., 2023; Liu et al., 2023; Sengar et al., 2024). They also concurrently present significant challenges to teaching in higher education, regarding academic integrity and the competency and role of teachers (Chen et al., 2023; Dien, 2023; Eke, 2023; Gruenhagen et al., 2024; Hastings, 2024; Hutson et al., 2024).

Considerable interplay among the rapidly evolving capabilities of AI, the established structures of higher education, and the consequent needs for curriculum reform is represented in Figure 1. The diagram highlights the critical intersections demanding attention, including cultivating new student competencies, embedding AI-powered tools and ethics into teaching practices, reshaping assessment strategies,

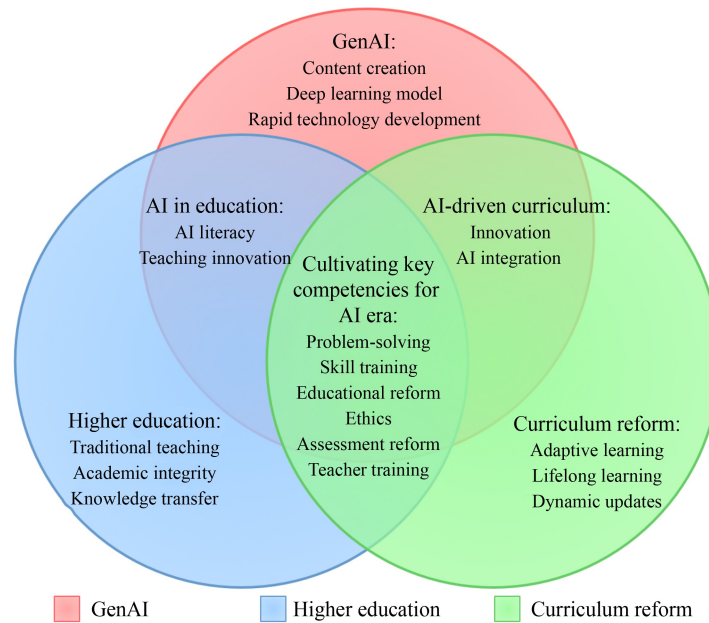


Figure 1 Intersections among GenAI, higher education, and curriculum reform. Intersections represent areas where these domains collaborate to address challenges and opportunities in modern education.

and ensuring comprehensive faculty development to navigate this new landscape.

GenAI presents a dichotomy of unprecedented opportunities and significant challenges in education. These tools offer potential for personalized learning experiences (Guettala et al., 2024), automated routine tasks (Brynjolfsson et al., 2023; Hutson et al., 2024; Naseer et al., 2024), and opening new avenues for student creativity (El Ardelya et al., 2024; Epstein et al., 2023; Hutson & Robertson, 2023; Messer, 2024), but they simultaneously raise serious concerns about academic integrity (Dien, 2023; Eke, 2023; Gruenhagen et al., 2024), the development of essential critical thinking skills (Hutson et al., 2024; Larson et al., 2024), and the fundamental nature of knowledge creation (Chen et al., 2023; Lee et al., 2023). Educators are thus faced with the complex task of effectively integrating these powerful tools into teaching and learning while mitigating inherent risks. For instance, the capacity of GenAI to produce AI text necessitates a pedagogical shift from rote memorization to higher-order thinking skills, including critical analysis, evaluation, and creative synthesis (Borge et al., 2024; Larson et al., 2024; Valquarasma, 2024). Moreover, the multifaceted ethical implications surrounding AI-generated content, such as spanning issues of bias (Hagendorff, 2024; Hastings, 2024), plagiarism (Dien, 2023; Eke, 2023; Gruenhagen et al., 2024), and intellectual property (Smits & Borghuis, 2022; Thongmeensuk, 2024), demand the development and implementation of new educational frameworks and guidelines.

However, despite a growing body of research on GenAI in education, several key gaps persist. Much

of the current literature concentrates on theoretical possibilities or narrow and discipline-specific applications. There lack of practical and interdisciplinary strategies that educators can readily adopt to integrate GenAI into teaching and learning process. Insufficient attention has also been paid to establishing dynamic updating mechanisms of the curriculum that are essential for educators to keep pace with the rapid evolution of AI technologies. These problems point to the reality that the swift advancements in GenAI require an urgent and comprehensive reform of higher education curricula, as the competencies required for success in an increasingly AI-shaped world differ fundamentally from those emphasized in traditional models. Graduates are expected to navigate professional landscapes where AI-powered tools are ubiquitous, calling for an understanding of how these technologies function and the critical capacity to evaluate their outputs, identify their limitations, and leverage their competencies for innovation. Merely incorporating these innovations into existing course structures is insufficient, as a more profound transition is essential to cultivate adaptive learning, critical thinking, and lifelong learning (Giannakos et al., 2024; Hutson et al., 2024; Yan et al., 2024).

The abovementioned gaps and requirements have been directly addressed in this study (Fui-Hoon Nah et al., 2023; Giannakos et al., 2024; Hutson et al., 2024). Primarily targeting higher education faculty, instructional designers, and administrators, our research team has developed a practical, framework-driven, evidence-based, and example-informed approach to preparing students for an AI-driven future.

This study sought to foster AI literacy and enhance problem-solving skills, but to move beyond a simple acknowledgement of AI's impact to instead formulate concrete strategies for reshaping curricula to build essential knowledge and competencies. Specifically, the study examined the need to integrate AI across disciplines, evolving pedagogical approaches from knowledge-based learning to problem-solving learning and creative thinking, as well as establishing the updating mechanisms of the curriculum that are responsive to the rapid evolution of AI. These initiatives encompass both the theoretical underpinnings of AI-driven curriculum reform and the practical considerations for implementation, including faculty training, resource allocation, ethical implications, and assessment strategies. While recognizing the inherent challenges of such a transformative undertaking, this study ultimately serves as a call to action for educators and institutions to embrace the opportunities presented by GenAI and proactively redefine higher education for the future.

2 AI Literacy in Higher Education

2.1 | Definition of AI Literacy

Developing AI literacy in higher education goes beyond the superficial awareness of AI to entail fostering a deep and nuanced understanding that spans AI's technical underpinnings, potential applications, ethical ramifications, and societal impacts. This comprehensive grasp becomes even more critical given the rapid advancements in GenAI. For this study, AI literacy in higher education is defined as a multifaceted competency as shown in [Figure 2](#), including understanding AI fundamentals, critical evaluation of

AI-generated content, ethical application of AI-powered tools, analyzing societal impact, and adapting to AI evolution.

First, understanding AI fundamentals is essential. This dimension requires students to become AI developers or master complex algorithms and entails an understanding of the basic operational concepts of AI systems, particularly generative models. This requirement includes differentiating between AI types (e.g., machine learning (ML) and deep learning (DL) models), comprehending the role of data in training these systems, and recognizing the inherent limitations of current AI technologies, such as their potential for errors, biases, and hallucinations, which means those outputs that seem authoritative but are factually incorrect.

Second, critical evaluation of AI-generated content is a cornerstone of responsible AI engagement. Students are expected to develop the discernment to assess the credibility of information produced by AI, identify potential biases embedded in that content as a result of skewed training data, consider the ethical implications of using AI-created material, and understand the probabilistic nature of generative outputs, recognizing that they may not always be factual or accurate.

Third, AI-literate students need to be capable of applying AI-powered tools effectively and ethically in their academic pursuits. This capability extends beyond using AI to merely generate answers and involves leveraging the technology to enhance learning, research, and creative expression. For example, AI should be employed in tasks such as literature exploration, data analysis, and brainstorming. It can be used to create content (e.g., drafting text and composing music), but always with rigorous critical evaluation and refinement by the student. Moreover, adherence to the established

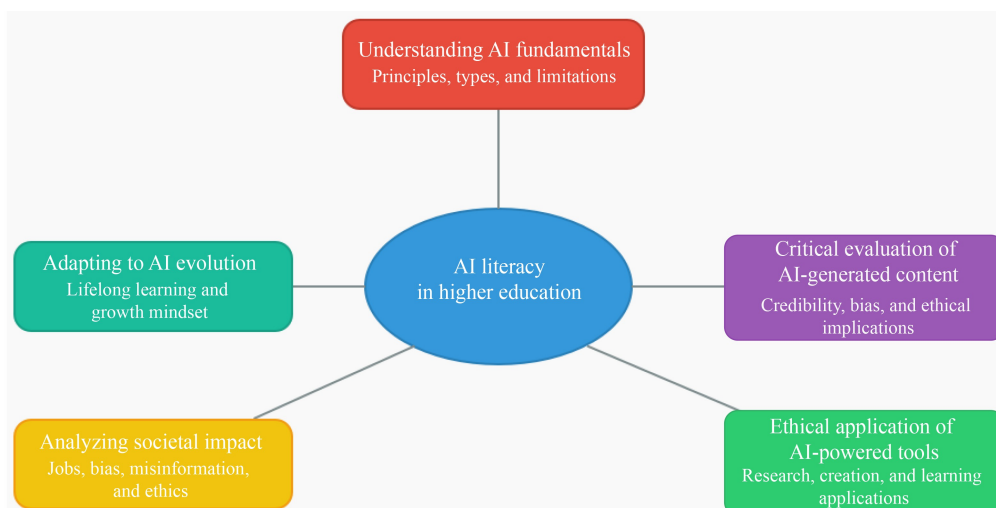


Figure 2 Core components of AI literacy.

ethical guidelines and academic integrity standards while using AI is non-negotiable.

Fourth, analyzing the broader societal impact of GenAI is integral to AI literacy. Students need to comprehend how these technologies currently influence and continue to shape economy, workforce, culture, and society at large. Achieving this goal involves considering complex issues, such as potential job displacement, perpetuation of algorithmic bias, proliferation of misinformation, and challenges surrounding intellectual property and misuse.

Fifth, the rapid pace of AI development underscores the fact that AI literacy is not a static skill set but a dynamic competency requiring a commitment to lifelong learning and continuous adaptation. Students need to cultivate a growth mindset, prepared to engage with and adapt to emerging AI technologies and their applications throughout their careers.

This comprehensive approach to AI literacy therefore emphasizes technical facility, critical thinking, ethical reasoning, and adaptability, which are the qualities essential for navigating an increasingly AI-driven world. This definition provides the foundation for integrating this competency throughout higher education curricula.

2.2 | Dimensions of GenAI Literacy

Based on the aforementioned definition, AI literacy comprises a number of interconnected dimensions crucial for a holistic understanding of GenAI and its implications. These dimensions are foundational knowledge, awareness of applications, ethical understanding, and practical skills.

2.2.1 Foundation of GenAI

A bedrock of AI literacy is grasping the core principles that govern how GenAI systems create new content as shown in [Figure 3](#), going beyond simple tool usage to a

conceptual understanding of their mechanisms. This involves comprehending basic concepts, such as ML as GenAI’s foundation, encompassing training data, algorithms, and models, along with distinguishing between supervised, unsupervised, and reinforced learning. Another key is understanding a subset of ML called DL, which employs multilayered artificial neural networks, as well as acquiring a simplified view of how these networks learn. A conceptual grasp of neural networks themselves—their basic structure (nodes, weights, and layers) and learning through weight adjustment—is necessary. Students need to comprehend what distinguishes generative models from other AI technologies: their ability to learn the underlying probability distribution of training data and generate novel and similar samples. This includes familiarity with principal GenAI architectures, such as GANs, variational autoencoders (VAEs), diffusion models, and LLMs. Grasping the pivotal role of data and training, which encompasses data quality, quantity requirements, and the inherent risks of reflecting training data biases in outputs, is another essential requirement. Equally important is a frank awareness of current AI limitations, such as their propensity for hallucinations, the lack of genuine understanding comparable to that of humans, and the significant computational costs involved. Finally, familiarity with key terminologies, such as “prompt engineering”, ensures the acquisition of core vocabulary. This foundational knowledge equips students with the ability to critically evaluate and effectively use AI-powered tools.

2.2.2 Wide Reach of GenAI

Appreciating the transformative potential of GenAI requires understanding its diverse applications across numerous disciplines and sectors as shown in [Table 1](#). In the creative arts, AI has revolutionized expression through image generation (e.g., DALL·E 2 and

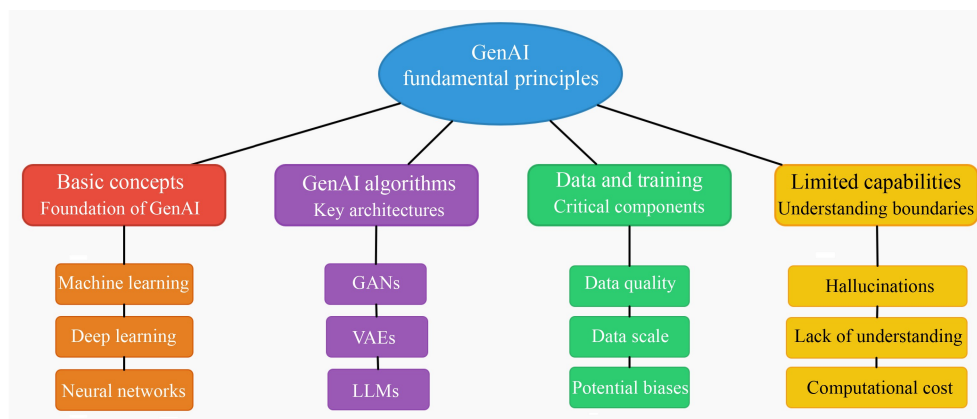


Figure 3 Overview of fundamental GenAI principles. GANs: generative adversarial networks, VAEs: variational autoencoders, LLMs: large language models.

Table 1 Discipline-specific AI applications

Discipline	AI application in disciplines
STEM	Data analysis, scientific simulation, code generation, generative design, and drug discovery
Humanities	Textual analysis, historical research, content generation, language translation, and style analysis
Business	Market analysis, personalized marketing, financial modeling, fraud detection, and customer service automation
Arts	Artistic creation, music composition, graphic design, style transfer, and animation

Note. STEM: science, technology, engineering, and mathematics.

Midjourney), music composition, text generation (e.g., articles and scripts via LLMs), and video generating or editing. The technology is leveraged in business and marketing for personalized advertising, the automated creation of content marketing, trend analysis, and the enhancement of customer service via chatbots. Its application in healthcare has accelerated drug discovery and diagnostic improvements through medical image analysis and the development of personalized treatment plans. AI is likewise advantageous for science and engineering, where the technology aids in the design of novel materials, the simulation of complex systems, the generation of optimized engineering designs, and the acceleration of scientific simulations. In education field, GenAI holds potential for personalized learning, automated feedback, and content generation. The breadth of coverage underscores the relevance of GenAI literacy to students across all fields.

2.2.3 Ethics of GenAI

A critical dimension of GenAI literacy involves grappling with the complex ethical and societal implications of GenAI. Understanding potential benefits alongside associated risks is paramount. Seven primary ethical considerations, as shown in Table 2, include: (1) bias and fairness, stemming from slanted training data, leading to potentially discriminatory

outputs; (2) privacy and data security, arising from the large-scale data processing involved; (3) misinformation and manipulation, potential for realistic synthetic content, such as deepfakes; (4) ownership and copyright, complex legal issues surrounding intellectual property and copyright of AI-generated content; (5) job displacement, potential socioeconomic impact of job displacement due to automation; (6) environmental impact related to the energy consumption of large AI model training; and (7) responsibility and accountability, assigning responsibility in ethical dilemma and examining different frameworks for accountability. These are not abstract issues but carry real-world consequences, requiring the ability to critically evaluate them.

2.2.4 Mastering AI-Powered Tools

Beyond foundational understanding and ethical awareness, proficiency in using GenAI technologies effectively is a necessary facet of practical GenAI literacy that involves the following three skills: First, tool selection necessitates knowing how to choose the appropriate AI applications for a given task on the basis of the strengths and weaknesses of various platforms. Second, prompt engineering involves crafting effective input queries using keywords, constraints, context, and iterative refinement to elicit desired outputs from AI

Table 2 Ethical and societal implications of GenAI

Ethical and societal issue	Main coping strategy	Detail and consideration of GenAI
Bias and fairness	Mitigating bias in AI systems	GenAI models may perpetuate and amplify biases presenting in training data. Students need to understand how bias manifests and to explore mitigation strategies
Privacy and data security	Protecting individual privacy and data	The use of GenAI involves collecting and processing vast amounts of data, raising concerns about privacy and data security. Students should understand responsible data handling
Misinformation and manipulation	Identifying AI-generated content	AI-generated content, such as deepfakes, poses a threat through misinformation and manipulation. Students need critical media literacy to evaluate such content
Ownership and copyright	Understanding and navigating intellectual property complexities	The ownership and copyright of AI-generated content raise complex legal and ethical questions. Students should explore the evolving legal landscape
Job displacement	Adapting to a changing workforce	Automation due to GenAI may lead to job displacement. Students need to analyze economic impacts and explore strategies for adapting to a changing workforce
Environmental impact	Improving technology to reduce energy consumption of AI	The training and operation of large AI models, especially generative models, require significant energy consumption. This contributes to carbon emissions and has broader environmental impacts
Responsibility and accountability	Frameworks for assigning responsibility	Assigning responsibility when AI systems make mistakes or cause harm presents an ethical dilemma. Students need to examine different frameworks for accountability

models. Third, equally vital is output evaluation and refinement, which demand stringently assessing AI-generated content for accuracy, potential bias, and coherence, followed by editing and revision to meet specific needs. Integrating AI-powered tools into existing workflows effectively enhances productivity and creativity. Given the rapid evolution of the field, maintaining GenAI literacy requires keeping pace with new tools and technologies. Mastering these competencies empowers students to become active and critical collaborators with AI, harnessing its power responsibly while maintaining human oversight.

2.3 | A Tiered Approach to AI Literacy Education

Effectively embedding AI literacy in higher education requires acknowledging the diverse needs of students from various disciplines and at different stages of their academic journeys. A monolithic approach is insufficient, and we need to develop a tiered framework for AI literacy education. This framework allows institutions to tailor instruction on the matter of interest, which ensures students to gain foundational competence while offering pathways for deeper and specialized learning aligned with specific goals and career trajectories. The core components of these tiers, such as foundational, applied, and advanced level, are shown in [Table 3](#).

2.3.1 Foundational AI Literacy for All

The baseline of AI literacy should be established as a core competency for higher education students, irrespective of their majors. This foundational understanding arms them with the knowledge and skills essential to responsibly and effectively navigating an increasingly AI-driven world. Such foundational-level training, whether delivered through a dedicated course or an integrated module in existing curricula, should comprise five vital components. First, students need an introduction to basic AI concepts, particularly those underlying GenAI, emphasizing conceptual grasp over technical minutiae. Second, a critical awareness of the ethical and societal implications of AI should be fostered, including discussions on biases, risks, and broader impacts. Third, developing skills in the critical

evaluation of AI-generated content is paramount, enabling students to assess potential quality, reliability, and prejudice, as well as recognize inherent limitations. Fourth, students need to gain hands-on experience through basic interaction with accessible AI-powered tools (e.g., text and image generators), focusing on usage, understanding basic functionality, and thoroughly examining outputs rather than programming. Fifth, the responsible and ethical use of AI should be strongly emphasized, with issues covered, such as academic integrity and intellectual property. This tier is aimed at cultivating informed digital citizenship, empowering graduates to engage thoughtfully and responsibly with AI technologies.

2.3.2 Applied AI Skills for Specific Fields

Building upon the foundational level, a deeper exploration of GenAI's applications within students' chosen fields would significantly benefit them. Applied AI literacy courses or modules should therefore concentrate on discipline-specific applications to examine how GenAI is currently used and can be leveraged, supported by real-world examples and case studies. This involves hands-on experience with specialized tools and techniques particularly relevant to a given discipline, potentially including the use of software or platforms more advanced than those encountered at the foundational level. These courses should also delve into discipline-specific ethical considerations. For example, students in journalism major might analyze the ethics of AI usage in news generation, while healthcare students can explore AI ethics with diagnostics. Developing problem-solving skills using AI within a certain disciplinary context through projects or simulations is key, as is possibly adopting AI for data analysis and visualization, especially when dealing with large datasets pertinent to the field. To illustrate, applied courses can be tailored to specific disciplinary needs. For instance, engineering students could leverage AI for generative design to optimize complex structures, like aircraft wings, while business programs might focus on using LLMs to automate nuanced customer sentiment analysis from reviews and social media. In healthcare, the curriculum could explore the use of GenAI in creating synthetic patient data for training diagnostic models without

Table 3 AI literacy components across academic levels

Component of AI literacy	Foundational level	Applied level	Advanced level
Core focus	Basic understanding and awareness	Discipline-specific application	Technical expertise and development
Technical content	Basic AI concept and terminology	Tool usage in specific field	Advanced algorithm and architecture
Practical skill	Basic tool interaction	Field-specific application	Model development and training
Ethical consideration	General ethical awareness	Domain-specific application	Advanced ethical framework

compromising privacy. Humanities scholars might apply AI to conduct large-scale thematic analysis across vast digital archives of historical texts, uncovering previously unseen patterns. Finally, in the arts, students could experiment with AI-powered tools to co-create interactive narratives or generate novel choreographic sequences. These specialized and applied courses are designed to equip students with the practical skills and contextualized knowledge necessary to effectively and responsibly capitalize on AI in their future professional environments.

2.3.3 Advanced AI Literacy for Specialists

Students specialized in AI-centric domains, such as computer science, data science, and AI engineering, require advanced AI literacy. These programs move beyond application to delving into the theoretical foundations and development processes in the field, as well as cutting-edge research on GenAI. This includes a deep dive into algorithms and architectures, enabling an exhaustive investigation of the mathematical and computational principles behind technologies, such as GANs, VAEs, LLMs, and diffusion models. Students gain practical experience in model development and training, which entails working with large datasets and programming with libraries, such as TensorFlow or PyTorch. Advanced ethical considerations are explored with greater sophistication, covering research ethics, potential misuses, and societal impacts of advanced AI systems. Exposure to and participation in state-of-the-art research through projects, conferences, and publications are encouraged. Learning should frequently revolve around the specialized application domains within AI, such as robotics, computer vision, and natural language processing. This advanced tier prepares graduates to not only use but also develop, deploy, manage, and innovate GenAI, equipping students for research careers, advanced development roles, and leadership positions in the AI industry.

3 Enhancing Problem-Solving Capabilities in the Era of AI

3.1 | Redefining Problem-Solving for an AI-Driven World

The rapid proliferation of GenAI has fundamentally reshaped what counts as essential skills, compelling a significant shift in educational priorities. While foundational knowledge remains important, the premium on solving complex and ill-defined problems has increased dramatically. In an environment where AI readily manages vast information access, processing, and generation, the unique contribution of human

intellect progressively resides in adaptability, critical thinking, creative problem-solving, and ethical reasoning. These higher-order cognitive competencies need to be actively cultivated and given priority over rote memorization.

Problem-solving in the era of AI transcends the mere pursuit of correct answers and evolves into a multifaceted process. This process centrally involves discerning critique, which demands the ability to dissect intricate issues, identify assumptions, and meticulously evaluate information from diverse sources, including AI-generated content. Moreover, this process requires to formulate insightful research questions and incorporate the indispensable skills of identifying and mitigating biases. Furthermore, creative solution generation is also needed, that is, capitalizing on AI-powered tools for brainstorming while simultaneously fostering original human ideation or using AI outputs as springboards for innovation rather than final products. Adaptive learning and iteration are vital, wherein a mindset of continuous learning, experimentation, evaluation, and refinement is nurtured to keep abreast of a rapidly changing technological context. Equal necessities are effective collaboration and communication, which encompasses interactions with both human peers and AI technologies to harness wide-ranging viewpoints. Additionally, ethical reasoning and responsible implementation are paramount, with users obligated to carefully weigh the ethical implications of proposed solutions and ensure that their deployment mitigates risks related to bias, fairness, privacy, and societal impact. Finally, interdisciplinary thinking, the ability to apply knowledge across domains, steadily becomes essential to tackling the layered real-world problems often amplified or addressed by AI.

These skills are not entirely novel, but their importance has been significantly amplified with the advent of AI, along with the transformation of the contexts in which such abilities are applied. Students are now expected to learn to effectively collaborate with AI in problem-solving by understanding both its capabilities and limitations. They should also develop the capacity to solve problems related to AI, such as contributing to ethical guideline development or bias mitigation strategies. Above all, they need to adapt to rapid change, continuously learning about new AI technologies and their implications. These key aspects are summarized in [Table 4](#).

The necessary move toward prioritizing advanced problem resolution demands a radical rethinking of pedagogical strategies, assessment methods, and overall curriculum designs. These transformations are explored in the succeeding sections, which focuses on the enhancement of active learning strategies via AI, the adoption of interdisciplinary approaches, and the cultivation of an innovative culture, as shown in [Table 5](#).

Table 4 Key aspects of problem-solving as a core competency in the era of AI

Key aspect of problem-solving	Description
Critical thinking and analysis	Analyze problems critically, identify assumptions, evaluate information, including AI insights, formulate research questions, and recognize biases in data
Creative solution generation	Leverage GenAI for brainstorming and novel solutions while also cultivating original creative thinking abilities
Adaptive learning and iteration	Embrace continuous learning, adapt strategies based on feedback and experiment with different approaches, and refine solutions iteratively
Collaboration and communication	Develop strong teamwork and communication skills to work effectively with others and AI-powered tools, integrating diverse perspectives
Ethical reasoning and responsible implementation	Evaluate the societal impact of solutions, ensure responsible implementation, and mitigate potential risks and biases
Interdisciplinary thinking	Apply knowledge and skills from multiple disciplines to develop comprehensive and innovative solutions facilitated by AI

Table 5 Key strategies for integrating GenAI into open-ended assignments

Key strategy for integrating with GenAI	Assignment description
AI-powered tools for brainstorming and design concept exploration	Students use image generators (e.g., Midjourney and DALL-E 2) to explore visual concepts for a design project or large language models (e.g., GPT-4 and Gemini) to brainstorm plot ideas for a short story
AI for generating creative content	Students utilize AI music generators (e.g., Amper Music and Jukebox) to compose original music or sound effects for the project
Assessment of AI-generated content	Students critically analyze AI-generated text for bias, accuracy, and style with revision and improvement
AI-powered tools for research and data analysis	Students employ AI-powered research assistants (e.g., Elicit and Scite) to conduct literature reviews or analyze datasets
Tailoring projects to individual interests	Students utilize AI to explore topics related to their interests, creating personalized learning experiences
Fostering creativity and understanding AI's limitations	Students experiment with different prompts and parameters to understand how AI models respond, which fosters both creativity and a critical understanding of the technology

3.2 | Integrating AI into Active Learning Strategies

Moving beyond passive information reception, active learning engages students in doing, creating, and thinking critically. GenAI presents powerful opportunities to augment and extend the established active learning methodologies.

3.2.1 Enhancing Problem-Based Learning with AI

Problem-based learning (PBL), a student-centered teaching or learning approach driven by challenging and open-ended problems, can be significantly enhanced by using GenAI to generate realistic and engaging problem scenarios tailored to learning objectives, such as simulations of complex business and engineering challenges. AI-empowered research assistants can help students gather and synthesize information, thereby accelerating research and allowing concentration on higher-level analysis. An important issue for consideration, however, is that rigorous training in critically evaluating AI-provided information, verifying sources, and identifying bias remains essential. GenAI can facilitate solution exploration by hastening brainstorming on options or the formulation of alternative scenarios, which students will be incisively evaluated and refined. Moreover, AI

can offer guidance on providing formative feedback and summative assessment, although this should always be a supplement to, not replace, instructor's feedback. For instance, in a civil engineering PBL scenario regarding the design of a sustainable bridge, students will be asked to use AI to explore structural designs, simulate performance, and research regulations, after which they can meticulously scrutinize AI outputs and justify final and human-led design choices on the basis of engineering principles.

3.2.2 Leveraging AI in Project-Based Learning

Similarly, project-based learning (PjBL), which engages students in extended endeavors meant to address actual problems or create authentic products, can be powerfully augmented by GenAI. Students might use such technologies as avenues for initial content generation, provided this is always followed by substantial evaluation, refinement, and original contribution. AI-powered tools can help with data analysis and visualization, particularly for projects that involve voluminous datasets. In disciplines, such as engineering or design, AI can accelerate prototyping and design exploring, as well as support personalized learning by helping customized experiences to individual interests. For example, a marketing initiative can involve the use of AI to generate diverse campaign

materials, analyze market data, and personalize outreach. The subsequent assessment can then focus on AI-generated content and the strategic justification of marketing decisions on the grounds of core principles.

3.2.3 AI Integration into Open-Ended Assignments

Open-ended assignments, designed to foster creativity and critical thinking, can also benefit from thoughtful AI integration. The technology can be used to stimulate idea generation, helping students overcome creative blocks and explore diverse perspectives. It enables content exploration and experimentation with different styles or formats (e.g., generating variations of a creative piece). Examples of such integration are shown in Table 5. As with the previous measures, however, a crucial component is the stringent scrutiny of AI outputs. Assignments should require students to evaluate the quality, relevance, and potential biases in AI-generated content, refine it significantly, and justify their modifications to distinguish their work from AI's contribution. In this context, as well, teaching effective prompt engineering emerges as a valuable strategy. For instance, a literature assignment might involve the use of an LLM to generate the first draft of a story in a specific author's style, followed by a rigorous process of critical analysis, substantial revision, and original enhancement. The assessment can consider both the final product and the student's analytical process.

Across all these active learning strategies, the emphasis needs to remain steadfastly on AI as a tool to be wielded critically and responsibly. The goal is not reliance but enhancement, which means to use AI to augment human creativity, deepen learning, and develop sophisticated problem-solving skills. Human oversight, critical evaluation, and original contribution remain cardinal standards, and the ethical implications of AI use should be explicitly addressed in each activity. The key features and benefits of integrating AI into open-ended assignments are summarized in Table 6.

3.3 | Fostering Interdisciplinary Integration

The complex challenges of the AI-driven world rarely

fit within the boundaries of a single academic discipline. Effective solutions demand interdisciplinary collaboration and integration, with users required to synthesize knowledge, skills, and views from diverse fields. GenAI, typified by broad applicability and effectiveness in closing disciplinary divides, creates both a pressing need and unique opportunity to cultivate interdisciplinary learning in higher education.

The imperative for interdisciplinarity stems from four factors. First, most significant real-world problems, particularly those influenced by AI, are inherently interdisciplinary issues. Developing ethical AI guidelines, for instance, requires synergistic expertise from computer science, ethics, law, and sociology, while tackling climate change with AI necessitates integrating climate science, engineering, economics, and public policy. Second, AI exerts cross-cutting effects, permeating nearly every societal sector, from healthcare to the arts. Consequently, students across disciplines need to understand AI's transformative effects on their fields and learn to contribute to its responsible deployment. Third, interdisciplinary synergy is a potent driver of innovation, with the convergence of various backgrounds sparking novel insights and inventive solutions. Fourth, such education cultivates highly valued T-shaped skills which include deep expertise in one area complemented by the ability to effectively collaborate and communicate across disciplinary boundaries.

GenAI offers powerful capabilities to facilitate and enhance interdisciplinary learning. It can significantly aid in bridging communication gaps by translating technical jargon, summarizing and synthesizing vast amounts of information from disparate sources to establish common ground, and creating visualizations to clarify complex interdisciplinary relationships. Moreover, AI can bolster collaborative projects by providing shared digital workspaces, acting as an avenue for interdisciplinary brainstorming and idea generation, as well as aiding the production of integrated content, such as reports or presentations. AI excels as well at analyzing interdisciplinary data, with the technology identifying patterns and correlations across substantial datasets spanning multiple fields that

Table 6 Key features and educational benefits of AI-enhanced open-ended assignments

Key feature of assignments	Educational benefit of assignments
Enhanced ideation and exploration	Facilitate brainstorming and explore diverse perspectives, moving beyond conventional creative boundaries
Augmented research and inquiry	Provide powerful tools for information synthesis and data analysis, enabling deeper and more efficient investigation
Focus on critical evaluation and refinement	Shift learning from content generation to critically assessing, fact-checking, and refining AI outputs, which fosters higher-order thinking skills
Personalized learning pathway	Allow students to tailor assignments to their own interests and paces, increasing engagement and intrinsic motivation
Development of human-AI collaboration skill	Prepare students for future work by teaching them to effectively partner with AI-powered tools, developing responsible and strategic usage habits

might elude human researchers, thereby fostering new discoveries at the confluence of disciplines. Table 7 shows how AI can enhance interdisciplinary collaboration.

Effectively delivering interdisciplinary AI education involves a number of measures. Institutions might develop joint courses or modules co-taught by faculty from different departments, with a focus on AI-related topics that demand a multitude of stances. Assigning interdisciplinary ventures that require collaboration between students from various majors to solve real-world problems using AI translates to practical experience. Organizing guest lectures, workshops, hackathons, or competitions themed around transdisciplinary AI problems can expose students to different viewpoints and foster innovation.

Encouraging interdisciplinary research collaboration among faculty and students further enriches the learning environment. For example, a joint course on AI and society, co-taught by computer science, ethics, and sociology faculty, can explore AI’s implications for communities, culminating in collective student analyses of AI’s impact or proposals regarding responsible deployment strategies. The principal dimensions involved in designing these interdisciplinary approaches are summarized in Table 8.

3.4 | Cultivating Innovation in the Era of AI

In an AI-driven world where automation increasingly handles routine tasks, human capacity to innovate takes

Table 7 Enhancing interdisciplinary collaboration with GenAI

Aspect of enhancing collaborative item	Description of GenAI in enhancing collaborative item
Communication platform	AI-powered platforms bridge disciplinary language barriers, facilitating efficient idea sharing through real-time translation, transcription, and summarization
Brainstorming and ideation	AI acts as a brainstorming partner, generating novel solutions, encouraging students to think outside their disciplinary boxes, and leading to more innovative outcomes
Data analysis	AI-powered tools assist in integrating and analyzing diverse datasets, revealing patterns and insights that may be missed with traditional methods, and leading to a more holistic understanding
Project management	AI-powered tools streamline project management by organizing tasks, tracking progress, managing deadlines, and automating routine tasks, which improves overall project efficiency
Presentation enhancement	AI enhances presentations through interactive visualization, multimedia content, and real-time feedback, which makes presentations more engaging and impactful
Dynamic learning experience	Employing AI creates dynamic learning experiences that foster interdisciplinary understanding, enhance teamwork skills, and promote innovative problem-solving competencies
Real-world application	Students gain valuable opportunities to apply their knowledge to real-world contexts, preparing them for the collaborative and technology-driven nature of the modern workforce
Ethical consideration	Navigating the ethical implications of using AI in collaborative settings adds another layer of valuable learning, preparing students to be responsible and ethical collaborators

Table 8 Key aspects of design for interdisciplinary courses and modules with GenAI

Key aspect of design	Description of each key aspect of design
Interdisciplinary integration	This is crucial for tackling complex real-world problems that transcend traditional academic boundaries. GenAI serves as a bridge between disciplines, connecting concepts and methods
AI as a bridge	AI-powered tools can analyze data from diverse sources (e.g., historical texts, social media, and economic indicators) to provide a holistic understanding of complex issues. It enables students to see interconnectedness and apply multidisciplinary knowledge
Collaborative learning	GenAI facilitates collaborative learning among students from diverse backgrounds. Shared platforms for brainstorming, data analysis, and project development enhance teamwork and communication
Bridging the communication gap	AI-powered tools can translate technical jargon and summarize complex information from different fields, ensuring that all students can contribute effectively to collaboration
Innovation and novel solution	Interdisciplinary insights combined with GenAI foster innovative solutions. AI can generate novel ideas, explore alternative approaches, and surpass the limits of orthodox thinking
Transferable skill	Interdisciplinary learning develops critical thinking, communication, collaboration, and problem-solving skills. AI-powered tools can be integrated into assessments to evaluate these skills
Real-world challenge	Courses can be designed around real-world challenges (e.g., climate change and public health) that demand a multidisciplinary approach. AI-powered tools can be used to analyze data, model solutions, and communicate findings
Holistic understanding	This approach promotes a more holistic and interconnected understanding of knowledge, preparing students for a future where interdisciplinary collaboration and AI fluency are essential

on utmost importance, including generating novel ideas, developing imaginative solutions, and adapting to dynamic circumstances. This critical competency is the central responsibility of higher education.

3.4.1 *Fostering an Environment for Experimentation and Innovation*

Innovation flourishes in environments that encourage experimentation, value creativity, and view failure as integral to learning. Promoting such a culture in higher education entails a number of key approaches. Institutions should create safe spaces for experimentation, where students feel comfortable taking intellectual risks, pursuing unconventional ideas, and learning from mistakes without fear of punitive consequences. This creation can be facilitated through low-stake assignments focused on exploration, priority accorded to the learning process over the final product, and feedback-rich environments centered on growth. Embracing the concept of intelligent failure is crucial, promoting reflection on setbacks, identifying their causes, and iterating on ideas transform mistakes into valuable learning opportunities. Moreover, educators should actively advocate for curiosity and questioning, encouraging students to challenge assumptions and explore alternatives through PjBL, open-ended inquiry, and robust discussion or debate. Providing opportunities for play and exploration with AI-powered tools in low-pressure sandbox environments or through creative challenges allows students to discover AI capabilities organically. Furthermore, celebrating inventiveness and innovation by showcasing student's work or establishing recognition mechanisms reinforces the value placed on original thinking and novel solutions.

3.4.2 *Harnessing AI for Enhanced Creativity*

GenAI offers powerful new avenues for augmenting, rather than replacing human creativity. It provides tools for venturing into new frontiers in artistic expression, design, and innovation. AI can serve as a valuable creative partner for idea generation and brainstorming, helping students overcome blocks and explore varied standpoints using LLMs for textual ideas or image generators for visual concepts. AI enables unprecedented experimentation with styles and forms, enabling variations of creative work and emulation of different artistic expressions or authors. In fields such as engineering and design, AI accelerates prototyping and iteration, enabling swift generation and testing of multiple options. Moreover, AI advances novel interactive and personalized creative experiences, such as responsive art installations or adaptive challenges full of imagination and tailored to individual skills.

However, students are taught to critically evaluate AI-generated creative content, refine it, and thoughtfully integrate it into their original work. The technology should be regarded as a means by which to enhance human creative potential, not supplant it.

3.4.3 *Refining AI-Generated Content*

While GenAI can produce impressive outputs, these are rarely finished products. A crucial aspect of responsible AI use and higher-order thinking is developing skills to critically evaluate, refine, and contextualize AI-generated content. Critical evaluation requires assessing quality, accuracy, relevance, and potential biases, which further involves fact-checking, source verification, and judging coherence. Refinement and editing are essential for improving the quality, clarity, and style of AI outputs, with students required to rewrite, add or delete information, restructure content, and adapt it to specific contexts. Students are required to learn to contextualize and interpret AI-generated content, situating it in a broader knowledge framework and understanding its limitations. Emphasizing these skills transforms AI from a black box system into a controllable tool that students can effectively manipulate to enhance their learning and creativity as well as ensure the discerning and responsible use of technology.

4 Keeping Curricula Abreast of AI Developments

4.1 | Pace of Change in GenAI

The domain of GenAI is characterized by extraordinarily rapid innovation and development, presenting a fundamental challenge to higher education institutions aspiring to maintain the relevance of curricula. New models, architectures, techniques, and applications emerge at an unprecedented rate, often rendering what is considered cutting-edge today obsolete within months or even weeks. This relentless velocity of change stems from a confluence of factors. To begin with, intense research activities worldwide generate a constant stream of novel publications and methods. The vibrant open-source development community ensures the immediate dissemination and accessibility of new tools, while significant commercial investment fuels aggressive innovation and deployment cycles as companies race to release new AI-powered products. Moreover, analogous to Moore's Law, exponential improvements in AI capabilities are driven by increasing computational power, large datasets, and algorithmic breakthroughs.

The sheer speed of this evolution is evident in recent advancements across various modalities. The past year alone has witnessed the release of remarkably improved LLMs, such as GPT-4, Gemini 1.5 Pro, and Llama 3, each exhibiting enhanced reasoning, coding, and prompt handling abilities. Similarly, image generation tools, including Midjourney Version 6, DALL-E 3, and Stable Diffusion 3, now produce photorealistic and intricate visuals from simple text prompts, pushing the boundaries of creativity. Generative capabilities are rapidly expanding into video and audio generation as well. Underlying these advances are constantly evolving architectures from GANs and VAEs to sophisticated diffusion models and transformer-based systems. These examples only scratch the surface. More importantly, they present profound implications for higher education.

Curricula designed around static tools or techniques quickly become outdated. Preparing students adequately for an AI-driven future necessitates a paradigm shift to dynamic and adaptable mechanisms for curriculum updates. Against this backdrop, the ability to continuously learn and adapt is not simply a desirable trait but an indispensable competency for educators and students alike.

4.2 | Building Responsive AI Curricula Through Continuous Evolution

Static curriculum models are no longer sustainable given the rapid change in GenAI. Higher education institutions need to embrace a paradigm of continuous evolution, fostering curricula that are responsive and adaptable to technological advancements. Achieving this requires a multifaceted strategy that comprises strategic partnerships, sustained faculty development, and data-informed decision-making.

4.2.1 Bridging the Gap via AI Partnerships

Establishing robust partnerships with both industry and research institutions is crucial for maintaining the currency and relevance of curricula amid AI's rapid evolution. Such collaborations offer invaluable access to cutting-edge research, casting light on the latest AI models, algorithms, and techniques for integration into coursework. They also create pathways to vital industry expertise regarding practical AI applications, in-demand skills, and emerging workplace trends, thus guaranteeing curriculum alignment with career preparedness. The access unlocked by partnerships likewise extends to real-world datasets and case studies, enriching student learning experiences, and opportunities for guest speakers, mentors, internships, and

potentially shared resources, such as cloud computing access. Building effective partnerships necessitates identifying relevant organizations, establishing clear mutual goals, formalizing agreements, maintaining regular communication, creating collaborative opportunities for faculty and students, and joining existing AI education communities to leverage shared resources and knowledge.

4.2.2 Essential AI Training and Support for Educators

The successful integration of GenAI into education hinges upon equipping faculty with the requisite knowledge, skills, and resources. Ongoing professional development is essential for preparing educators to effectively use AI-powered tools in teaching and guiding students in the responsible and ethical adoption of such technologies. While a comprehensive approach is detailed, key elements include offering targeted training programs customized for varying expertise levels and disciplinary needs. These initiatives should cover foundational AI concepts, hands-on tool training, pedagogical integration strategies, and ethical considerations. Implementing scalable training models, such as train-the-trainer initiatives or online modules, is vital for reaching faculty broadly. Providing ongoing support through mentorship programs, online communities, technical help desks, and curated resources ensures sustained engagement. Incentivizing faculty participation and proactively addressing institutional resistance and budget considerations are also critical components of a successful faculty enablement strategy.

4.2.3 Data-Driven Curriculum Adjustment

Maintaining the relevance of curricula requires institutions to adopt a data-driven approach to continuous adjustment. This involves systematically collecting and analyzing data from diverse sources to inform decisions about updates and revisions. Regularly soliciting student feedback on their learning experiences, particularly with AI-integrated components, through surveys or focus group discussions sheds light on issues of importance. Using learning analytics can help track student progress and identify areas needing pedagogical refinement. Monitoring industry trends through job posting analysis, partner feedback, and conference attendance ensures alignment with workforce demands. Continuously monitoring AI technology advancements via research publications, conferences, and practical experimentation guides content updates. Gathering inputs from alumni clears the way for varying perspectives on the long-term relevance of a

curriculum. This data collection and analysis cycle is formalized by establishing a regular curriculum review process.

4.3 | Adopting Modular Curricula

To effectively manage the swiftness of developments inherent in GenAI and craft responsive curricula, higher education institutions should strategically adopt modular curriculum design. While beneficial generally, modularity becomes essential when dealing with swiftly evolving fields such as AI. This approach involves breaking down traditional courses into smaller, self-contained units or modules, which can then be updated, replaced, or rearranged with significantly greater ease and speed than is possible for monolithic course structures. The ease ensuing from modularity prevents widespread disruption.

4.3.1 Principles of Modular Course Design for Curricular Agility

Effective modular design adheres to a number of core principles that render institutions conducive to agility in AI curricula. Self-contained modules, each focusing on a specific topic or skill and relatively independent from one another, allow for targeted updates without impacting an entire course. Each module requires clear learning objectives that need to be satisfied upon completion. Assessment alignment ensures that evaluations directly measure the achievement of objectives specific to each module. Designs should permit flexible sequencing, enabling customized learning paths or course structures. Moreover, module content can be structured as smaller and reusable learning objects (e.g., videos, exercises, and readings), facilitating even more granular updates and repurposing.

The benefits of modularity for AI education are substantial. It enables rapid updates, allowing outdated content related to specific AI models or techniques to be swiftly replaced. This inherent flexibility and adaptability ensure curricula can evolve in response to the changing needs of students, industry, and the AI landscape. Modularity facilitates personalized learning by allowing students to select modules relevant to their interests and career goals. Finally, it promotes efficiency and reusability, as modules and learning objects can be shared across different courses and programs. For instance, GenAI in marketing course can comprise modules such as introduction to GenAI, LLMs for marketing, AI image generation, and AI marketing ethics. Should a new LLM emerge, only the module specific to it needs updating.

4.3.2 Strategies for Updating Modular Content

The core advantage of modularity lies in the capacity for rapid and efficient content updates to reflect AI advancements. Effective strategies include using version control systems, such as GitHub, to track changes and manage revisions. Maintaining a centralized repository facilitates easy access and updating of modules and learning objects by instructors. Exploring possibilities for automated updates of certain content types, such as external links, while always ensuring careful review can enhance efficiency. Establishing a regular review cycle, with frequency determined by the pace of change in a given AI area, potentially semesterly for quickly evolving topics, guarantees ongoing relevance. Incorporating formal feedback mechanisms (student, instructor, and industry input) helps identify necessary improvements. Encouraging collaboration and sharing of updated materials among faculty further puts the modular approach to advantage.

4.3.3 Personalizing Learning Through Modular Pathways

Modular curricula inherently offer tremendous opportunities for personalizing learning experiences, a particularly valuable feature given the diverse backgrounds and needs of students engaging with AI. Institutions can create recommended learning pathways catering to different student profiles or interests, such as AI ethics and development. Offering a range of elective modules allows students to delve deeper into specific AI areas. Modular structures can more easily accommodate self-paced learning, accommodating varying styles and schedules. Implementing prior learning assessment becomes more feasible, enabling students to potentially bypass modules covering knowledge that they already possess. Finally, modularity supports the issuance of stackable credentials or micro-credentials, providing verifiable evidence of specific skills acquired through module completion. By embracing modular design, institutions can foster learning environments that are flexible, adaptable, personalized, and crucially responsive to the dynamic nature of GenAI, empowering both educators and learners for a future that demands continuous learning.

4.4 | Fostering Self-Directed Learning in the Era of GenAI

The rapid evolution of GenAI fundamentally necessitates a pedagogical shift toward fostering self-directed learning. Empowering students to become lifelong learners who are capable of independently acquiring knowledge, adapting to new technologies,

and critically evaluating information in an increasingly complex and AI-saturated environment is paramount.

4.4.1 Mastering Information Literacy Skills

Although always crucial, information literacy which is the ability to effectively find, evaluate, and use information, has assumed new urgency and complexity in the era of GenAI. The proliferation of AI-generated content, potentially typified by convincing hallucinations, demands sophisticated evaluation skills that transcend conventional methods. Enhanced source evaluation in the era of GenAI requires students to critically assess the provenance of information, considering not only orthodox credibility-related factors but also the possibility of AI generation or manipulation. This involves developing awareness of AI capabilities and limitations, learning to pinpoint potential red flags indicating synthetic content, and reinforcing the importance of cross-verification. Proficiency in lateral reading and advanced fact-checking techniques becomes indispensable for verifying accuracy. Understanding how prejudices in training data influence AI model outputs is essential for analytically interpreting information. Prompt literacy, or understanding how prompt variations affect AI outputs, aids in appraising the content generation process itself. Increasingly vital, as well, are the awareness and identification of deepfakes and synthetic media. These advanced information literacy skills are extremely necessary for avoiding misinformation and are fundamental to becoming critical and informed consumers and creators in an AI-driven information ecosystem.

4.4.2 Cultivating a Growth Mindset for Lifelong Adaptation

A growth mindset, which is the belief in developing abilities through effort and learning, is foundational for self-directed learning, particularly under the rapid evolution of AI. Students need to embrace lifelong learning, recognizing that acquiring knowledge and skills is a continuous process that is necessary to keep pace with technological change. Students need to learn to view challenges as opportunities for advancement rather than indicators of fixed limitations, as well as actively seek feedback and learn from mistakes. Developing strong meta-cognitive aptitude to understand one's learning processes, strengths, weaknesses, and effective strategies, allows students to adapt how they learn. Teachers should value effort and persistence as students gain command of complex new skills and knowledge. Educators are instrumental in fostering this mindset, which they can be accomplished

by providing constructive feedback, creating environments that support and encourage risk-taking, modeling lifelong learning themselves, and emphasizing the importance of continuous professional development.

4.4.3 Leveraging AI-Powered Tools to Support Self-Directed Learning

Paradoxically, GenAI itself offers powerful tools with which to advocate for self-directed learning when used thoughtfully. AI platforms can personalize learning pathways, recommend relevant resources, and provide commentary suited to individual needs and interests. AI tutors and chatbots offer twenty-four seventh access to learning resources and supports. By automating tedious tasks such as basic grading, AI can free up educator time for more meaningful student interaction. AI research assistants can facilitate exploration and discovery, helping students navigate vast information landscapes and identify conceptual connections. Moreover, AI-powered tools significantly elevate accessibility for students with disabilities through features, such as text-to-speech functionality or real-time translation. GenAI places the power to create engaging interactive learning experiences, such as adaptive simulations, in the hands of educators. Nevertheless, these tools are expected to be deployed in a pedagogically sound and responsible manner so that they do not impede the development of critical thinking. AI should serve to enhance and support self-directed learning, not undermine learner's agency. By implementing the aforementioned recommendations, higher education institutions can mold students into lifelong learners adept at navigating the complexities of an AI-driven future.

5 Practical Considerations for AI Integration in Education

5.1 | Equipping Faculty for AI-Driven Education

The cornerstone of successful AI integration lies in arming faculty with the knowledge, skills, and resources necessary to achieve this goal. Effectively using GenAI in teaching and research demands an exhaustive and sustained approach to the faculty professional development that surpasses technical proficiency to encompass pedagogical strategies, ethical understanding, and the awareness of institutional contexts. Faculty development programs should be grounded in the varying needs of each discipline rather than underlain by a one-size-fits-all model.

5.1.1 Comprehensive and Scalable Faculty Development

Effective faculty development should be comprehensive, covering basic AI literacy to advanced applications and ethics. It should be experiential, allowing faculty to practice using tools and design AI-integrated activities. A strong pedagogical focus is crucial, with emphasis directed toward educational implications in lieu of purely technical aspects. Training should be discipline-specific where appropriate, ongoing, and sustained to keep pace with AI's evolution, suitably incentivized (e.g., via course release or recognition), and offered in flexible formats.

Achieving scalability requires strategic approaches. Developing self-paced online modules and centralized resource repositories provides accessible and updatable training materials and support resources (tutorials and practices). A train-the-trainer model, in which internal "AI champions" mentor their colleagues, offers a sustainable and cost-effective method for cascading expertise. Formal mentorship programs that pair experienced faculty with novices allow for personalized guidance, while regular workshops and seminars led by internal or external experts can address specific tools or pedagogical concerns. Fostering communities of practice encourages peer learning, collaboration, and experience sharing. Finally, actively showcasing internal best practices provides concrete models and inspires broader adoption. [Table 9](#) summarizes key strategies for faculty development.

5.1.2 Addressing Institutional Resistance

Integrating GenAI is inevitably confronted with institutional resistance, rooted in both faculty and administration concerns. These concerns should be proactively and strategically resolved for successful

implementation. Common reservations from faculty include fears about job security, increased workload, lack of expertise, ethical worries, and pedagogical doubts. Administrative concerns often involve budget constraints, data privacy and security matters, inadequate infrastructure, and general risk aversion to new technologies.

Overcoming resistance requires a multipronged strategy. Building a coalition of support among key stakeholders, such as administrators, influential faculties, and Internet technology (IT) staff, is essential to champion the initiative. Clearly demonstrating the value and return on investment of AI integration which has improved student outcomes, potential efficiencies, and enhanced institutional reputations, is crucial to secure buy-in. These claims can be reinforced by data-driven evidence from pilot projects. Another vital measure is to address concerns directly and transparently, engaging in open dialogue with stakeholders and providing them with accurate information. Ensuring adequate resources and supports for faculty, including training and technical assistance, alleviates practical barriers. Adopting a startup and scaleup strategy, beginning with preliminary endeavors and gradually expanding successful initiatives, paves the way for manageable implementation. Developing clear institutional policies and guidelines regarding acceptable AI use, academic integrity, and data privacy provides the necessary structure and reassurance. Lastly, foregrounding success stories, both internal to the institution and external from other institutions, can inspire confidence and demonstrate feasibility.

5.1.3 Navigating Budget Considerations

Although AI integration involves costs, institutions can employ various strategies to manage budget limitations

Table 9 Key strategies for faculty development

Strategy	Description	Benefit	Implementation
Targeted training program	Focused on tools, ethics, and pedagogies of the program	Enhanced faculty skills integrating GenAI fundamentals into ethical awareness	Tailored programs for disciplines and experience levels, hands-on workshops, and practical application sessions
Incentive and recognition	Stipends, courses release times, and showcasing innovative practices	Increased faculty engagement, motivation, and value for continuous learning	Stipends for workshops and courses release for curriculum development, and recognition of AI-integrated teaching
Community of practice	Forums for sharing experiences, practices, and resources	Collaborative learning, peer support, and experimentation with new approaches	Online forums, workshops, conferences, and regular meetings for sharing experiences
Access to resource and support	Easy access to online tutorial, research article, AI-powered tool, and technical support	Simplified access, encouraged exploration, and enhanced faculty expertise	Centralized hub for AI resources, readily available technical support, and access to AI-powered tools
Collaboration with experts	Interaction with industry and research professionals	Real-world context and practical experience, bridging theory and practice	Workshops, conferences, and joint projects with industry and research experts
Integration into existing activities	Embedding AI-related professional development into regular meetings	Normalized continuous learning, shared institutional priority, and increased AI literacy	Short presentations, discussions in faculty meetings, departmental retreats, and teaching workshops

effectively. The careful prioritization of investments in infrastructure, software, and training areas with the greatest impact on learning and institutional goals is key. Maximizing existing resources, such as campus laboratories, libraries, and learning platforms, minimizes the emergence of new expenditures. Employing scalable and cost-effective cloud computing services (e.g., Amazon Web Services (AWS), Microsoft Azure, and Google Cloud Platform) reduces the need for expensive on-premises hardware. Favoring free and open-source tools and software (e.g., Python, TensorFlow, and Hugging Face) significantly lowers licensing costs, and leveraging open education resource (OER) reduces material development expenses. Moreover, seeking external funding actively through grants and partnerships can supplement internal budgets. Partnerships, in particular, advance resource and expertise sharing. Phased AI integration, starting with affordable but high-impact initiative, aids the regulation of upfront investment. Furthermore, developing a long-term plan and budget that anticipates future needs enables sustainable integration. By strategically mapping out and maximizing cost-effective solutions, institutions can successfully integrate GenAI into education, even amid monetary restrictions, and direct resources where they yield the greatest educational impact.

5.2 | Resourcing GenAI in Higher Education

Successfully adopting GenAI likewise necessitates careful resource planning and allocation, tailored to institutional contexts while addressing central requirements. Supporting AI-driven learning and research requires attention to computing infrastructure, software, data, human resources, and network capabilities, ideally guided by clear prioritization and financially sustainable strategies.

With regard to computing infrastructure, leveraging cloud computing services (e.g., AWS, Microsoft Azure, and Google Cloud Platform) typically offers the most economical and scalable avenue in which to secure necessary computational power, including the on-demand tensor processing units (TPUs) and graphics processing units (GPUs) required to use many generative models, as well as adaptable and managed services that reduce IT burdens. While institutions carrying out extensive AI research may require high-performance computing on their premises, this translates to exorbitant costs for an affordance that is generally unnecessary in basic educational integration. As with the discussion on budgetary strategies, free and open-source tools, software, and frameworks is advisable, with appropriate options spanning the dominant AI programming language, Python, along with leading DL frameworks, such as

TensorFlow and PyTorch, as well as libraries, such as Hugging Face Transformers for pretrained models and scikit-learn for general ML, potentially supplemented by the R project for statistical computing. Using cloud-based platforms, such as Google Colab or Jupyter Notebook, provides accessible development environments and pretrained models. Some specialized commercial tools, such as generative design software, may be necessary for certain applications, but their cost-benefit ratios should be carefully evaluated, with primacy always accorded to open-source alternatives.

Another crucial resource is appropriate data. Institutions should leverage OER and publicly available datasets whenever possible. Utilizing institutional data for research or teaching is feasible but requires strict adherence to privacy and ethical guidelines. Investment in resources for data curation and management should not be overlooked, as this often represents a significant hidden cost in AI projects. A reliable network infrastructure, including high-speed internet access and sufficient bandwidth, is essential for accessing cloud resources and supporting requirements for the transfer of data for AI applications. While not always necessary, dedicated physical spaces, such as specialized laboratories, can sometimes be beneficial. Above all, however, the most critical component is human resource. Faculty expertise is paramount, making investment in faculty development a top priority. Adequate technical support staff, potentially requiring training for existing IT personnel or hiring new staff with AI expertise, is needed to assist faculty and students. Instructional designers skilled in AI integration can also tremendously facilitate effective course implementation.

In navigating the abovementioned resource needs, several prioritization and cost-effective strategies should guide institutional planning. Prioritizing cloud computing and open-source tools minimizes infrastructure and licensing expenses. Investing strategically in faculty development yields substantial returns, as well-trained faculty can maximize limited resources. Adopting a startup and scaleup strategy with pilot projects allows for gradual expansion, while seeking external funding and exploring resource sharing partnerships can alleviate budget constraints. Ultimately, successful integration requires focusing strategic investments on areas with the greatest impact on student learning and institutional goals, capitalizing on the efficiencies of cloud and open-source solutions, as well as the expertise of solidly supported faculty. The abridged principal requirements are listed in [Table 10](#).

5.3 | Navigating the Ethical Dimensions of GenAI in Education

The integration of GenAI into higher education

Table 10 Key resource and infrastructure needs for GenAI

Key resource and infrastructure for GenAI	Key consideration	Detail and requirement
Computing resource	High performance	Investment in HPC infrastructure, including GPUs and cloud-based resources (e.g., AWS, Microsoft Azure, and Google Cloud Platform), is crucial for training and inference development for GenAI models. Explore shared resources, cloud platforms, and grant funding
AI-powered software and tool	Accessibility	Provide access to programming libraries (e.g., TensorFlow and PyTorch), development environments (e.g., Jupyter Notebook and Google Colab), and user-friendly platforms for various AI tasks (text, image, and code generation). Consider open-source options, educational licenses, and cloud services
Data access	High quality datasets	Invest in building and maintaining data repositories relevant to different disciplines. Explore partnerships, open access datasets, and data augmentation techniques to address data limitations. Ensure that infrastructure and resources are accessible to all students, including those with disabilities, by providing assistive technologies and adaptable learning environments
Network connectivity	Reliability and high speed	Ensure reliable and high-speed network connectivity for accessing cloud resources, collaborating on projects, and utilizing online AI-powered tools
Technical support	Timely assistance	Establish help desks, online forums, and training resources to provide technical assistance for using AI software, troubleshooting issues, and accessing computing resources
Budgetary planning	Resource allocation	Allocate resources for hardware, software, data acquisition, technical support, and faculty training. Explore grant opportunities, industry partnerships, and cost-effective solutions, such as cloud computing

Notes. HPC: high-performance computing, GPUs: graphics processing units, AWS: Amazon Web Services.

introduces an intricate web of ethical implications that demand proactive and thoughtful attention. These dimensions move past abstract concerns, carrying tangible real-world consequences for students, faculty, institutions, and society.

Primary concerns are bias and fairness. GenAI models, trained on vast datasets, risk perpetuating and even amplifying the societal prejudices (e.g., gender, racial, and socioeconomic) present in data. This problem can engender unfair or discriminatory outcomes in educational contexts, such as slanted grading by an AI system. These adverse effects can be mitigated by the careful scrutiny and preprocessing of training data, regular algorithmic auditing for bias, endeavors to ensure transparency and explainability in AI model development and deployment, human oversight particularly in high-stakes scenarios, the promotion of diversity in AI development teams, and the integration of discussions regarding AI bias directly into curricula.

Privacy and data security represent another central issue, as educational AI use often involves processing sensitive student data from training inputs to student-generated content and platform interactions. Addressing this problem requires strict adherence to data minimization principles, with only necessary data collected. Anonymization or de-identification where possible is crucial, as is secure data storage and transmission, alongside rigorous compliance with relevant privacy regulations, such as the *General data protection regulation*, *Family educational rights and privacy act*, and *Children's online privacy protection act*. Transparency with students regarding data usage and obtaining informed consent is essential, and these initiatives should be underpinned by clear institutional

data governance policies that outline collection, use, storage, and protection protocols.

The ease with which AI generates human-quality content poses a substantial threat to academic integrity and plagiarism. The temptation for students to submit AI-generated work as their own undermines the learning process, thus requiring the establishment of clear institutional policies on acceptable AI use in assignments, the education of students on AI ethics and proper attribution, and the design of activities that reduce the potential for trivial AI completion. While AI detection applications exist, they are asked to be used cautiously due to limitations and potential inaccuracies, serving as only one part of a broader integrity strategy. Focusing assessment on the learning process rather than the final product and fostering an institutional culture that values original intellectual work are also critical.

On top of the challenges described above, the intellectual property and copyright issues surrounding AI-generated content are complicated and legally evolving, with ambiguity often characterizing the matter of ownership. Institutions should educate students and faculty on current copyright law and its implications for AI-generated content. Promoting appropriate attribution, even amid legal uncertainty, is good practice. Additional necessary steps for responsible use are staying informed about legal developments and choosing AI-powered tools accompanied by clear terms of service regarding intellectual property.

Meanwhile, the black box nature of many generative models calls attention to apprehensions about transparency and explainability. The difficulty in understanding how AI arrives at its outputs can erode

trust and hinder accountability. Mitigation strategies include advocating for and utilizing more explainable AI models where feasible. Even with intricate models, striving for deliverables that are understandable and interpretable by humans is important. Transparency is also enhanced by the provision of context and justification when using AI-generated content. Beyond openness and disclosure, the considerable energy consumed in training and operating large AI models should also be examined, as this affects the environment. This effect points to the need to promote energy-efficient models, considering the environmental cost of AI usage, advocating for sustainable AI practices in the field and the institutions operating in it, and selecting less energy-intensive computing resources when possible.

Finally, ensuring accessibility and equity is imperative, with institutions duty-bound to ensure equitable access to necessary AI-powered tools and resources for all students, preventing AI from exacerbating existing inequalities. This includes actively addressing potential biases in AI systems that can disadvantage certain student groups and leveraging AI's capabilities to create more inclusive and accessible learning experiences for students with diverse needs. Addressing these multifaceted ethical dimensions demands collaboration among educators, administrators, policymakers, and developers. It necessitates ongoing dialogue, critical reflection, and continuous adaptation as AI technologies rapidly evolve, representing a sustained process of ethical engagement rather than a one-time solution.

5.4 | Reimagining Assessment in an AI-Driven World

The integration of GenAI fundamentally necessitates a rethinking of assessment practices in higher education. Traditional methods centered on recall and rote memorization prove inadequate for evaluating the higher-order thinking and complex problem-solving skills paramount in an AI-pervasive world, which is an issue compounded by the significant academic integrity concerns arising from AI's content generation capabilities.

Assessment design should focus on higher-order thinking skills and the evaluation of students' attempts at critical analysis, creative synthesis, ethical reasoning, and problem-solving. Moreover, assessments should be directed toward authenticity, with teachers assigning tasks that mirror real-world activities and challenges to enhance engagement and relevance. As previously stated, learning process should be given priority because it expands insight into the research, critical thinking, and problem-solving strategies. Formative assessment offers valuable feedback on skill

development, and utilizing multiple evaluative approaches captures a more holistic view of student learning. Furthermore, do not forget the criticality of clearly communicating assessment criteria and expectations, including guidelines for appropriate and ethical AI use, to students.

Building on the aforementioned principles, specific assessment strategies can be effectively adapted or newly implemented. PjBL and open-ended assignments are particularly well suited, as they inherently require application, creativity, and critical thinking, making them more resilient against superficial AI use. Administering oral examinations and presentations allows for direct appraisals of understanding and verification of authenticity given that students explain concepts and their use of AI-powered tools. Portfolio assessment, evaluating a curated body of student work over time (e.g., essays, projects, and reflections), captures a detailed picture of learning progression and skill development. Designing hybrid assignments that explicitly combine AI use with critical human input, as is the case with calling on students to analyze and revise an AI-generated draft substantially, synthesize AI-assisted research into an original argument, or evaluate and justify an AI-generated design, which makes room for explicitly assessing critical engagement with the technology. Moreover, employing process-oriented techniques (e.g., think-aloud protocols, reflection papers, peer reviews focused on AI use, and specific AI literacy rubrics), can substantially illuminate students' thinking and responsible AI engagement.

While these assessment strategies help mitigate integrity risks, directly addressing academic integrity remains crucial. This endeavor involves instituting straightforward institutional policies, educating students about AI ethics, using detection tools cautiously and judiciously, and vigorously advancing a culture that values original scholarship. By embracing these principles and strategies, institutions can design assessments that measure meaningful learning outcomes effectively while remaining resilient and relevant in the age of GenAI. They can redirect effort from mere knowledge recall to evaluating critical thinking, problem-solving, and responsible AI utilization, as shown in [Table 11](#).

5.5 | Preserving Academic Honesty amid AI-Driven Learning

The facility with which GenAI produces human-quality content poses major challenges to academic integrity in higher education. While AI detection tools offer some assistance, the shortcoming intrinsic to them preclude relying on them as the sole solution. Instead, preserving

Table 11 Assessment strategies in an AI-driven learning environment

Assessment strategy	Focus	Method	Benefit
Process-oriented assessment	Learning process over the final product	Evaluating research, brainstorming, drafts, and reflections	Providing insights into critical thinking, problem-solving, and ethical use of AI
Authentic assessment	Real-world application	Projects, case studies, simulations, and presentations	Demonstrating practical skills in leveraging AI to solve real-world problems
Higher-order thinking skill	Critical thinking, analysis, and creativity	Analyzing AI outputs, proposing solutions, and defending reasoning	Developing critical and creative thinking with and about AI
Oral presentation and project defense	Articulating thought process	Explaining AI-powered tool usage and responding to questions	Providing deeper understandings of learning and communication skills
Portfolio-based assessment	Development of AI-related skills over time	Project reports, code samples, AI outputs, reflections, and peer reviews	Presenting comprehensive views of student growth and achievement
Peer assessment and collaboration	Collaborative learning	Peer evaluation, feedback on AI use, and teamwork	Fostering collaboration and developing feedback and evaluation skills
AI literacy rubrics	Clear expectation and consistent evaluation	Specific criteria for AI understanding, ethical use, and societal implication	Providing clear guidelines for assessment
Adapted plagiarism detection	Maintaining academic integrity	New approaches to identifying AI-generated content while recognizing legitimate AI use	Addressing challenges of AI-generated content in assessment

academic honesty entails a proactive and multidimensional strategy centered on student education, thoughtful assessment design, and institutional culture that places a premium on honor and decency.

This strategy is founded on the establishment of clear institutional policies regarding the acceptable use of GenAI in coursework. These policies explicitly define permissible and impermissible applications, delineate the consequences of violations, are communicated transparently to all stakeholders, and are subjected to periodic reviews and updates to keep in step with AI's evolving capabilities. Example policy statements may permit AI for brainstorming while mandating original analysis, allow AI-generated content as a starting point, but require heavy emendation and proper citation, or strictly prohibit assignments generated entirely by AI.

Complementing clear policies is the active education of students about academic integrity in the context of AI. The active education should explain the purpose of academic integrity, clarify institutional AI use policies, provide concrete examples of acceptable and unacceptable uses in various assignment types, teach appropriate citation methods for AI-generated content, and discuss AI's deficiencies while stressing the importance of developing independent critical thinking skills.

Another pillar is designing AI-resilient assessments, which involves dedicating evaluation to the refined thinking skills that are difficult for AI to replicate, utilizing authentic assessments mirroring real-world tasks, emphasizing process-oriented evaluation over final products, incorporating oral components (e.g., exams and presentations), employing hybrid assignments that blend AI use with critical human analysis, and personalizing assignments to hinder reliance on generic AI outputs.

Academic integrity can also be monitored via AI detection tools (e.g., Turnitin and GPTZero), but they should be used with caution because they have the potential to generate both false positives and false negatives. These tools should supplement other components of a broader integrity strategy rather than functioning as the sole determinant of misconduct. Faculty members require training on these tools' drawbacks, and they should apply such technologies judiciously and ethically, always interpreting results alongside other evidence, such as student work history and process explanations.

Ultimately, technological solutions and policies are most effective when woven into an environment that upholds academic integrity. Institutions should uncompromisingly promote respect for intellectual property and original work, emphasize the intrinsic value of learning over grades alone, create supportive environments where students feel comfortable seeking help, and ensure educators model ethical behavior.

When integrity issues arise, the focus should primarily be on learning and education, not only on punishment. The goal is to help students understand ethical expectations and develop responsible practices for an AI-driven world. Punitive measures, when necessary, should be a last resort and proportionate to offenses as shown in [Table 12](#).

6 Conclusions

This research has underscored the urgent necessity for curriculum reform in higher education to address the transformative impact of GenAI. The rapid evolution of AI technologies compels a fundamental shift in pedagogy, assessment, and curriculum design to

Table 12 Strategies for maintaining academic integrity in an AI-driven environment

Strategy	Focus	Method	Benefit
Clear guidelines and policies	Defining acceptable AI use	Policies on plagiarism, attribution, and limitations of AI-generated content	Fostering shared understanding of responsible AI use
Student education	Responsible AI use	Emphasizing ethics, original thought, and responsible technology use	Empowering students to use AI ethically and as a learning aid
AI-specific plagiarism detection	Identifying AI-generated content	Developing or investing in AI-specific detection tools	Maintaining academic standards by detecting AI-generated content
Critical evaluation of information	Assessing information sources	Teaching bias identification, credibility assessment, and verification	Promoting critical thinking and diverse perspectives
Assignment design	Minimizing opportunities for misuse	Open-ended questions, personal reflections, and real-world applications	Encouraging authentic engagement and minimizing over-reliance on AI
Culture of academic integrity	Promoting ethical scholarship	Valuing honesty, originality, and active learning	Fostering pride in original work and ethical behavior
Faculty training and awareness	Supporting academic integrity	Training on AI capabilities, detection strategies, and assessment design	Enabling faculty to guide students effectively
Regular policy review	Addressing emerging challenges	Updating policies and guidelines to reflect AI evolution	Ensuring policies relevance and effectivity

adequately prepare students for an increasingly AI-dominated ecosystem. This research has proposed a practical and framework-driven approach to this integration that rests on a number of principal strategies, central among which is fostering comprehensive AI literacy across all disciplines through a tiered scheme that ensures foundational understanding while leaving room for specialization. No less important is prioritizing problem-solving capabilities by eschewing rote memorization and devoting attention to higher-order thinking skills, cultivated through active learning, project-based work, and open-ended assignments. Moreover, recognizing the field's dynamism, this research advocates for embracing dynamic curriculum updates via mechanisms, such as industry partnership, modular design, and data-driven feedback. Furthermore, promoting self-directed learning skills, including advanced AI literacy and a growth mindset, is crucial for lifelong adaptation. Finally, the proposed framework comes with practical strategies for navigating significant implementation challenges, encompassing faculty development, institutional resistance, budget limitation, ethical considerations, assessment redesign, and academic integrity.

The primary contributions of this work lie in offering a comprehensive, practical, and actionable framework for integrating GenAI into higher education curricula, grounded in evidence and illustrated through concrete examples, as shown in Electronic Supplementary Material. Its interdisciplinary approach ensures applicability beyond technical fields. The framework consistently emphasizes ethical considerations, guiding responsible AI integration. It also foregrounds the imperative for continuous improvement, reflecting the fluidity of AI through ongoing updates and evaluation while providing

concrete and implementable strategies for educators and institutions navigating this transition.

Looking ahead, future research should pursue some promising directions. Rigorous empirical studies should be devoted to evaluating the impact of AI-integrated curricula on diverse student learning outcomes, including critical thinking and problem-solving. More comprehensive ethical frameworks and practices for AI use in various educational contexts should be developed. Further investigations into effective strategies for achieving faculty advancement at scale and designing robust and dynamic updating mechanisms for curricula are also needed. Longitudinal studies tracking the long-term effects of AI on education and the workforce will likewise provide valuable insights.

The integration of GenAI into higher education is not a distant prospect but an immediate imperative. Institutions are expected to act decisively now to prepare students for the future. This necessitates a profound commitment to curriculum innovation, embracing new pedagogical models and assessment strategies. It requires substantial investment in comprehensive and ongoing faculty development and the cultivation of strategic partnerships with industry and research organizations. Upholding ethical responsibility in all facets of AI integration is a hard-and-fast rule. Ultimately, nurturing a culture of continuous learning and adaptation among both educators and students is key. These principles are expected to enable the higher education sector to effectively harness the transformative potential of GenAI, creating more engaging, effective, and equitable learning experiences that empower students to thrive in a rapidly evolving world. The time for proactive engagement and thoughtful action is now.

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