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Research Article

Designing and validating a digital competency framework for AI-augmented learning: An exploratory factor analysis study

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ABSTRACT

The rapid emergence of generative artificial intelligence (GenAI) necessitates a robust and validated framework for digital competency in higher education. This study developed and validated the artificial intelligence-augmented digital competency framework (AIDCF) to address the gap between general digital literacy and artificial intelligence (AI)-specific operational requirements. The research was conducted at a public technological university in Thailand. Employing a developmental mixed-methods design, the primary instrument, a 24-item questionnaire, was reviewed by nine experts, yielding a mean content validity ratio (CVR) of 0.861, with item-level CVRs ranging from 0.778 to 1.000. Exploratory factor analysis with a sample of 300 participants supported a five-factor structure: (1) AI awareness & ethics, (2) prompting & tool proficiency, (3) critical thinking with AI, (4) AI-integrated learning design, and (5) reflective digital practice. These factors collectively explained 65.12% of the total variance, with factor loadings ranging from 0.682 to 0.884 and an overall Cronbach's alpha of 0.87. The framework's pedagogical utility was examined through a five-week instructional intervention utilizing the collecting, reviewing, analyzing, framing, and tailoring (CRAFT) model with 36 graduate students. Results revealed high levels of perceived competency (mean = 4.51, standard deviation = 0.53) and qualitative evidence of metacognitive development. The AIDCF provides a theoretically grounded and empirically validated roadmap for fostering advanced AI literacy in the GenAI era.

Keywords: AI literacy, digital competency, critical thinking with AI, technology integration, exploratory factor analysis, CRAFT framework

INTRODUCTION

Context and Problem

In the 21st century, digital competency has transitioned from an optional advantage to a foundational prerequisite for global citizenship and professional success (Barboutidis & Stiakakis, 2023). As higher education becomes increasingly driven by digital infrastructure, the demand for sophisticated digital skills has intensified—a trend significantly accelerated by the pedagogical shifts following the COVID-19 pandemic (Chan, 2022). Recently, artificial intelligence (AI) has emerged as a disruptive yet powerful enabler, integrated to enhance learning efficiency, facilitate personalized feedback, and support complex online education models (Elkot et al., 2025). However, the rapid proliferation of generative artificial intelligence (GenAI) has outpaced the pedagogical preparedness of most educational institutions, creating a critical disconnect between technological availability and functional competence (Yu et al., 2024).

Need For New Competency Frameworks

While international policy organizations have attempted to integrate AI into existing frameworks, such as the European Union's digital competence framework (DigComp 2.2) and the International Society for Technology in Education (ISTE) (ISTE, 2016) standards, a significant implementation gap persists (Crompton & Burke, 2024; Vuorikari et al., 2022). Current digital competency models often remain at a conceptual or macro-policy level, lacking specific operationalization for AI-augmented environments (Zhang et al., 2023). Recent literature indicates that many educators and learners experience AI anxiety or lack the practical experience to utilize AI tools meaningfully, which directly impacts their professional efficacy and readiness for systematic AI integration (UNESCO, 2023; Yu et al., 2024). Furthermore, existing frameworks often treat digital skills as a static set of proficiencies rather than a dynamic, iterative process required for sophisticated human-AI collaboration (Long & Magerko, 2020).

Rationale For AIDCF and CRAFT

A critical research gap exists in the shortage of validated frameworks that specifically bridge general digital literacy with AI-specific operational competencies, particularly those that can be empirically measured and applied within a structured pedagogical workflow (Dangprasert, 2025). To address this gap, this study proposes the artificial intelligence-augmented digital competency framework (AIDCF), which is uniquely operationalized through the collecting, reviewing, analyzing, framing, and tailoring (CRAFT) model. The CRAFT model provides a structured, AI-integrated academic workflow that transforms scholarly processes from passive tool usage to critical collaboration (Kolb, 1984; Miettinen, 2000). By aligning the AIDCF with the CRAFT stages, digital competency is reimagined as a dynamic process supported by technology-enhanced feedback systems (Žerovnik, 2024), which is essential for maintaining academic integrity and mitigating the risks of AI hallucinations and algorithmic bias.

Research Objectives

The primary objective of this study is to develop and validate the AIDCF and its associated measurement instruments within the context of King Mongkut's University of Technology North Bangkok (KMUTNB), a public technological university in Thailand. By utilizing rigorous psychometric techniques to ensure robust item functioning (Finch & French, 2023), this research aims to provide a theoretically grounded and empirically validated roadmap for higher education institutions by achieving the following specific goals:

1. To identify and validate the construct dimensions of AI-augmented digital competency using exploratory factor analysis (EFA).
2. To assess the content validity and quality of the research instruments, including the digital competency questionnaire, through expert evaluation.
3. To examine the pedagogical utility of the AIDCF-CRAFT integration through perceived competency, learning reflection, and qualitative evidence.

By combining theoretical grounding with empirical validation, this research offers a sustainable model for digital transformation in the GenAI era.

LITERATURE REVIEW

Digital Competency in the Era of AI

Digital competency is conceptualized as the confident, critical, and responsible use of digital technologies for learning, work, and participation in society (Vuorikari et al., 2022). It transcends basic technical proficiency, encompassing a complex blend of cognitive, metacognitive, and socio-emotional skills required to navigate high-technology environments (Redecker, 2017; UNESCO, 2023). In the current educational landscape, this definition has expanded to include "AI literacy," which involves the ability to understand, use, monitor, and critically evaluate AI technologies (Long & Magerko, 2020; Ng et al., 2021).

The evolution of digital competency frameworks reflects a significant shift toward AI integration. The European Commission's DigComp 2.2 framework now emphasizes understanding how AI algorithms

Table 1. Synthesis of global digital competency frameworks and AI-augmented requirements

Competency area	DigComp 2.2	ISTE	UNESCO	Synthesis & AI-augmented transition
Information & data literacy	✓	✓	✓	Moving beyond basic search toward AI-assisted data synthesis and factual verification
Communication & collaboration	✓	✓	✓	Transitioning from user-to-user to human-AI collaboration and collaborative prompting
Digital content creation	✓	✓	✓	Integrating GenAI proficiency (text, image, and code) and human-AI co-creation
Critical thinking & problem-solving	✓	✓	✓	Evaluating AI outputs for hallucinations, algorithmic biases, and logic
Ethical & responsible use	◐	✓	✓	Shifting focus to algorithmic transparency, AI ethics, and intellectual property
Technical proficiency	✓	◐	✓	Mastery of prompt engineering and iterative AI-human feedback loops

Note: ✓: Explicitly addressed & ◐: Partially addressed

influence information visibility and decision-making (Vuorikari et al., 2022). Similarly, the ISTE (2016) standards highlight the role of digital citizens who can solve problems ethically and leverage technology to enhance student agency. These global standards suggest that being digitally competent now necessitates a sophisticated understanding of human-AI collaboration.

However, a persistent "implementation gap" exists in how these competencies are operationalized within pedagogical workflows. While frameworks like DigComp 2.2 and UNESCO (2023) provide the "what," they often lack the "how" regarding the integration of GenAI tools into specific academic tasks such as literature synthesis or data analysis (Dangprasert, 2025; Zhang et al., 2023). Furthermore, as AI tools can generate biased or "hallucinated" information, learners must possess critical AI literacy to verify outputs and maintain intellectual integrity (Long & Magerko, 2020; Ng et al., 2021).

Table 1 presents a synthesis of global digital competency frameworks and AI-augmented competency requirements.

Experiential Learning and Pedagogical Foundations

Experiential learning is a pedagogical approach emphasizing that knowledge is constructed through the transformation of experience and critical reflection (Dewey, 1986; Kolb, 1984). In contemporary higher education, this approach facilitates deep learning by requiring students to apply concepts within authentic, technology-mediated contexts (Miettinen, 2000). This shift from passive reception to active construction is essential for developing the high-level cognitive skills needed to navigate complex AI-integrated environments (Duchatelet et al., 2024; U-senyang, 2024).

The theoretical cornerstone of this study is Kolb's (1984) experiential learning theory (ELT), which describes a holistic four-stage cycle:

(1) concrete experience, where learners engage in a new task,

(2) reflective observation, involving reflecting on the experience,

(3) abstract conceptualization, where reflection gives rise to new ideas, and

(4) active experimentation, where learners apply their ideas to the world.

Subsequent expansions by Miettinen (2000) and Chan (2022) have further integrated motivational reasoning and digital reflection, suggesting that these experiential cycles are fundamental to sustaining lifelong learning in digital ecosystems.

Table 2 presents the theoretical foundations and their pedagogical applications in the AIDCF and CRAFT model.

GenAI in Higher Education

GenAI refers to computational systems, such as large language models (LLMs), capable of synthesizing new content from vast datasets (Dwivedi et al., 2023; Yu et al., 2024). Tools like GPT-4, Claude, and Gemini act as personalized "cognitive co-pilots," facilitating real-time summarization, complex translation, and adaptive

Table 2. Theoretical foundations and pedagogical application in AIDCF & CRAFT

Theorist (year)	Core theoretical concepts	Application in AIDCF & CRAFT model
Dewey (1986)	Learning by doing; continuity of experience	Integration of hands-on AI tool usage within authentic, complex academic tasks
Kolb (1984)	Four-stage cycle: concrete experience, reflective observation, abstract conceptualization, and active experimentation	Mapping the CRAFT stages (collecting to tailoring) as an iterative cycle of AI-human dialogue and testing
Miettinen (2000)	Motivational and diagnostic reasoning	Enhancing learner agency to diagnose AI-generated errors and hallucinations
Chan (2022) & Miettinen (2000)	Reflection-in-action; lifelong learning in digital contexts	Using the reflective digital practice dimension to monitor and adjust prompting strategies
Duchatelet et al. (2024) & U-senyang (2024)	Decision-making and problem-solving in authentic learning	Assessing "critical thinking with AI" through real-world problem-solving scenarios

simulations (Dwivedi et al., 2023; Yu et al., 2024). These technologies redefine human-computer interaction by allowing multimodal engagement through text, code, and images.

The pedagogical integration of GenAI necessitates a shift from operational usage to critical AI literacy to mitigate substantial risks. These risks include algorithmic bias, data privacy concerns, and the phenomenon of "hallucinations"—where AI generates plausible but factually incorrect information (Dwivedi et al., 2023; UNESCO, 2023). Consequently, higher education institutions must adopt frameworks like the AIDCF that balance AI's affordances with ethical awareness and reflective practices (Dangprasert, 2025; Yu et al., 2024).

Critical Thinking and Ethical Considerations

Critical thinking is a cornerstone of 21st century competence, enabling learners to analyze, evaluate, and synthesize information to form reasoned judgments (Facione, 2020). In AI-enhanced learning, this must expand to include the ability to scrutinize AI-generated content for logical inconsistencies and factual inaccuracies (Dwivedi et al., 2023; UNESCO, 2023). This "critical AI literacy" requires students to apply Socratic questioning—focusing on clarity, accuracy, and relevance—when interacting with LLMs.

Ethical concerns in AI-augmented learning have shifted from theoretical risks to immediate challenges, such as the erosion of epistemic agency and data surveillance (Floridi, 2023; Sidiropoulos & Anagnostopoulos, 2024). Learners must transition toward "proactive ethics," where they act as evaluators of AI-generated content rather than passive recipients (Floridi, 2023; UNESCO, 2023). This necessitates a culture of "verification by default," ensuring that human scrutiny remains central to the AI-augmented scholarly process.

The AIDCF

The proposed AIDCF positions digital competency as a multidimensional construct designed to bridge the gap between general literacy and AI-human collaboration (Hair et al., 2010; Vuorikari et al., 2022). It is synthesized into five key dimensions:

(1) AI awareness & ethics,

(2) prompting & tool proficiency,

(3) critical thinking with AI,

(4) AI-integrated learning design, and

(5) reflective digital practice.

Each dimension is grounded in experiential learning principles, ensuring the framework is pedagogically robust.

The AIDCF is uniquely operationalized through the CRAFT model, which provides a structured AI-integrated academic workflow. By embedding AI-augmented tasks within this experiential framework, learners move beyond simple tool usage toward strategic, reflective, and ethically grounded mastery (Dangprasert, 2025; Kolb, 1984).

Table 3. Synthesis of AIDCF dimensions, operational definitions, and theoretical anchors

AIDCF dimension	Operational definition	Representative indicators & theoretical anchor	Pedagogical integration (Kolb's, 1984 4 stages)
1. AI awareness & ethics	Understanding AI's fundamental logic, limitations, and societal risks to promote responsible use	Recognizing algorithmic bias, ensuring data privacy, and upholding academic integrity (Floridi, 2023)	Concrete experience: Initial exposure to AI capabilities and ethical risks
2. Prompting & tool proficiency	The ability to formulate effective iterative prompts and manage AI tools for specific tasks	Crafting goal-oriented prompts and selecting appropriate LLM models (Long & Magerko, 2020)	Active experimentation: Testing and refining iterative prompts in real-world tasks
3. Critical thinking with AI	Analyzing and evaluating AI-generated outputs through reflective and analytical reasoning	Identifying hallucinations and performing source triangulation (Facione, 2020)	Reflective observation: Critically questioning AI outputs for bias or logical fallacies
4. AI-integrated learning design	Structuring learning activities that incorporate AI as a collaborative and scaffolding partner	Aligning AI tool usage with pedagogical goals and adapting workflows (Ng et al., 2021)	Abstract conceptualization: Synthesizing AI outputs into new conceptual models
5. Reflective digital practice	Continuous monitoring and refinement of AI interaction to foster cognitive and ethical growth	Maintaining reflective journals and self-evaluating digital strategies (Redecker, 2017)	Iterative cycle: Continuous refinement of skills through reflective-action loops

CONCEPTUAL FRAMEWORK

The conceptual framework of this study integrates core insights from global digital competency models—including DigComp 2.2, ISTE (2016), and UNESCO (2023)—with ELT and contemporary GenAI research. It positions the AIDCF as a multidimensional construct designed to bridge the "implementation gap" between general digital literacy and the specific cognitive demands of human-AI collaboration. This study argues that digital competency in the AI era is not a static skill set but a dynamic, iterative process of action, reflection, and adaptation.

Each dimension is conceptually mapped to Kolb's (1984) four stages of experiential learning, supporting its application to authentic academic workflows in higher education and its pedagogical implementation with graduate students at KMUTNB. The AIDCF is uniquely operationalized through the CRAFT model, which serves as the instructional vehicle for the framework. By aligning the five competency dimensions with the CRAFT stages, the framework facilitates a "human-in-the-loop" approach, moving learners from passive tool consumption to critical, ethically grounded mastery.

Table 3 shows the synthesis of AIDCF dimensions, operational definitions, and theoretical anchors.

METHODOLOGY

Research Design

This study employed a developmental mixed-methods research design, structured into three sequential phases to ensure theoretical rigor, structural validity, and practical applicability. Phase 1 focused on the qualitative construction of the framework and instrument development. Phase 2 utilized a quantitative approach for structural validation through EFA. Phase 3 involved a mixed-methods pedagogical implementation to evaluate the framework's instructional utility within an authentic academic environment.

Participants and Research Context

The research was conducted during the 2025 academic year across three participant groups. In phase 1 (content validation), nine subject matter experts in educational technology and AI were purposively selected to evaluate item essentiality of the content validity ratio (CVR) analysis. All nine experts completed the item-essentiality assessment used for the CVR calculation; seven also returned complete framework-level rating forms and were therefore included in the descriptive evaluation reported later. Phase 2 (construct validation) involved 300 participants, including undergraduate students, graduate students, and university faculty members recruited via digital channels. This heterogeneous higher-education sample was used to examine the proposed structure across academic roles. In phase 3 (pedagogical implementation), a cohort of 36 graduate students enrolled in the advanced research methodology and research methodology in digital technology for technical education courses, as well as students undertaking independent study and thesis research at KMUTNB, was selected through convenience sampling to participate in a five-week instructional intervention based on the developed framework.

Instrumentation and Item Development

The primary instrument, the artificial intelligence-augmented digital competency questionnaire (AIDCF-Q) (**Appendix A**), was developed through a systematic three-step process to address the specific demands of AI-integrated learning.

1. Item drafting and mapping: Potential items were newly synthesized from established behavioral indicators in global frameworks, including DigComp 2.2, ISTE (2016) standards, and UNESCO's (2023) AI competency guidelines. Each of the 24 items was specifically mapped to the five proposed theoretical dimensions: AI awareness & ethics, prompting & tool proficiency, critical thinking with AI, AI-integrated learning design, and reflective digital practice.
2. Expert review and pilot testing: The initial items underwent content validation by nine experts. Using Lawshe's (1975) formula and the exact-binomial critical values reported by Ayre and Scally (2014), the minimum acceptable CVR for a nine-member panel was 0.778. Nine items received unanimous essentiality ratings (CVR = 1.000), and 15 items received essential ratings from eight of nine experts (CVR = 0.778), producing a mean (M) CVR of 0.861 across the 24 items. Prior to the large-scale phase 2 survey, a pilot test was conducted with a small group of learners to refine linguistic clarity and ensure that the technical terminology was appropriate for the target audience.
3. Refinement: Based on expert feedback and pilot results, the items were adjusted to emphasize "human-in-the-loop" interactions rather than simple tool operation.

Instructional Intervention: The CRAFT Model

The CRAFT model served as the pedagogical vehicle for the intervention. Over five weeks, graduate students at KMUTNB integrated GenAI tools (e.g., GPT-4, SciSpace, and QuillBot) into their actual research workflows. The intervention prioritized a "human-in-the-loop" approach, where students were required to critically verify AI outputs and maintain reflective journals to document their prompting iterations and ethical decision-making.

Data Analysis

Data were analyzed using integrated statistical and qualitative methods. To establish construct validity, EFA was conducted using principal component analysis (PCA) extraction with Varimax rotation. Criteria for component retention included eigenvalues greater than 1.0, visual inspection of the scree plot, theoretical interpretability, and factor loadings above 0.40, with internal consistency verified by Cronbach's alpha. For the implementation phase, descriptive statistics (M and standard deviation [SD]) were used to interpret perceived competency and satisfaction. Qualitative data from student reflection forms were subjected to thematic analysis to identify outcomes such as iterative prompting mastery and critical skepticism.

Ethical Considerations

The study strictly adhered to international ethical standards and was approved by the Naresuan University Network of Research Ethics Committee (NU-NREC; NRE No. P4-0009/2568, COA No. 011/2025) on 28 November 2025. NU-NREC served as the network ethics review body, while data collection was conducted at KMUTNB. All participants provided written informed consent following a comprehensive disclosure of the study objectives. Data were anonymized and stored in an encrypted environment to ensure participant confidentiality and protect intellectual privacy.

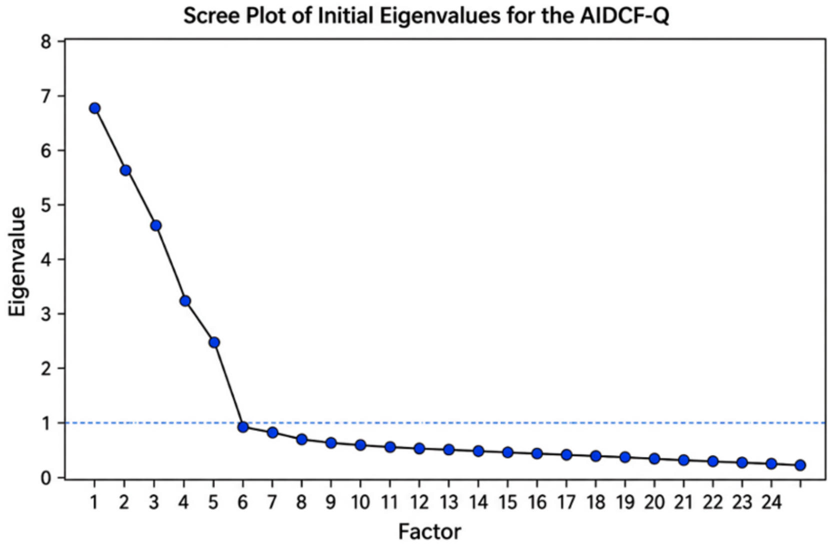

Figure 1. Scree plot of Eigenvalues for AIDCF components (generated by the author from the study data)

Table 4. Rotated component matrix and variance explanation for the AIDCF (n = 300)

Factor/dimension	Item loadings range	Eigenvalues	Percentage of variance	Cumulative percentage
F1: AI awareness & ethics	.712-.842	6.84	28.5%	28.5%
F2: Prompting & tool proficiency	.695-.854	3.22	13.4%	41.9%
F3: Critical thinking with AI	.684-.814	2.45	10.2%	52.1%
F4: AI-integrated learning design	.682-.833	1.86	7.8%	59.9%
F5: Reflective digital practice	.731-.884	1.26	5.2%	65.1%

RESULTS

Construct Validity and Factor Structure (N = 300)

The primary objective of the quantitative analysis was to establish the structural integrity of the AIDCF. Prior to the EFA, the dataset was screened for univariate outliers and extreme departures from univariate normality. The available screening results indicated that skewness and kurtosis values were within the prespecified ±1.0 range. The internal consistency of the 24-item instrument was robust, yielding an overall Cronbach's alpha of 0.87, with subscale reliability coefficients ranging from 0.808 to 0.882.

The suitability of the data for factor extraction was confirmed by the Kaiser-Meyer-Olkin measure of sampling adequacy, which yielded a value of 0.804, exceeding the recommended threshold of 0.70. Bartlett's test of sphericity was statistically significant, $\chi^2(276) = 3452.497$, $p < .001$, indicating that the correlation matrix was non-identity and appropriate for factor extraction.

Factor extraction was performed using PCA with Varimax rotation. The number of factors was determined by the Kaiser (1974) criterion (eigenvalues > 1.0) and a visual inspection of the scree plot.

Figure 1 shows the scree plot of Eigenvalues for AIDCF components.

The five-factor solution collectively accounted for 65.12% of the total variance, representing a substantial proportion of variance in the 24 indicators. Factor loadings for all 24 items ranged from 0.682 to 0.884 and exceeded the 0.50 criterion used for construct inclusion in this study (**Table 4**).

Table 5. Validated dimensions and functional descriptions of the AIDCF

No	Component	Description of competency
1	AI awareness & ethics	Identifying ethical risks, algorithmic bias, and privacy issues in AI usage
2	Prompting & tool proficiency	Mastering iterative prompt engineering and selecting appropriate AI tools
3	Critical thinking with AI	Verifying AI outputs, identifying hallucinations, and source triangulation
4	AI-integrated learning design	Strategically embedding AI into pedagogical workflows and research tasks
5	Reflective digital practice	Metacognitive evaluation of AI interactions to foster self-regulated growth

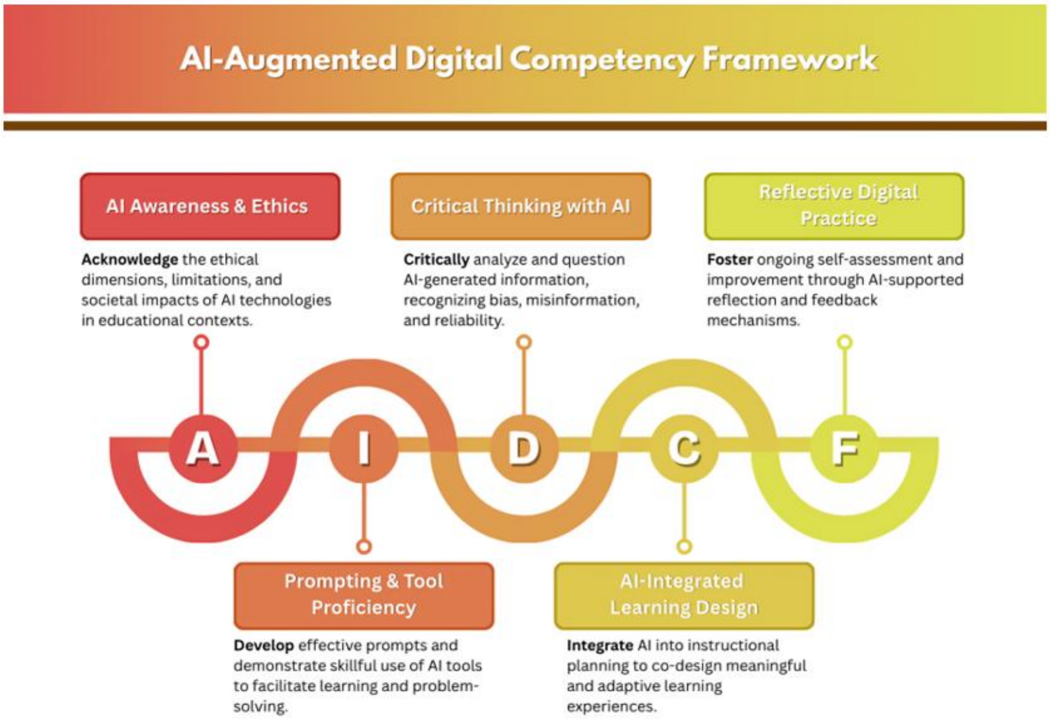

Figure 2. Validated model of the AIDCF (developed and illustrated by the author)

Theoretical Nomenclature of the AIDCF Dimensions

The five validated factors were named based on a synthesis of contemporary AI literacy literature and the semantic clusters of the items (**Table 5**).

Nomenclature and Structural Integrity of the AIDCF

Figure 2 illustrates the finalized validated model of the AIDCF. The five validated components are organized in a cyclical learning path, moving sequentially from awareness to reflection. This structural arrangement facilitates the ethical, analytical, and creative application of AI in higher education settings.

The model demonstrates a strategic harmony between ethical consciousness, pragmatic AI tool application, and contemplative teaching methodology. By framing these dimensions as an iterative cycle, the AIDCF serves as a comprehensive roadmap for transitioning from basic digital literacy to sophisticated human-AI collaboration. This visual representation underscores the framework's capacity to maintain student agency while leveraging AI as a "cognitive co-pilot" throughout the scholarly workflow.

Table 6. Expert evaluation scores for the AIDCF framework (N = 7)

Evaluation criteria	M	SD	Interpretation
1. Clarity of components	4.57	0.53	Very high
2. Content coverage	4.43	0.53	High
3. Appropriateness for AI contexts	4.71	0.49	Very high
4. Practical applicability	4.43	0.53	High
5. Relevance to graduate-level learners	4.57	0.53	Very high
Overall expert rating	4.54	0.51	Very high

Table 7. Results of student learning reflection via AIDCF-CRAFT activities (N = 36)

Items for learning reflection	Dimension alignment	M	SD	Interpretation
1. Identifying learning outcomes	Reflective digital practice	4.64	0.49	Very high
2. Engagement with impressive activities	AI-integrated learning design	4.69	0.47	Very high
3. Recognizing problems and obstacles	Critical thinking with AI	4.17	0.65	High
4. Proposing future AI applications	AI-integrated learning design	4.42	0.55	High
5. Commitment to self-improvement	Reflective digital practice	4.61	0.50	Very high
Overall learning reflection score		4.51	0.53	Very high

Table 8. Student satisfaction with the AI-augmented learning experience (N = 36)

Satisfaction domain	M	SD	Interpretation
1. Content appropriateness	4.65	0.45	Very high
2. CRAFT-based activities	4.58	0.52	Very high
3. AI tool usability	4.52	0.54	Very high
4. Skill development	4.57	0.49	Very high

Expert Validation and Content Rigor

To ensure content validity, the 24 AIDCF-Q items were evaluated by nine subject matter experts. Item-level CVRs ranged from 0.778 to 1.000, meeting or exceeding the minimum critical value of 0.778 for a nine-member panel (Ayre & Scally, 2014), and the M CVR across the 24 items was 0.861. All nine experts completed the item-essentiality assessment; the separate descriptive framework-level evaluation was based on the seven complete rating forms and resulted in a "very high" overall applicability rating (**Table 6**).

Phase 3: Pedagogical Implementation and Learning Reflection

The framework was operationalized through a five-week intervention using the CRAFT model with 36 graduate students at KMUTNB. The overall M for learning reflection was 4.51 (SD = 0.53), indicating that students perceived a high level of AI-augmented digital competency after participating in the learning activities (**Table 7**).

Elaborated Qualitative Outcomes: Thematic Analysis

The thematic analysis revealed that students moved beyond simple tool usage toward iterative prompting mastery. Participants documented a transition from "single-shot" queries to sophisticated, multi-turn dialogues with AI, which enabled deeper conceptual scaffolding. Furthermore, critical skepticism emerged as a key theme; students developed a "verification by default" mindset, manually triangulating AI-generated citations with academic databases to mitigate the risk of hallucinations. Finally, metacognitive growth was evidenced by students' ability to set personal guidelines for AI engagement, shifting AI's role from an "authority" to a "dialogic partner."

User Satisfaction and Operational Efficiency

Participants reported a very high level of satisfaction with the CRAFT instructional design, particularly regarding the usability of the integrated AI tools (**Table 8**).

Finally, the study utilized a specialized suite of digital tools to ensure data integrity and research efficiency (**Table 9**).

Table 9. Overview of digital tools employed across research phases

Tool	Research role	Outcome
Make (Integromat)	Distributed survey & tracked responses	Accelerated data collection
Google Sheets	Real-time data verification	Minimized transformation errors
SPSS	Statistical analysis (EFA, reliability)	Supported preliminary structural validation
Canva/PowerPoint	Infographic & model design	Enhanced visual communication

DISCUSSION

The Robustness of the Five-Factor AIDCF Structure

The primary objective of this study was to validate AIDCF as a multidimensional construct for the GenAI era. The EFA supported a five-factor structure explaining 65.12% of the total variance, indicating that the retained factors accounted for a substantial proportion of variance in the 24 indicators. Unlike traditional models such as DigComp 2.2, which prioritize general digital skills, the AIDCF explicitly positions AI awareness & ethics and prompting & tool proficiency as foundational pillars, reflecting a shift from technical operation toward sophisticated human-AI collaboration. The high internal consistency (overall Cronbach's alpha = 0.87) further supports the reliability of the instrument for measuring these related competencies.

Bridging the Application Gap Through the CRAFT Model

A notable descriptive finding from the instructional intervention was the high level of perceived competency across all dimensions (overall M = 4.51, SD = 0.53). However, the relatively lower score in critical thinking with AI (M = 4.17) compared with other dimensions highlights the perceived complexity of identifying AI hallucinations and technical obstacles. This gap supports the use of the CRAFT model as an instructional bridge. Specifically, the "analyzing" stage addresses the human-in-the-loop requirement by requiring students to verify AI outputs against empirical evidence, thereby supporting the critical skepticism identified in the qualitative themes.

Reflective Practice and Metacognitive Growth

The "very high" score for reflective digital practice (M = 4.61) indicates that participants perceived a strong reflective orientation toward AI use. By maintaining reflective journals and documenting prompt iterations, students at KMUTNB moved beyond passive tool consumption. The thematic analysis suggested that this reflection-in-action was associated with a shift from "single-shot" queries to complex, multi-stage dialogues, enabling students to maintain epistemic agency while using AI as a cognitive co-pilot.

Expert Validation and Policy Implications

The expert evaluation rating of 4.54 indicates that the AIDCF is timely and contextually grounded. The high scores for relevance to graduate-level learners (M = 4.57) suggest that the framework serves as a vital benchmark for professional development. At a policy level, these findings suggest that national digital strategies in Thailand and institutional policies at KMUTNB should transition from focusing on technological access to fostering high-level AI-augmented competencies. This necessitates a culture of "verification by default," ensuring that human scrutiny remains central to the AI-augmented scholarly process.

Limitations and Future Research

Despite its contributions, this study is subject to several limitations. The reliance on self-reported data introduces the potential for social desirability bias. The phase 2 validation sample combined undergraduate students, graduate students, and faculty members; although this broadened the higher-education context, differences among academic roles and prior AI experience may have influenced responses, and subgroup measurement invariance was not examined. The phase 3 implementation employed a one-group posttest-only design with 36 graduate students and did not include a pretest or comparison group. Consequently, the descriptive findings cannot establish learning gains, causal effects, or intervention effectiveness. The study was also confined to a single public technological university in Thailand over a five-week period. Future research should use independent samples for confirmatory factor analysis, test measurement invariance across relevant subgroups, and employ pre-/post-test or comparison-group designs with objective performance measures.

CONCLUSION

The practical implementation through the CRAFT model yielded high perceived competency, reflection, and satisfaction scores, providing preliminary evidence of the framework's pedagogical utility without establishing causal improvement.

Educational and Policy Implications

The AIDCF provides a foundational roadmap for higher education institutions to develop curricula that transcend basic operational skills, focusing instead on critical and reflective AI usage. For educators, the framework serves as a pedagogical guide for designing "human-in-the-loop" activities that maintain academic integrity. At a policy level, these findings suggest that national digital strategies in Thailand and beyond should transition from focusing on technological access to fostering high-level AI-augmented competencies, ensuring sustainable digital transformation.

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AI statement: During the preparation of this work, the author used OpenAI's ChatGPT to improve language and readability. After using this tool, the author reviewed and edited the content as needed and takes full responsibility for the content of the published article.

Declaration of interest: The author declared no competing interest.

Data availability: Data generated or analyzed during this study are available from the author on request.

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APPENDIX A

Table A1. AIDCF-Q items

Dimension	No	Questionnaire items
1. AI awareness & ethics	1	Able to explain the risks and limitations of using AI in learning
	2	Able to identify ethical issues related to the use of AI in the classroom
	3	Aware of bias problems in AI-generated outputs
	4	Able to explain personal data protection when using AI
	5	Recognizes the importance of using AI in a socially responsible manner
2. Prompting & tool proficiency	6	Able to design prompts to obtain results that meet specific needs
	7	Able to select appropriate AI tools for academic tasks
	8	Able to refine prompts (prompt refinement) to improve results
	9	Able to explain the differences between various types of AI tools
	10	Able to use AI tools to assist in academic information searches
3. Critical thinking with AI	11	Able to verify the accuracy of information obtained from AI
	12	Able to compare AI-generated information with other sources for credibility
	13	Able to reasonably question AI-generated results
	14	Able to distinguish facts from opinions in AI-generated text
	15	Able to explain the limitations of using AI as a substitute for human critical thinking
4. AI-integrated learning design	16	Able to design learning activities that integrate AI
	17	Able to select AI tools to promote collaborative learning or group work
	18	Able to use AI as an assistant in creating instructional content
	19	Able to adjust teaching plans by using AI-generated results as support
	20	Able to explain guidelines for using AI to promote creative learning
5. Reflective digital practice	21	Able to reflect on personal AI usage to identify strengths and areas for improvement
	22	Able to record and track personal AI usage for continuous skill development
	23	Able to exchange AI usage experiences with others for collaborative learning
	24	Able to adjust personal approaches to AI usage to suit different situations