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Cultivating Critical Thinking in Future Professionals through Advanced Information Literacy and Learning Technologies

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Abstract - **In an era defined by information overload, Generative AI-driven content, and sophisticated misinformation, the ability to think critically has shifted from a desirable professional attribute to an essential one. Conventional educational frameworks often reduce information literacy to a procedural skill set for finding and citing sources, inadequately preparing students for the intricate nature of the modern digital landscape. In an attempt to bridge the educational gap, this paper designs and offers support for a new conceptual framework, which we term as Synergistic Framework for Critical Information Engagement (SFCIE). The specific research objective of this study is to develop an integrated and comprehensive framework that synergizes information literacy (IL) capabilities at an advanced level with modern learning technologies in higher education. This study targets higher education curricula and programs which prepare future professionals in a spectrum of fields, including but not limited to management, law, and health science, among many others. This paper follows the research design of a review of the literature and a conceptual development. This research thus reviews the development of IL and its pedagogical tools, the underlying cognitive abilities for critical thinking (CT), and the functional affordances of learning technologies, such as Artificial Intelligence tutors and collaborative digital workspaces to support these dimensions, especially in the case of the recent rise of Generative AI and its paradoxical effect for both supporting and undermining CT. The main finding of this article is an integrative framework of building and supporting CT at the intersection of core literacies, higher-order cognitive skills such as algorithmic thinking, source analysis, and ethical integration of information, and pedagogical methods enabled by learning technologies. SFCIE thus provides teachers and instructors with a principled approach for designing learning experiences that enable and support the development of robust CT. We concluded that higher education programs must progress beyond lower-order learning skills and take an integrative approach, putting pedagogy at the center, to better prepare graduates as professionals who are insightful, analytical, and ethically aware. The article also provides a blueprint for educators and higher education leaders to support CT in a world of increasing integration of AI and AI-powered systems.**

Keywords: **Critical Thinking, Information Literacy, AI Literacy, Learning Technologies, Higher Education, Generative AI, Digital Pedagogy, E-learning**

I. INTRODUCTION

The professional environment of the 21st century is one of its most complex and information-saturated. The growth of the digital ecosystem, driven by the advancement of artificial intelligence (AI), has created a professional world in which the ability to distinguish quality information from sophisticated disinformation, or an "infodemic" (Haider & Sundin, 2022), is a baseline professional skill. The recent GenAI boom has intensified this complexity by providing unprecedented capabilities for the generation of "realistic and fluent, but also potentially misleading, biased or entirely fictional information" (Almansour & Alfhaid, 2024; Bhattacharyya et al., 2023; Nematov et al., 2025). For students and early professionals in virtually all fields from law and medicine to management and engineering key professional tasks such as information analysis, decision-making, and creative problem-solving are now directly contingent on their ability to critically engage with and

synthesize vast amounts of digital information. As a result, the development of critical thinking skills is perhaps the most important aim of the modern university (Bellaera et al., 2021).

Yet, there is a remarkable distance between this need and the traditional teaching practices of the higher education system. Information literacy, the usual academic response to this problem, is often reduced to a single session at the library dedicated to research processes and citation mechanics (Caffrey et al., 2022). On the information side, for instance, while practical and certainly not useless, this is an outmoded approach. By and large, it has no way of addressing issues around algorithmic bias, information filter bubbles and the design of digital platforms, data ethics, or even just plain vanilla evaluation of AI-generated text. It is completely unprepared to face up to the distinctive challenges of GenAI which, in its various ways, will also significantly and distinctively impact graduates' work experiences, from "hallucinated" reference verification to the need for entirely new strategies to interrogate machine-written text (Prabhakar & Tamrakar, 2026; Chen et al., 2024; Neumeister, 2023). The result is that students are graduating without any meaningful toolkit to make sense of the very information ecologies in which they will make their working lives. The same can be said at the same time of the technologies available to teach, although from the other side. Learning technologies, especially those driven by advances in AI, have exploded in recent years, from tutors to online collaboration environments to immersive simulations. But too often these tools have simply been grafted onto traditional pedagogies to make existing instructional approaches more efficient, rather than informing the design of environments to support the development of higher-order cognitive skills (Wang et al., 2025). The same has been true of the integration of GenAI into instruction itself, which after a period of "move fast and break things" rapid adoption, has often continued with relatively little attention to its pedagogical underpinnings, with recent studies even showing some evidence of cognitive offloading and associated skill decay and reduced metacognitive monitoring as a result of its use (Bai et al., 2023; Zhai et al., 2024). In other words, an opportunity is being missed to use this technology to better design authentic, problem-based learning experiences that both require and support critical thinking. This paper directly addresses this intersection of information science, education, and technology. The key contribution of this paper is a new conceptual framework, the Synergistic Framework for Critical Information Engagement (SFCIE) which is meant to inform the design of curricula and pedagogical approaches in the context of higher education (Bouzid & van Vliet, 2024). The framework both aims to go beyond skills to describe a set of more advanced information literacy competencies and to show how these can be strategically developed with a view to using contemporary learning technologies (Gharagozlou & Mahboobi, 2015). In offering this model, which is designed to speak to the specific cognitive and pedagogical challenges associated with GenAI's full-scale adoption into campus life, we hope to provide a grounded, theoretically informed, and practical framework for educators and institutions interested in preparing students to meet the complex information demands of their professional lives (Chan, 2023).

II. Literature Review

In order to establish a strong theoretical foundation for the framework that this paper proposes, this literature review is divided along three related and overlapping threads that, together, represent the current state-of-the-art in the relevant areas. The first of those three threads represents literature on the conceptualization of information literacy: from a simple set of basic skills to a multi-layered, critical competency. That concept has already matured into what is currently and increasingly required in the form of AI Literacy, which, in turn, represents the focus of the second of the three related threads (Hermansyah, 2023). The third research thread covers the development in cognitive science literature of the working consensus of the critical thinking concept (Virani et al., 2025). The meeting of the last two threads is what, as this paper argues, has to be, however counterintuitively, informed by, or at least come to terms with the third, which is the discussion of new learning technologies as a scaffold for the development of cognitive skills. It is this particular and third thread that introduces into the equation the aforementioned counterintuitive role of Generative AI.

2.1 From Information Literacy to AI Literacy

Over the past decades, the answer to the question of "what does it mean to be 'information literate'?" has radically shifted, adapting to the foundational changes in the ways we create, access, and interact with information. The concept began with an emphasis on order and structure. The very first definition of information literacy as a helpful and useful set of skills was drafted by the (American Library Association, 2006) (ALA) at the time when orderliness was the watchword in the academic research world (ALA, 1989). The primary competencies of an information-literate person – the ability "to recognize when information is needed and have the ability to locate, evaluate, and use effectively the needed information" (ALA, 1989, p. 1) were the bare necessities for a student-researcher learning to navigate the physical landscape of card catalogs, periodical indexes, and academic journals.

This, of course, is a very brief and, to a degree, a rearview narrative. Happy state of affairs did not last. Digital technologies, as (Devlin, 2023) neatly states, "burst right through the library's walls." The walls were pulled down overnight to make room for an unruly and infinitely pliable alternative: the Internet. Understandably, the new situation called for a broader perspective. The concept started to include digital literacy. Quoting (Ding et al., 2023), it "meant much more than searching for information online. It required students to understand the structure of the digital world—the technical architecture, its social conventions, and the new communication tools". One more recent addition, however,

has been that what is needed is not just a set of skills and abilities, but a more critical and questioning approach. Critical information literacy has meant a move away from the comforting but naïve assumption that information can remain objective and that systems providing it can function neutrally (Chiewphasa & Sisk, 2022). The point is that no information system is ever neutral as they are always embedded in, and determined by, the existing social, political, and economic power structures, which, as (Masiero, 2023) puts it, favor some views and narratives and exclude others. By asking these questions, the critical paradigm took the conversation beyond a more technical discussion about accessibility and usability, and moved it into the epistemological sphere: Who owns this platform? What assumptions or biases could be built into this search algorithm that provided me with these results? Whose knowledge is privileged, and who's not? Succinctly put by (Miller et al., 2021), a critical stance on information and the questions it provokes and privileges is what connects information to questions of social justice and meaningful civic engagement.

Building on the critical underpinning, however, the current moment, with the added complication of generative AI, is in need of yet another addition, or, more aptly, another layer, which can now be termed AI Literacy. Generative AI and the added layer of opaqueness that it now represents between the user and the information has called for and will continue to call for an entirely new set of competencies (Chan & Lee, 2023). This is not just an academic nitpick, or the latest fad, but a large-scale international policy development, with an increasing number of major global organizations, from the European Commission to the OECD and UNESCO, all working on official policy documents to define and operationalize AI competencies for students and citizens ((European Commission & OECD, 2025; UNESCO, 2023). These frameworks are largely in alignment with one another, and at a minimum, an AI-literate individual must have an understanding of the fundamental functionality and limitations of these systems, a grasp of the societal and ethical impacts that they produce, and the skills required to use and interact with them effectively and responsibly (World Economic Forum, 2025). The policy-level acknowledgment of AI literacy is quickly resulting in the institutionalization of these skills as an essential and fundamental requirement in formal education. As such, higher education institutions are now de facto required to demonstrate that they are developing and assessing these skills in their students in order to remain in line with global developments and to graduate employable individuals (Chan, 2023). The framework proposed in this paper is an intentionally strategic and practical model for this effort.

This advanced literacy is not a general, untested, and ill-defined criticism, but rather a body of particular, practical skills. It begins with algorithmic awareness, the understanding that the information with which we are being fed is being filtered through code, whose only "goal" is to maximize our attention and, potentially, our addiction to a "filter bubble" or "echo chamber". It also requires a granular approach to source deconstruction, a skill of understanding, looking beyond an information source and its content to understand its funding, ideology, and mission. This goes well beyond a simple evaluation of the source's credibility and authority. It also requires a level of ethical data synthesis, an ability to not simply analyze and understand data, but to also be able to reproduce it responsibly with attention to privacy and misrepresentation. Finally, this advanced literacy includes an element of format agnosticism, a refined ability to subject a peer-reviewed research article, a raw scientific dataset, a popular YouTube video and even a well-presented AI-written report to the same level of intense critical analysis, acknowledging that authority comes from evidence and logic, not the font and the polish.

2.2 The Cognitive Architecture of Critical Thinking

Before we can teach and learn to improve it, we need to know what critical thinking looks like in practice. It is not as easy and obvious as many teachers and textbooks seem to believe. A common misconception about critical thinking is that it is a process of nitpicking or cynicism that takes things apart. The opposite is in fact true; it is constructive and often a positive process. (Scriven & Paul, 1987) define it as "the explicit practice of all the mental abilities and techniques we use in acquiring, assessing, and applying information". It is a process of sound judgment and reasoning that we, for example, use when we need to make rational decisions when we work. In this chapter, we will see how cognitive scientists and education researchers have deconstructed the process of thinking into a number of specific components (Liu et al., 2025; Tenenberg, 2024; Holmes & Miao, 2023). For example, it all begins with analysis, or the ability to break information, a problem or an argument into its constituent parts in order to understand how they relate and connect to each other. It is the skill to home in on a detailed report, a complex issue, or a dense paragraph and break it up into more manageable parts rather than getting overwhelmed by the whole. However, from there we also need to make sense of those pieces by interpreting, or understanding and explaining, their meaning. It is an active process that goes beyond paraphrasing or summarizing, but instead helps the thinker make sense of data, experiences, or evidence to create a coherent picture. Building on this, the next mental action is then inference, or the ability to draw conclusions based on information that is often incomplete. However, some inferences are stronger than others, and this is where the element of evaluation comes into play. This is the component of critical thinking that is concerned with the assessment of issues such as credibility, relevance, and importance. It requires asking questions about the source of information, the strength of an argument, and the value of evidence. Finally, there is one last overarching component, which can be found in many models of thinking and learning. This is the process of self-regulation, which Facione (1990) defines as the critical thinker's "ability to reflect on one's thinking and to regulate it accordingly". In other words, it is the metacognitive skill of monitoring and adjusting one's own

mental processes. It is the rational person's inner voice that questions and reflects: "*Am I letting my assumptions or emotions bias my thinking? Does the evidence really support this conclusion? Is there another way of looking at this issue?*".

In the age of generative AI, this metacognitive element of self-regulation will become even more important. Generative AI systems like ChatGPT can generate authoritative-sounding answers, that can be persuasive but are ultimately incorrect, misleading, or nonsense. This is why students need to learn to not only check information that they receive from external sources but also to monitor their own mental processes and check for potential biases like so-called "automation bias", or the uncritical acceptance of machine-generated information (Heersmink, 2024). One final critical insight from this research is that critical thinking is not an abstract or general skill that can be taught and learned in isolation. As (Willingham, 2007) (makes a strong case, it is tightly linked to content knowledge in specific disciplines or domains. We do not teach or learn to "think critically" in the abstract; we learn to think critically as a historian, or as a scientist, or as a lawyer, or as an engineer. This does not happen in general classroom exercises, but through regular practice, extensive application and, most importantly, first-hand experience and exposure to the kind of complex, ill-structured problems one faces when one works, problems that often do not have a single clear answer at the end of a textbook chapter.

2.3 Learning Technologies as Cognitive Environments: The Generative AI Paradox

The current acceleration in learning technologies can be an opportunity to reframe how we think about education. We can build forward to real cognitive environments, instead of backward to outmoded information delivery systems. One of these theoretical reframings is to stop thinking about these tools as assistive technologies that augment our existing skillset (i.e. a calculator is to computing), and begin to understand them as "cognitive tools" that can completely reorganize our thought processes (Salomon, 1997). The use of these tools is by "working with it as an intellectual partner" (Salomon et al., 1991) that is to offload some of the "computational work" to the external agent and use the freed up cognitive space to engage at a higher level with a concept which, in turn, can be internalized as a new way of thinking. The recent proliferation of ever more powerful and capable GenAI tools such as ChatGPT has brought this idea into sharp focus for teachers. In a way best described by the term the "Generative AI Paradox". The beginnings of a chorus of voices have started to be heard in the literature describing the positive potential of the technology from many different angles. GenAI can be used as a very effective cognitive scaffold, in the role of a personalized tutor (AlAli & Wardat, 2024), a means to access multiple perspectives (Mollick & Mollick, 2023), or as a guide to help students in formulating and evaluating arguments (Mollick & Mollick, 2023). The strategic use of AI as a constant Socratic partner, to raise deeper questions to which students must provide logical, defensible answers, can help improve their problem-solving skills, and overall learning at a more complex level (Duran, 2024).

The same literature is also ringing a very large alarm bell about the risk of this same technology to the skills that it can help build. A major and growing concern in the literature has to do with a "bias to automation" with GenAI. A user effect that has been found across studies and tasks is that people tend to approach these tools with a default trust of the answer provided, lacking a critical stance and lower metacognitive monitoring of their performance (Bender et al., 2021; Heersmink, 2024). Students who use the tools to perform core academic skills such as summarizing, analysis, and writing risk "skill atrophy" in these higher order cognitive skills if they rely too heavily on AI (Lee et al., 2024; Zhai et al., 2024). There is also a very clear risk of error propagation: GenAI models have been shown to be able to confidently "hallucinate" false facts, citations, and images; however, when students are willing to trust the model outputs, they are less likely to fact-check and instead end up "believing" that false information, using it uncritically in their own work (Chen et al., 2024; Park et al., 2024). Students who use AI in this way, without any intervention, show lower standards of reasoning, self-reflection, and evidence-seeking in their work (Wong, 2024). This can contribute to an overall loss of "epistemic vigilance" with the use of GenAI, a reduction in their motivation to think skeptically and conduct deep independent research (Wong, 2024). This is the paradox: same technology, opposite reports about the impact on critical thinking skills. As you can see from the above, the difference is not an effect of the technology itself. Its capacity to offload cognitive labor is the source of its positive power (efficiency, scaffolding) and the root of the central risk (complacency, cognitive offloading). Pedagogy is in the vital mediator's seat. The most important difference is not if students use AI, but how and why they are being taught to use it. If a pedagogical strategy forces critical engagement with the tool, it can be transformed from a cognitive crutch into a cognitive gym: a new space to practice and build critical thinking. The principle that pedagogy must precede technology is the founding concept of SFCIE.

2.4 Synthesis and Identified Gap

There were already identified the two communities which, for all the very explosive growth trajectories in both, seemed to us not nearly as integrated as they should be. On the one hand, the information literacy construct, over several decades of development, had arrived at a state of being perhaps all too mature, impressively and sophisticatedly well-developed (for which we praised it), but now, at a stage where we think it needs, more than anything, a hard pivot to the new (and no less critical) but as yet very under-elaborated territory of AI literacy, which, in turn, in practice is all too often pursued with little or no appreciation of what cognitive science actually knows about how brains actually do (or do not) come to develop the capabilities, to which critical thinking are but definitions imposed from outside. On the other hand, the parallel universe of new learning technologies is (and has

been for many decades now) in the grip of an endless hype cycle in search of the next big thing, which for a while has been "learning analytics" and is now, all too predictably, "GenAI". Both GenAI and learning analytics are very real game-changers, for many very good reasons: But as so often happens in that field, very often with precious little attention to the need for high-leverage teaching and learning strategies, if these tools are to become a real force for deep, authentic cognitive change, as opposed to merely the next wave of "cool toys".

Our own systematic reviews of both those domains don't just echo that analysis (of course they do), but quite clearly underwrite it, by discovering, in each case a striking paucity of any kind of integrative conceptual framework to drive what GenAI research, but also work on instructional and pedagogical uses of AI, is already a rapidly growing but hopelessly fragmented field of research and practice. (Bai et al., 2023; Bozkurt et al., 2024). We believe the consequence of that fact to be a huge opportunity cost. The good theory, the right competencies, the powerful tools are all there for the taking. But called upon much too seldom, or if so, rarely in any coordinated fashion. This paper is our effort to start to remedy that gap, at that point of intersection. It's no longer just a lacuna, it's a paradox we need to start to integrate, both GenAI's own cognitive features and the learning of the AI Literacy that is rapidly becoming, we will argue, a real must-have. We will work to make the connections between these domains, by offering an integrative framework which explicitly and directly ties advanced information literacy competencies with specific pedagogical strategies, all of them supported by the new learning technologies. We will attempt to weave these parallel strands into a single tight thread, focused on one singular target: deep and durable critical thinking.

III. Methodology

This paper sought to create a focused, systematic search, analysis, and synthesis of extant foundational and current literature from the overlapping, relevant literatures of information science, cognitive psychology, and educational technology. This work was then used as a base for the creation of an integrated novel conceptual framework – the Synergistic Framework for Critical Information Engagement (SFCIE) – to fill an identified research gap.

3.1 Search Strategy and Selection Process

A 3-phase search strategy was developed and run in Scopus, Web of Science, ERIC, and Google Scholar from January 2024 to September 2025. Search strings were developed in 3 phases to optimally target foundational, current, and emerging scholarship. Terms used to develop search strings were derived from the most recently published systematic reviews in the area (Bai et al., 2023; Bozkurt et al., 2024):

1) Foundational Concepts

Captured key theoretical constructs of underpinning research – ("critical thinking" OR "higher-order thinking") AND ("higher education" OR "university") AND ("information literacy" OR "digital literacy").

2) Technology Integration

Captured literature that directly targeted technologies applied in a pedagogical manner – ("learning technology" OR "educational technology" OR "e-learning" OR "digital pedagogy") AND ("cognitive tool" OR "scaffolding").

3) Contemporary Developments

This final stage was used to capture the most recent literature (date limited to 2023–2025) on the impact of emerging AI technologies. Search strings included terms that are most salient to the impact of new AI tools such as ("generative AI" OR "ChatGPT" OR "large language models") AND ("critical thinking" OR "student learning" OR "higher education") AND ("impact" OR "effect" OR "risk" OR "benefit").

The selection process followed a 4-stage screening protocol. The initial search returned 1254 records across the databases. After removing 312 duplicates, the title and abstract of 942 articles were screened in accordance with the inclusion criteria. 815 articles were excluded as clearly irrelevant based on title and abstract screening (e.g., the article focused on a non-educational context, non-scholarly opinion piece, the target population was the wrong level of education). The full text of 127 articles were assessed for eligibility. An additional 78 studies were excluded at this stage as they were either purely technical in focus (i.e., on the underlying AI architecture) without a pedagogical focus, or did not focus on the higher education context. The resulting 49 highly relevant conceptual and empirical studies made up the final corpus of work for inclusion in the thematic synthesis for framework development.

3.2 Inclusion, Exclusion, and Quality Assessment Criteria

Selection of included studies was based on a set of inclusion and exclusion criteria designed to maximize relevance and scholarly quality.

- *Inclusion.* The review included peer-reviewed journal articles, conference papers, and major reports from international agencies (e.g., UNESCO, OECD). Only articles written in English were included. The main emphasis was on articles with a higher education focus, although also considered were conceptual papers relevant to the field that did not specifically reference higher education. Both conceptual and empirical articles related to the research questions were included.

- *Exclusion.* The exclusion criteria were created to omit irrelevant material. First, articles more than 15 years old were excluded unless they were widely cited as seminal

to the field (e.g., Scriven & Paul, 1987; Facione, 1990). This limit was used to exclude out-of-date theories that predated the digital era. Second, purely technical papers on the underlying AI architecture without a pedagogical focus were also excluded. Third, while many of the reviewed conceptual frameworks (e.g., the AILit Framework) were originally developed for the K-12 context, studies with a clear focus on K-12 were excluded from the main synthesis due to the difference in context and implementation challenges (albeit noted as a source for comparative context). Fourth, non-scholarly sources (blogs, opinion pieces) were excluded.

- *Quality Assessment.* The final included studies were evaluated on conceptual clarity, methodological rigor (empirical papers), and contribution to the primary themes of the review. Highly cited foundational theoretical papers were prioritized in the selection for their citation impact and known relevance in the field.

3.3 Synthesis and Framework Development

A thematic analysis approach guided the reading of the chosen material. The prominent ideas, concepts, theories, and evidences are identified and extracted, and then mapped in order to surface the initial emerging themes, theoretical tensions (i.e., Generative AI paradox), and conceptual gaps. The four layers of the SFCIE were derived directly from this synthesis. The process moved systematically from a broad review of disparate fields to the deliberate construction of an integrated, synergistic model designed to connect the *what* (advanced competencies), the *how* (pedagogical strategies), and the *tools* (technological enablers) to the ultimate goal of fostering critical thinking. TABLE I summarizes key foundational studies that directly informed the framework's structure and components.

TABLE I SUMMARY OF SELECTED FOUNDATIONAL STUDIES SYNTHESIZED FOR FRAMEWORK DEVELOPMENT

Author(s) & Year	Core Argument / Finding	Contribution to SFCIE Development
(Willingham, 2007)	Critical thinking is not a generic skill; it is intrinsically tied to domain-specific knowledge.	Justified the need for domain-specific Problem-Based Inquiry (Layer 3) rather than generic critical thinking exercises.
(Salomon et al., 1991)	Technologies can function as "intellectual partners," reorganizing thought by offloading cognitive tasks.	Provided the theoretical basis for Technological Enablers (Layer 4) as cognitive environments, not just delivery tools.
(Bender et al., 2021)	Large language models can reproduce and amplify biases present in their training data.	Informed the necessity of Source Deconstruction and Algorithmic Awareness as core competencies (Layer 2).
(Zhai et al., 2024)	Over-reliance on GenAI can lead to skill atrophy and a decline in metacognitive monitoring.	Highlighted the "Generative AI Paradox" and justified the need for pedagogy (Layer 3) to mediate technology use and prevent cognitive offloading.
(UNESCO, 2023)	Global education requires a focus on technology as a tool for learning, guided by clear pedagogical principles.	Provided the policy-level imperative for an integrated framework like the SFCIE, linking technology, pedagogy, and learning goals.

IV. The Synergistic Framework For Critical Information Engagement (SFCIE)

Based on the synthesis of the literature, we propose the Synergistic Framework for Critical Information Engagement (SFCIE). The term "synergistic" is used to emphasize that the components of the framework are designed to work together in a mutually reinforcing way, creating an effect greater than the sum of their parts. The framework is composed of four interconnected layers, as illustrated in Fig. 1.

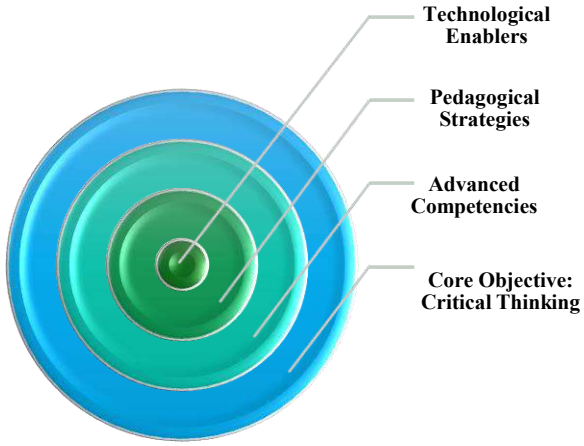

Fig. 1 The Synergistic Framework for Critical Information Engagement (SFCIE)

In response to the fragmentation identified in the literature, we developed the SFCIE as an integrated and actionable model for educators. The integrated framework is not merely a philosophy or a set of ideas. It is a useful instructional design framework to map learning experiences that leverage technology and align with sound pedagogical principles. The Integrated Framework, shown in the image above, weaves together the why (durable critical thinking), to the what (advanced information literacy competencies), to the how (teaching strategies), to the tools (learning technologies). In the sections below, we will briefly review each of the four layers, and discuss how the layers work in concert.

4.1 Layer 1: The Core Objective

The 1st layer of the integrated framework identifies the big-picture end goal at the center of the framework: *critical thinking*, as defined in the literature review, is the higher order cognitive abilities of analysis, inference, evaluation, interpretation, and self-regulation. The other layers of the framework are built to align with this goal.

4.2 Layer 2: Advanced Information Literacy Competencies

The 2nd layer clearly defines the knowledge and skills students need to learn. It deliberately moves beyond basic digital literacy to focus on the more nuanced and critical competencies required to navigate the modern information ecosystem. These competencies, detailed in TABLE II, represent the "what" of the learning process.

TABLE II ADVANCED INFORMATION LITERACY COMPETENCIES

Competency	Description	Example Application in Professional Context
Algorithmic Awareness	Understanding that digital information is curated and ranked by algorithms that have inherent biases and commercial objectives.	A marketing professional analyzing why certain products trend on social media, considering the platform's algorithm, not just consumer interest.
Source Deconstruction	The ability to investigate the funding, political leanings, and contextual history of an information source, moving beyond surface-level credibility checks.	A law student evaluating the report of a think tank by investigating its funding sources and ideological agenda before using it as evidence.
Ethical Data Synthesis	The capacity to ethically collect, analyze, and present data, including an understanding of privacy, consent, and the potential for data misinterpretation.	A health sciences student designing a community health survey that ensures participant anonymity and uses data to represent findings without stigmatizing any group.
Cognitive Bias Recognition	The metacognitive skill of recognizing one's own cognitive biases (e.g., confirmation bias) and actively seeking out disconfirming evidence.	A business student, when analyzing a potential investment, deliberately searching for negative reviews and counterarguments, not just positive reports.

The development of these competencies is intended to shift students from being passive recipients of information to become active, critical investigators. The goal is to produce individuals who do not accept information uncritically but have the abilities and mindset to question, examine, and place what they find in context. They learn to perceive the hidden structures—such as algorithms and funding sources—that influence the information they encounter.

4.3 Layer 3: Pedagogical Strategies

This layer explains *how* the advanced competencies should be taught. It promotes active, student-focused learning methods that naturally generate a need for critical thinking and information engagement. Students are deep in the doing of what is required, not just being in it. A summary of the primary pedagogical strategies that we make use of is given in TABLE III below:

TABLE III CORE PEDAGOGICAL STRATEGIES FOR CULTIVATING CRITICAL ENGAGEMENT

Pedagogical Strategy	Description
Problem-Based Inquiry	The learner is presented with a complex, ill-defined problem with many potential solutions and must provide an appropriate solution in the form of a fact-finding and fact-checking exercise.
Collaborative Verification	The learners must, as a group, fact check a list of potentially misleading and factually incorrect sources of information by tracing each claim to its original source and collaboratively work toward a final report on the credibility of each source.
Socratic Dialogue	The learners are engaged in a series of questions and tasks/challenges from an instructor (AI Tutor) that tests the logical consistency of their position, evidence they provide and challenge their assumptions.

These strategies seek to create a "big shift" in the learning experience, from one in which a teacher is seen to be "delivering" knowledge to one in which students must "discover" knowledge through the process of learning. The use of these strategies should place students in the midst of actively engaging with and using the skills which are to be targeted in an authentic way. The class must be a place of critical thinking through investigation, collaboration and reasoning through the use of evidence as the main form of acquiring knowledge.

4.4 Layer 4: Technological Enablers

The outermost layer in Fig. 1 is concerned with the learning technologies that can be used to best effect to operationalise the pedagogical strategies. An important guiding principle for this layer is that it exists to serve the pedagogy, not the other way around. Tools are a means to the end and not an end in itself. It is the pedagogy that provides the learning experience, and technology is merely the enabler to provide scalable and meaningful learning experience. TABLE IV gives an example of such a mapping of technologies to pedagogical strategies.

TABLE IV MATCHING TECHNOLOGIES TO PEDAGOGY AND COMPETENCIES

Technology	Pedagogical Strategy Supported	Competency Cultivated	Example Implementation
AI Tutor / Chatbot	Socratic Dialogue	Cognitive Bias Recognition	A computer program in the form of a tutor pushes back on a student's initial diagnosis of a case study by asking for other ways of understanding the evidence and justifying claims.
Digital Collaboration Platform (e.g., Miro, Perusall)	Collaborative Verification	Source Deconstruction	History students collaboratively take apart a political speech using a social annotation tool, identifying biased word choice and fact-checking evidence in real-time.
Immersive Simulation / Virtual Lab	Problem-Based Inquiry	Ethical Data Synthesis	Business students run a simulated company, but must source ethical supply chain materials after being given conflicting reports about labor practices and environmental concerns.
Digital Library Archives	Problem-Based Inquiry	Source Deconstruction	Journalism students write a story of an event using only the digitized primary sources from an archive, reconciling conflicting reports in the process.

The end product of this concentrated effort in technological integration is a flexible, scalable and exciting learning environment. Technology (when used in conjunction with powerful pedagogy) can also make learning possible when it otherwise would not be. It can help students experience instantaneous feedback (such as through an AI tutor), it can foster deep collaboration across time and space, and it can allow students to solve real-world problems in safe, virtual settings in a way that both augments and extends the entire learning experience.

V. DISCUSSION

Needless to say, this framework would not be nearly complete without also having a practical application. The Synergistic Framework for Critical Information Engagement is also a tool for change. A vector of transformative change in higher education. In fact, it has many significant implications for how we teach, what we teach, and even what tools we use to teach. These are discussed below.

5.1 A New Vision for Information Literacy in the Age of AI

The vague and altogether hopelessly outdated definition of "critical information literacy" being practiced in many institutions today. A definition that can so easily lead to simple recipes in the pedagogical toolkit. Those that ask students to simply "find information" or cite the "correct" number of sources with no higher-order skills or guidance (like evaluating that information). Such instruction is not just stuck in a bygone paradigm of scarcity-based information, it is increasingly hopelessly out-of-touch when information overload is the norm and "sources" can be anything from Twitter threads to legal decisions to webpages generated on-demand by GenAI tools. By explicitly defining more advanced competencies, like Algorithmic Awareness and Source Deconstruction, the SFCIE provides a far more ambitious, relevant, and hopefully, motivating set of learning objectives to the educator. Algorithmic Awareness, in particular, is a key building block of the AI Literacy frameworks recently published by the OECD and UNESCO (European Commission & OECD, 2025; UNESCO, 2023).

Frameworks that include the information use and critical understanding needed to navigate the reality that the majority of information students will be exposed to has been algorithmically generated and filtered. This skill also re-orients information literacy instruction to the information systems, not simply the information. This is a vital re-alignment of the teacher's educational objectives to the real-world, future problems the professional they are training is certain to face. The critical thinking skill Source Deconstruction (TABLE II) also has new relevance in the GenAI era. Just as students will need to understand human authors or publishing organizations, they will also need to understand the internal logic and societal biases of the training data powering an AI, which are then often amplified in the AI's output (Bender et al., 2021).

5.2 Technology with Purpose: Implementing the SFCIE

A second point to emphasize is the framework's constant and consistent focus on the technology-pedagogy-skill intersection, which also has powerful implications for the use of learning technologies in the classroom. A technology implementation focus serves as a corrective against the too-common institutional practice of "just adding" new tools, what has been termed tech "for tech's sake" (Ahonen-Blank & Blank, 2020). A healthy focus on the technology-pedagogy-skill dynamic also invites the educator to reframe the role of learning technologies from simple content-delivery vehicles to highly designed, active learning cognitive environments. This is in fact the internal logic of the framework as illustrated in Fig. 1, where pedagogy (Layer 3) is always explicitly and actively mediating the relationship between technology (Layer 4) and the development of the core skill objective (Layer 1). The focus on technology also helps to provide a concrete solution to the Generative AI paradox raised in the literature above. The key is not just to use these AI tools in an educational setting, but to purposefully, proactively, and rigorously engineer the experience of using these tools to work against the very risks we are warning about. The examples in TABLE IV make the principle clear in practice. Take the first example of using a Learning Technology AI Tutor for the pedagogical strategy of Socratic Dialogue. This project takes a creative approach in using a GenAI tutor that directly engages with the potential hazard of cognitive complacency that comes with these tools. Instead of simply or passively using the AI to find answers for a question they care about (a bad habit sure to lead to the kind of overreliance and skill atrophy that the studies in Bai et al., 2023; Zhai et al., 2024 are warning about), this pedagogical activity repurposes the tool by positioning it as an adversary. A critical conversation partner which forces the student to justify their position, ask for evidence, and supply alternative interpretations. In this example, the learning technology is put to work to actively develop the competency Cognitive Bias Recognition (see TABLE II). The technology very clearly serves the pedagogy, which in turn serves the core objective of developing self-regulation and evaluative capabilities.

The same logic of cognitively repurposing powerful Learning Technologies by tightly binding them to a pedagogical strategy applies to the Digital Collaboration Platform and Collaborative Verification (see TABLE IV). In this case, a technology tool is being used to transform what would otherwise be passive content consumption into a rich pedagogical environment. Working together, students trace and cross-verify the sources behind a claim and by making it a visible, social activity, they also naturally and incidentally develop the 'Source Deconstruction' competency (see TABLE II).

Again, the technology is not being used as a one-way vehicle for information but as a highly-configurable environment for active, social knowledge construction. This required shift has a lot of deep implications for the academy, not the least of which is a new fluency requirement for the educator. This demands a new form of professional development, one that goes beyond training on the use of tools, but rather empowers faculty to become authentic learning experience designers who intentionally wrap activities around the new technologies.

5.3 An Adaptable Blueprint for a Diverse Academy

The framework itself is purposefully interdisciplinary. The set of core competencies and pedagogical approaches in TABLES II and III is not a particular implementation, but rather a template that can be extended, exploited and mix-and-matched in a vast variety of professional training programs. This quality makes the framework not just a vision, but a practical and powerful tool for actual curriculum reform efforts.

A law program, for instance, could use the Problem-Based Inquiry strategy in TABLE III to build a complex digital evidence file around a novel case. Students could then be asked to sort out the conflicting evidence from body-cam footage, social media posts, and hacked emails, an activity which could be designed to both support and assess the development of the Source Deconstruction, Perspective Diversification, and Empathy/Affective Engagement competencies. A health sciences program could similarly use the Collaborative Verification pedagogical strategy to empower a team of students to jointly evaluate highly-technical, often emotive claims about a novel treatment which have been scattered across pre-print servers and online patient advocacy forums. A business school might similarly use an Immersive Simulation to rapidly immerse students in a fast-moving corporate crisis, one which is being both fueled and distorted by social media misinformation. In these circumstances, students would be forced to make high-stakes decisions about information that is both incomplete and potentially unreliable, and then be asked to both defend and critique those decisions.

5.4 The Realities of Implementation: Acknowledging the Challenges

Of course, the implementation of the SFCIE is not without its challenges. e should not underestimate or dismiss this. The framework as an emancipatory choice over an otherwise bloated and ossified status quo is not deployed without very real and surmountable hurdles that demand institutional "buy in." TABLE V summarizes these challenges and mitigation strategies.

The most obvious is, of course, the challenge of actually catalyzing the required shift in pedagogical culture. The SFCIE framework asks teachers to fundamentally move away from the instructor-led lecture as the default modality of learning and toward a more active (and often more difficult) model of student-centred, inquiry-based education. This shift will not be imposed. It will only be possible by major and sustained investment in faculty development. The logistical and technical challenges are also non-trivial. Though many of these tools are low-cost or even

free, access to the necessary tools is a non-trivial challenge and an issue that should (from a social justice perspective) be a non-issue. Ensuring this is the case will also be a non-trivial challenge that will need to be tackled directly and explicitly.

TABLE V SUMMARY OF IMPLEMENTATION CHALLENGES AND MITIGATION STRATEGIES

Challenge	Description	Proposed Mitigation Strategies
Pedagogical Culture Shift	Moving away from instructor-centric and towards the student-centered, inquiry-based SFCIE	- Build long-term, teaching pedagogy-centered faculty professional development - Create faculty learning communities to share best practices - Incentivize pedagogical innovation through grants and recognition
Logistical & Technical Barriers	Ensuring that every student has access to the necessary technology to succeed and the seamless integration of new tools with the institution's existing IT	- Perform a technology access audit of students' access needs and plan to support - Develop a phased technology integration plan with clear IT support - Prioritize open-source or institution-wide licensed tools to minimize cost barriers
The Assessment Dilemma	Tests created by the instructor or system cannot measure the high-level cognitive skills of the SFCIE and have become obsolete with the arrival of GenA	- Create and scale authentic assessments (portfolios, simulations, process-based assessments) - Provide faculty training on designing "AI-resilient" assignments that assess process over product - Establish institutional repositories of authentic assessment samples and rubrics

Beyond the initial issue of access however, there is the non-trivial issue of the operational and financial cost of integration, particularly when it comes to meaningfully (and safely) integrating these new tools into pre-existing (likely legacy) institutional IT infrastructures. Assessment is likely the most complicated of these issues however. Assessment has always been an issue, but the introduction of GenAI has put this in particularly stark terms. The higher-order cognitive skills at the core of the SFCIE are notoriously difficult to assess in traditional ways. Multiple choice tests and other forms of knowledge recall are woefully inadequate as a measure of a student's ability to synthesize information or even to self-reflect on their own cognitive biases. GenAI's ability to write quality essays, problem sets or computer code have made large swaths of traditional academic assignments completely useless as a measure of a student's independent critical thinking or domain knowledge (Lindebaum & Ramirez, 2023; Rahman & Watanobe, 2023). This has created something of an existential crisis for assessment that prizes the product of learning (i.e. the essay) over the actual process of creation. If we are to be serious about measuring these skills that the SFCIE is trying to inculcate (evaluation, self-regulation, etc.) then our assessments will need to change as well. The success of the SFCIE will not just require a change to teaching but also a change to assessing. Institutions will need to invest the time and resources necessary to support the development and scaling of authentic forms of assessment. Portfolio-based evaluation, performance review of complex simulations or student reflective journals in which students are asked to document and self-critique their own learning process, both in their interaction with and evaluation of AI, are just some examples of the kinds of assessment which are capable of authentically capturing thinking in process as opposed to merely measuring the output of inert knowledge.

VI. Conclusion

Improving our critical thinking abilities at a higher level of information literacy is no longer a luxury or supplement in twenty-first-century higher education. It is now its most urgent—and possibly existential—priority. The old skills-based model of information literacy has been surpassed by the expansion of our algorithmic information environment, one where content is increasingly filtered through search algorithms, where online information can be AI-generated, and where misinformation has become an increasingly professionalized industry.

6.1 Summary of Contribution

In response to this state of critical thinking crisis, we have developed the Synergistic Framework for Critical Information Engagement (SFCIE). It is a model for the integration of higher-level skills, active learning strategies and new learning technologies into a highly effective synergy for students. The first, and most obvious, of these is, of course, the framework. It is presented as an off-the-shelf, theoretically-sound and pragmatic framework for educators who are looking to do more than pay information literacy lip-service and are instead looking to provide the deeper, more durable, critical thinking skills that future professionals are increasingly calling for. But this is only one element of the synergy that is the SFCIE's unique contribution. By intentionally co-aligning what students are learning, how they are learning it, and what tools they are using to do so, the SFCIE is a means to create powerful learning experiences that are particularly well-suited to the challenges of the current moment. It is, most fundamentally, its synergistic approach that is its main contribution. The tensions between the affordances of our new tools and the pedagogical risks they present are incommensurate and can only be reconciled by an intentional and strategic choice to privilege pedagogy, and to allow it to drive the technology conversation.

6.2 Practical Recommendations for Implementation

It is important to stress that the work of translating the SFCIE from concept to practice will require investment on all levels of higher education. The work of individual instructors will, naturally, need to begin with a manageable first step. There is no need to completely redesign an entire course to begin adopting the SFCIE. An instructor can start by integrating one single pedagogical strategy, for example 'Collaborative Verification' into one module or assignment. Another instructor might instead focus on modelling this critical engagement with these new AI tools in the classroom. This can be done by simply and explicitly articulating their own process of writing a high-value prompt, or questioning an output, verifying with other sources, or flagging possible biases in the content being generated. This shift in pedagogy must also be echoed in the realm of assessment design. Assignments can be made "AI-resilient" by requiring students to use AI and grading their process of interaction with it, rather than simply the final product. Students could be asked, for example, to submit their prompts, the AIs's initial response, and then a reflective analysis where they offer a critique of this response, fact-check it, and then build on or improve upon the AIs response, making their own process of critical thinking visible.

Curriculum designers and department heads, by virtue of their roles, will naturally be responsible for the work of change at a larger scale. This work is guided by the same core principle: taking one element of the framework, whether a pedagogical strategy, for example 'Collaborative Verification' or an advanced competency like 'Ethical Data Synthesis' and using it as a heuristic to do a deeper review of the existing curriculum as a whole. This exercise will be helpful in identifying both where these skills are already being taught, where they are lacking, and how the different components of the framework can be scaffolded over multiple courses to enhance student learning. Curricular and departmental teams will also be well-positioned to take advantage of these efforts to create a set of common resources, whether a shared repository of best practices, sample AI-resilient assignments, or rubrics for authentic assessment, to support and guide faculty members, avoid duplicating work and effort, and ensure a greater degree of consistency in the student experience. Above all, these administrators should take steps to ensure that the integration of AI Literacy is an explicit program-level learning outcome to guarantee curricular coherence and to ensure that the curriculum is future-proofed and in alignment with global developments and professional expectations (Chan, 2023; World Economic Forum, 2025).

Finally, for institutional leaders, deans, and provosts, there is the broader responsibility of creating the conditions for success. Professional development will need to be ongoing and targeted, but it will focus less on the technical nitty gritty of how these tools function, but on the instructional design of inquiry-based learning experiences which incorporate them (Chan, 2023; UNESCO, 2023). Institutional leaders can also play a role in the shift towards more authentic assessment practices by empowering and resourcing faculty teams working to design and scale new modes of learning evaluation. They will also need to come to terms with the fact that some forms of authentic assessment (portfolio reviews, performance tasks, etc.) can be more laborious than traditional exams and will require a structural support to be rolled out effectively. Finally, it is also in the interest of institutional leaders to move the conversation away from the question of AI's ethical status, to a conversation around the articulation of clear, flexible, and pedagogically-informed guidance around the ethical use of AI (Chan, 2023). Blanket policies of prohibition do not help the students and faculty who will need more nuanced and specific guidance to foster critical and responsible engagement with these tools rather than merely banning them.

6.3 Future Research

The most important research questions to address in future work will naturally be those specific to the framework itself: What is the long-term impact on students' metacognitive self-regulation of regularly interacting with AI as a Socratic partner? How do different authentic assessment models correlate with the development of the SFCIE's different advanced competencies? And finally, how might the implementation of the SFCIE itself vary in its effectiveness across different fields of study, such as STEM disciplines versus the humanities? (Pappa et al., 2024). This type of research will be essential for future iterations of the model and in providing the evidence base for scaling its adoption. In a time when the quality of information we produce and consume matters directly to the health of our professions, our communities, and our democracies, higher education has no greater responsibility than to prepare students to be critical, perceptive, and ethical participants in our global information society.

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