



CONSTRUCTING A DIGITAL LITERACY FRAMEWORK FOR UNIVERSITY STUDENTS: A LITERATURE-GROUNDED THEORY APPROACH

Xueyi Cai

National University of Malaysia, Malaysia
Jiangsu College of Engineering and Technology, P. R. China
E-mail: P125441@siswa.ukm.edu.my

Aidah Abdul Karim

National University of Malaysia, Malaysia
E-mail: eda@ukm.edu.my

Abstract

As artificial intelligence and digital technologies become increasingly embedded in higher education, university students' digital literacy has emerged as a critical indicator of educational quality and future developmental capacity. However, existing research remains conceptually fragmented, with limited clarity regarding the structural organization and generative logic of digital literacy. To address this gap, this study adopts a grounded theory-based literature analysis of high-quality international publications from 2000 to 2025. Through open, axial, and selective coding, key concepts and categories were systematically abstracted to construct an integrated digital literacy framework for university students. The findings indicate that digital literacy extends beyond technical or information-processing skills, constituting a multidimensional competence system integrating cognitive understanding, contextualized application, capability development, and ethical regulation. By synthesizing 162 initial concepts, 48 first-order categories, and 15 major categories, a four-dimensional framework was identified, encompassing digital transformation, digital use, digital competence, and digital security. Digital transformation emphasizes the development of digital thinking and students' understanding of digital environments; digital use highlights contextualized engagement with digital technologies in learning and communication; digital competence focuses on higher-order abilities such as knowledge integration, problem solving, and innovation; and digital security underscores ethical awareness, risk management, and responsible digital behavior. Further analysis reveals a developmental trajectory from cognitive understanding to capability integration and contextual transfer, with data thinking and digital ethics functioning as key mechanisms within AI-enabled learning environments. This framework advances the structural theorization of digital literacy and provides a systematic foundation for curriculum design, assessment, and policy development in higher education.

Keywords: university students, digital literacy, grounded theory, digital education

Introduction

In contemporary higher education, university students are increasingly required to engage with digital technologies not only as tools for information access, but as integral components of learning, knowledge construction, and academic participation. As digital environments continue to reshape how information is produced, evaluated, and communicated, the capacity to navigate these environments critically and responsibly has become a foundational condition for effective learning and long-term development. Within this context, digital literacy has

emerged as a core competence expected of university students. With the rapid advancement of digital technologies and the widespread application of emerging innovations such as artificial intelligence, the metaverse, and blockchain, digital literacy has been widely recognized as central to higher education (Morgan et al., 2022). Digital literacy extends far beyond the operational use of digital tools; it encompasses a multidimensional set of abilities related to information access, evaluation, creation, communication, and ethical responsibility in digital environments (Gutiérrez-Ángel et al., 2022). Empirical studies indicate that digital literacy among university students directly affects learning outcomes (Kaplan & Kara, 2025), as well as their innovative capacity and social adaptability (Chen, 2025; Setyadi et al., 2025; Yu, 2022). Despite growing scholarly attention, considerable divergence remains across regions, disciplines, and educational levels regarding the conceptualization and structural composition of digital literacy (Tinmaz et al., 2022; Yang et al., 2025). Many existing digital literacy frameworks emphasize general skills or employability-oriented competencies (Hammada & Foli, 2024; Reddy et al., 2023; Wu et al., 2025), while insufficiently addressing the distinctive learning, research, and knowledge-construction contexts faced by university students (Tinmaz et al., 2022). Moreover, prior research has predominantly focused on teachers, K–12 learners, or workplace populations (Falloon, 2020; Karchmer, 2001; Reddy et al., 2023), whereas systematic investigations explicitly dedicated to constructing a comprehensive digital literacy framework for university students remain limited. Although some scholars have examined university students' digital competencies from the perspective of educational informatization (Kuzu & Kayabasi, 2025; Wang et al., 2021; Zhao et al., 2021), most of these studies rely on top-down approaches such as questionnaire surveys or model testing. Such methods often presuppose predefined constructs and thus provide limited insight into the generative logic underlying digital literacy. In addition, notable inconsistencies persist across studies in terms of conceptual boundaries and dimensional classifications. Some frameworks prioritize technical operational skills, others foreground information management and security awareness (Li et al., 2025), while still others emphasize creativity and critical thinking. This conceptual fragmentation undermines theoretical coherence and poses challenges for subsequent assessment development and curriculum implementation (Gkrimpizi et al., 2023). In contexts where digital technologies increasingly shape learning decisions, information production, and knowledge construction, university students' digital literacy can no longer be understood merely as technological adaptation or information-processing competence. Instead, it is progressively evolving into a comprehensive literacy system integrating cognitive judgment, ethical awareness, innovative practice, and social responsibility. The absence of a structurally integrated and theoretically grounded framework constrains the explanatory power and practical relevance of digital literacy research within higher education, underscoring the necessity for a systematic reconceptualization grounded in robust theoretical synthesis.

Literature Review

Evolution of the Concept of Digital Literacy

The concept of digital literacy has undergone a progressive evolution, shifting from a narrow focus on technical skills toward a multidimensional competence framework. In its early stage, digital literacy was primarily understood as the ability to operate and use digital tools such as computers and network technologies (Mohammadyari & Singh, 2015). This perspective emphasized functional usage and technical proficiency, viewing digital literacy largely as a set of instrumental skills. As information technologies became increasingly embedded in everyday life, scholarly attention gradually expanded to include information access, evaluation, and use, as well as media literacy (Koltay, 2011). Pool (1997) was among the first to argue that digital

literacy should not be reduced to operational competence, but should instead be understood as a form of critical thinking that enables individuals to interpret and make meaning from digital texts and environments. Entering the twenty-first century, research further emphasized the cognitive complexity underlying digital literacy. Eshet-Alkalai and Chajut (2010) proposed that digital literacy comprises multiple interrelated subskills, including visual literacy, navigation literacy, and information reproduction literacy, highlighting the central role of higher-order cognitive processes. From this perspective, digital literacy came to be recognized as a comprehensive capability involving the acquisition, evaluation, transformation, and creation of digital information, rather than merely the manipulation of technological tools.

In recent years, an increasing body of research has conceptualized digital literacy as a structured, multidimensional construct across higher education and other educational contexts (Baber et al., 2022; Wang & Si, 2023). Since 2006, digital competence has gradually become an important issue in international education policy. The European Parliament first identified digital competence as a key competence for compulsory education, followed by UNESCO's ICT Competency Framework for Teachers, which emphasized educators' roles in technology integration. Within the EU's Education and Training 2020 (ET2020) framework, digital transformation in education has been continuously promoted, while findings from the Teaching and Learning International Survey (TALIS) revealed persistent gaps between teachers' ICT training and their actual digital competence. From 2010 onward, the European Commission systematically developed the Digital Competence Framework for Citizens (DigComp), which underwent several iterations between 2014 and 2017 to enhance its structural clarity and operational applicability. The subsequent release of DigCompEdu marked a significant shift toward professional digital competence in teacher education (Redecker & Punie, 2017).

At the conceptual level, Tinmaz et al. (2022) identified recurring themes such as "digital literacy," "digital competence," and "digital thinking," noting a broader transition in the field from isolated skill-based approaches to integrated competence structures and cognitive models. Similarly, Trilling and Fadel (2012) incorporated digital literacy into the framework of "21st-century skills," underscoring the importance of critical thinking, collaboration, creativity, and ethical responsibility in digital environments. Within higher education, a systematic review by Gutiérrez-Ángel et al. (2022) of empirical studies published between 2010 and 2021 revealed that while university students generally demonstrate moderate to high proficiency in communication and collaboration, they exhibit notable deficiencies in digital content creation, digital risk awareness, and multimedia production. The rapid development of artificial intelligence, big data, social media, and blended and online learning environments has further expanded the conceptual boundaries of digital literacy. On the one hand, data literacy and artificial intelligence literacy have been increasingly proposed as essential subdomains within digital literacy (Chiu et al., 2024; Şeker et al., 2025). On the other hand, the long-standing assumption of "digital natives" has been critically challenged. Empirical evidence suggests that growing up in digital environments does not automatically equip young people with sophisticated digital literacy competencies (List, 2019; Pangrazio, 2016). From a policy and framework perspective, recent models tend to categorize digital competence into domains such as information and data literacy, communication and collaboration, content creation, safety, and problem solving, while emphasizing the integration of knowledge, skills, and attitudes, as well as differentiated proficiency levels (Falloon, 2020; Van Audenhove, 2024). These developments reflect not only conceptual refinement but also policy-level responses to questions concerning the nature of digital literacy and the competencies required across diverse educational contexts.

In summary, the evolution of digital literacy can be broadly characterized by three stages: an initial focus on technical operation, an expansion toward information and media use, and a subsequent shift toward multidimensional competence structures emphasizing cognition, creativity, ethics, and contextual adaptability. In the context of higher education, research on

university students' digital literacy should move beyond basic technological use to focus on their capacities for critical judgment, creative application, and adaptive engagement. Accordingly, a framework for university students' digital literacy should integrate technological, cognitive, social, and ethical dimensions.

Construction of Digital Literacy Frameworks

As the concept of digital literacy has continued to evolve, a growing body of research has sought to construct digital literacy frameworks in order to clarify its structural dimensions, core components, and assessment pathways. Overall, existing research on digital literacy frameworks shows wide variation across domains, but often lacks strong alignment with specific learner groups and educational contexts, and remains limited in terms of assessment tools and practical applicability. However, they are often characterized by limited alignment with specific learner groups and educational contexts, as well as insufficient integration of assessment tools and practice-oriented applications. At the policy and macro-framework level, the European Digital Competence Framework for Citizens (DigComp), first released in 2013 and subsequently revised in 2016 and 2017, represents one of the most influential and widely adopted models for conceptualizing citizens' digital competence (Ferrari et al., 2013). DigComp delineates key competence domains and proficiency levels and has served as a reference framework for numerous European countries. From a cognitive perspective, Eshet (2012) defined digital literacy as a set of six thinking skills: photo-visual, branching, reproduction, information, socio-emotional, and real-time thinking skills. Building upon DigComp 2.0, the UNESCO Institute for Statistics (2018) proposed the Digital Literacy Global Framework (DLGF), which aimed to provide an internationally comparable structure for assessing learners' digital literacy across diverse contexts.

Systematic reviews further highlight the increasing complexity and conceptual plurality of digital literacy frameworks. Tinmaz et al. (2022) conducted a systematic review of 43 studies on digital literacy and noted that multiple terms, such as "digital literacy," "digital competence," and "digital thinking," coexist in model development, with frameworks becoming increasingly complex in their dimensional structures. Similarly, Reynolds (2016) proposed the development of an integrative digital literacy framework that consolidates existing thematic strands into a more operational structure, suggesting that framework construction has entered a phase of theoretical integration. While these efforts have advanced conceptual clarity, they also reveal persistent issues of conceptual redundancy and inconsistent categorization across frameworks. Research on digital literacy frameworks for university students and faculty in higher education has increased in recent years, yet overall contextual alignment remains limited (Falloon, 2020; Öncül, 2021; Taib et al., 2023). Smith and Storrs (2023) explored undergraduate students' understandings of digital literacy in the context of social media and reported that students viewed digital literacy as a multidimensional concept, including content creation, collaboration, media use, and risk awareness. However, these understandings differed from dominant theoretical frameworks. Other studies suggest that while teacher-oriented frameworks are designed for educators, their structural dimensions—such as teaching practice, learner empowerment, professional engagement, and digital competence development—may offer transferable insights for constructing student-focused frameworks (Basilotta-Gómez-Pablos et al., 2022; Karakuş & Kılıç, 2022; Na et al., 2024). Notably, the European Framework for the Digital Competence of Educators (DigCompEdu) proposed by Redecker and Punie (2017) identifies six competence areas, including professional engagement, digital resources, teaching and learning, assessment, empowering learners, and facilitating learners' digital competence. Although existing digital literacy frameworks cover a wide range of dimensions, most remain generic or teacher-oriented, and frameworks specifically tailored to the university student context are still lacking.

Moreover, while these frameworks propose dimensional classifications, limitations persist in terms of assessment tools, contextual application, and empirical validation.

Another critical issue concerns the assessment and practical implementation of digital literacy frameworks. Although many frameworks articulate clear competence dimensions, their corresponding measurement instruments and empirical validation remain insufficient. A systematic review by Demeshkant et al. (2022) on digital competence assessment in higher education revealed that many existing instruments lack robust cross-cultural validity and reliability, with a particularly evident gap in validated tools applicable to Asian higher education contexts. This limitation constrains the practical utility of existing frameworks for curriculum design and educational evaluation. From a broader perspective, recent research trends indicate that digital literacy framework construction is gradually shifting toward approaches that emphasize contextualization, task orientation, and group specificity. Early frameworks predominantly focused on generic skill sets, whereas more recent studies highlight the need to align digital literacy dimensions with specific educational contexts, such as university learning, academic research, and collaborative project-based work. A recent systematic review by Farias-Gaytan et al. (2023) identified common digital literacy domains in higher education research, including information and data literacy, communication and collaboration, content creation, safety and ethics, and problem solving and innovation. Nevertheless, inconsistencies in terminology, domain boundaries, and dimension definitions persist across studies, suggesting that research on digital literacy frameworks specifically for university students is still in its early stages.

In summary, existing research on digital literacy frameworks provides valuable theoretical foundations and reference models, yet it also reveals several unresolved issues, including the lack of frameworks tailored to university students, limited alignment with university learning contexts, and insufficient development of assessment tools and practical implementation strategies. These gaps highlight the need for a systematically constructed digital literacy framework that is empirically grounded, contextually sensitive, and explicitly designed to address the learning and developmental needs of university students.

Grounded Theory and Its Applications

Grounded theory was originally developed by Barney G. Glaser and Anselm L. Strauss. Grounded theory, developed by Strauss in the 1960s, is a qualitative research methodology aimed at generating theories or frameworks through systematic data collection, constant comparison, coding, and abstraction, rather than starting from predefined hypotheses (Heath & Cowley, 2004). A core principle of grounded theory is that theory should be “grounded in data,” requiring researchers to remain theoretically open, engage in continuous comparison, and pursue theoretical saturation to ensure the explanatory power and transferability of the resulting framework (Dunne, 2011). Classical grounded theory typically follows three key analytical procedures: open coding, axial coding, and selective coding (Walker & Myrick, 2006). Subsequent developments in grounded theory, particularly constructivist grounded theory, further emphasize the role of researchers’ positionality, contextual sensitivity, and reflexivity in the process of theory construction (Charmaz, 2017). Within literature-based research, grounded theory has prompted renewed reflection on the role of literature as a legitimate data source. Although classical grounded theory advises against extensive early-stage literature review to avoid imposing preconceived theoretical assumptions, completely ignoring existing literature may weaken a study’s conceptual foundation and scholarly positioning (Niasse, 2022). Consequently, contemporary grounded theory scholars recognize that incorporating existing literature can strengthen a study’s conceptual grounding without imposing predefined assumptions.

In recent decades, grounded theory has been widely applied across social sciences, education research, and health-related disciplines. A systematic review by Connor et al. (2023) revealed frequent use of classical grounded theory in nursing research but also identified notable methodological shortcomings, particularly regarding transparency in coding procedures and the reporting of theoretical saturation. Nathaniel (2022) proposed a staged approach to literature engagement in grounded theory, distinguishing between the “introduction,” “integration,” and “synthesis” phases, thereby providing a clear pathway for researchers to connect literature review with theory generation. In educational research, the bottom-up logic of grounded theory has proven especially suitable for exploring underdeveloped or emerging constructs, such as competence frameworks and structural models (Sosa-Díaz et al., 2022; Tavakol et al., 2006). For instance, studies on the digital competence of university faculty have employed grounded theory methods—using interviews, observations, and document analysis—to inductively generate competence frameworks, highlighting the method’s potential for systematic framework development (Carlin & Kim, 2019). These studies illustrate that when the research focus involves abstract constructs such as competencies, structural relationships, or conceptual frameworks, grounded theory provides a coherent pathway from raw data to categories, dimensions, and integrated theoretical models.

Against this methodological backdrop, the present study adopts a literature-based grounded theory approach, treating published academic literature as the primary data source. This approach applies the coding logic of grounded theory while using existing literature as a structured “data corpus” for open coding, category development, and framework construction, instead of using conventional interview or field observation data. This methodological choice offers several advantages. First, it enables the systematic integration of numerous studies and the identification of shared conceptual patterns, thereby enhancing the theoretical foundation of the proposed framework. Second, it avoids reliance on researchers’ intuitive judgments or expert opinions alone, adhering instead to the grounded theory principle of generating concepts directly from data. Third, it establishes a robust conceptual structure that can support subsequent empirical research, such as questionnaire development and scale validation. Given the conceptual complexity and multidimensional nature of digital literacy, employing a literature-based grounded theory approach to construct a digital literacy framework for university students is methodologically sound and practically applicable.

Research Questions

A synthesis of existing studies indicates that, although research on digital literacy has made notable progress in terms of conceptual definitions, dimensional classifications, and measurement instruments, the field continues to exhibit conceptual fragmentation, heterogeneous frameworks, and insufficient explanatory logic. In particular, under conditions where digital technologies are deeply embedded in higher education, digital literacy among university students has evolved beyond a narrow focus on technical operation or information processing, gradually encompassing a more integrated set of capacities involving cognitive judgment, value internalization, innovative practice, and social responsibility. Nevertheless, much of the existing literature remains confined to static listings of competence elements, offering limited insight into the overall structural coherence of digital literacy or the mechanisms through which it is generated and developed. Consequently, a theoretically integrated framework capable of responding to transformations in digitally mediated learning practices has yet to be fully articulated. To address these limitations, this study adopts a literature-based grounded theory approach, using relevant peer-reviewed academic literature as the primary data source. Through open, axial, and selective coding, prior research on university students’ digital literacy is systematically synthesized and conceptually abstracted (Cutcliffe, 2000; Wolfswinkel et al.,

2013). Compared with questionnaire-based studies driven by hypothesis testing or deductive extensions of existing models, literature-based grounded theory emphasizes the inductive generation of concepts and structures directly from data. This approach is particularly well suited to complex and multidimensional research domains, as it facilitates the construction of theoretical frameworks with strong internal coherence and explanatory power (Urquhart & Fernández, 2013). Accordingly, employing a literature-based grounded theory approach to construct a digital literacy framework for university students allows for both conceptual integration and structural reconstruction at the theoretical level, while also providing a practical reference for curriculum design and competence assessment in higher education.

Guided by these research concerns and methodological considerations, this study focused on the value orientation, structural structure, and generative mechanisms of university students' digital literacy, and formulated the following research questions:

RQ1: Based on existing scholarly literature, what core dimensions and structural elements can be identified in university students' digital literacy, and how are their internal relationships organized?

RQ2: In the context of digital technologies becoming deeply integrated into higher education, how does its conceptualization and theoretical framing differ from previous understandings?

RQ3: How can a literature-based grounded theory approach be employed to systematically identify and integrate the core categories and structural relationships of university students' digital literacy, thereby constructing a framework that is theoretically coherent and explanatory?

Together, these research questions provide a clear analytical orientation for the subsequent processes of coding, category integration, and framework construction. They also establish a theoretical foundation for interpreting the meaning and practical significance of university students' digital literacy within an AI-enhanced educational ecosystem.

Research Methodology

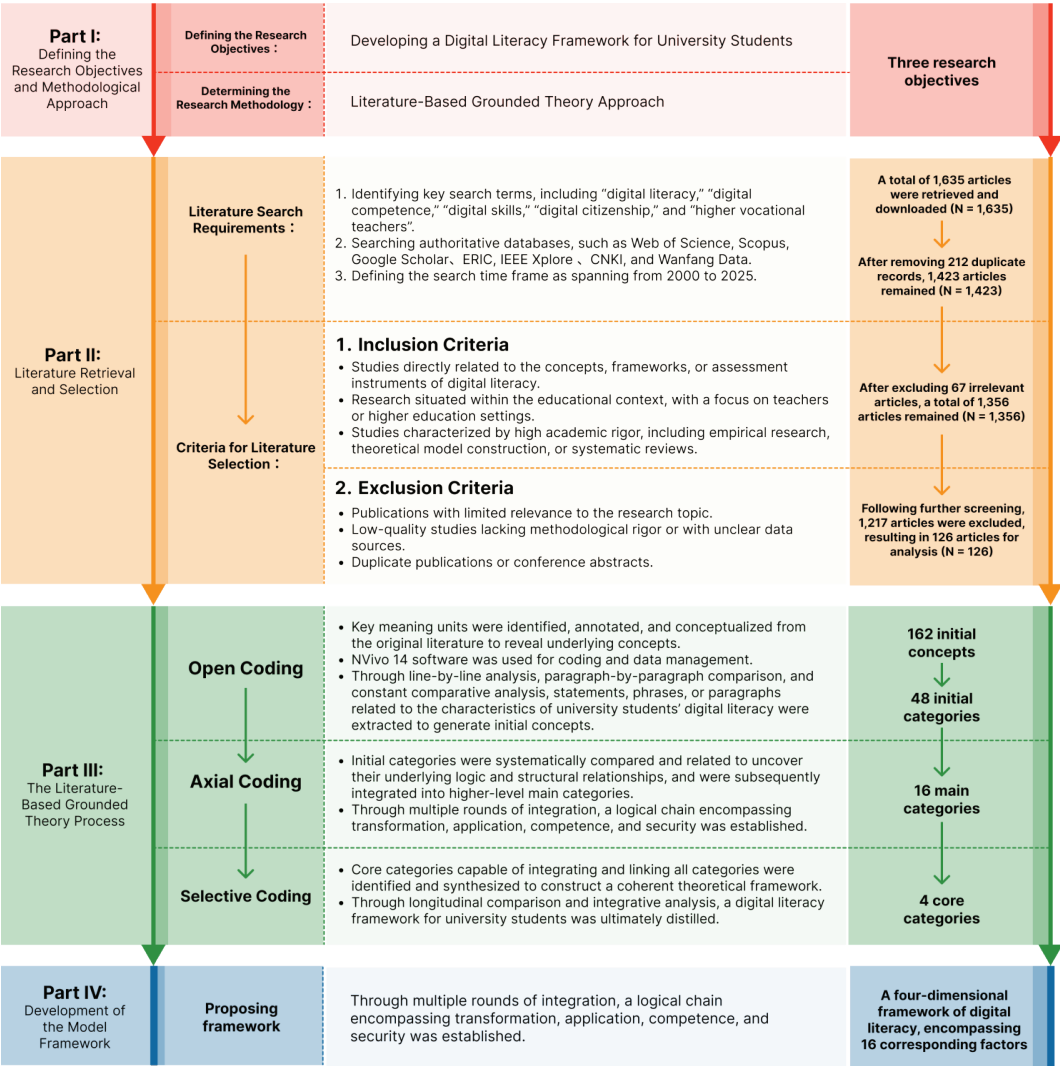
Design

This study adopted a qualitative research design to address key challenges in prior research on university students' digital literacy, such as dispersed conceptual definitions, fragmented structural frameworks, and insufficient contextual alignment in the context of higher education's deep digital integration. Literature-based grounded theory was adopted as the core methodological approach, enabling the systematic analysis of high-quality academic publications to generate a digital literacy framework that demonstrates both theoretical coherence and practical explanatory capacity. In terms of research design, the study follows the fundamental grounded theory principle that theory should emerge from data. Published scholarly literature was treated as the primary data source, with emphasis placed on inductive reasoning, systematic comparison, and theory generation throughout the research process (Charmaz, 2017; Urquhart & Fernández, 2013). Through constant comparative analysis and multiple rounds of coding, concepts, categories, and structural relationships were progressively distilled from the literature, culminating in the construction of an integrated theoretical framework.

The study was conducted from September 3, 2024, to November 16, 2025. Relevant studies published between 2000 and 2025 were systematically retrieved and analyzed. The study focused on university students' digital literacy within higher education contexts, covering key educational areas including learning, research, and digital participation. Rather than being confined to a single country or disciplinary tradition, the study drew upon international scholarship to extract a theoretical structure with cross-contextual explanatory potential. Overall, the research design consisted of four interrelated stages: (1) clarification of research objectives

and methodological orientation; (2) systematic literature retrieval and screening; (3) literature-based grounded analysis, including open, axial, and selective coding; and (4) integration and theoretical construction of the digital literacy framework. Through this research pathway, the study methodologically developed a grounded analytical framework treating literature as data, and constructed a theoretical model of university students' digital literacy reflecting digitally empowered learning contexts. The detailed research procedure is illustrated in Figure 1.

Figure 1
Research Procedure

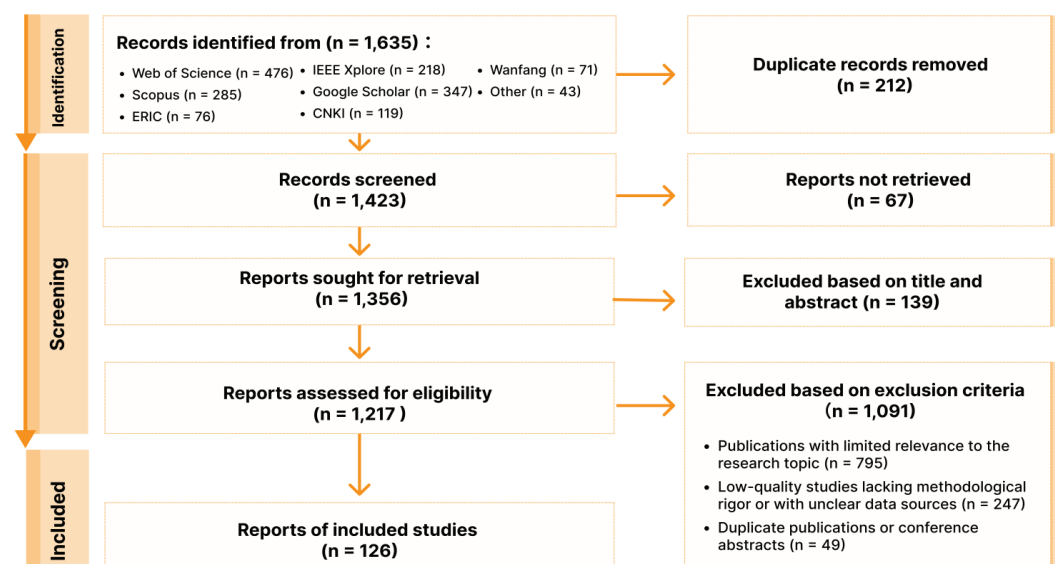


Literature Selection and Screening Criteria

The literature identification, screening, and selection procedures followed the PRISMA 2020 guidelines, ensuring transparency, methodological rigor, and reproducibility throughout the review process (Page et al., 2021). To capture the interdisciplinary scope of digital literacy research in educational contexts, a comprehensive multi-database search strategy was employed. Records were retrieved from Web of Science ($n = 476$), Scopus ($n = 285$), ERIC

($n = 76$), IEEE Xplore ($n = 218$), Google Scholar ($n = 347$), CNKI ($n = 119$), Wanfang Data ($n = 71$), and other relevant sources ($n = 43$), yielding an initial total of 1,635 records. After the removal of duplicate entries ($n = 212$), 1,423 unique records remained for subsequent screening. Titles and abstracts were then systematically reviewed to exclude studies that were clearly unrelated to the research focus, resulting in the exclusion of 139 records. During this stage, 67 reports could not be retrieved in full text and were therefore removed from further consideration. As a result, 1,217 studies proceeded to full-text eligibility assessment. Full-text screening was conducted based on explicitly defined inclusion and exclusion criteria. Studies were retained if they (1) directly addressed the concept, framework, or measurement of digital literacy; (2) were situated within educational contexts, with particular relevance to higher education or teacher populations; and (3) demonstrated adequate academic quality through empirical research designs, theoretical modeling, or systematic review methodologies. Studies were excluded if they (1) showed limited relevance to the research topic, such as those focusing on general information technology skills outside educational settings ($n = 795$); (2) lacked methodological rigor or presented unclear data sources ($n = 247$); or (3) consisted of duplicate publications or conference abstracts ($n = 49$). Through this multistage screening process, a final corpus of 126 core studies was retained for grounded theory analysis (Figure 2). To minimize selection bias and enhance procedural reliability, screening and eligibility assessments were conducted independently by two researchers, followed by cross-verification and consensus-based discussions. Any discrepancies were resolved through joint examination of the full texts, ensuring consistent application of the selection criteria. The resulting set of 126 studies constitutes a theoretically coherent and methodologically robust literature base, providing sufficient conceptual breadth and analytical depth for subsequent coding, category development, and framework construction.

Figure 2
Article search and selection process



Literature Structure and Analytical Dimensions

Following the completion of the literature selection process, the retained studies were systematically organized and subjected to multi-dimensional analysis in accordance with the

research objectives and guiding questions. This analytical procedure was designed to elucidate the theoretical trajectories, core thematic concerns, and developmental trends within the body of research on university students' digital literacy. Overall, the analysis adopted an integrated approach that combined thematic orientation with hierarchical structuring, allowing for both conceptual depth and analytical coherence. Specifically, the literature was organized into three interrelated analytical layers: the theoretical foundation layer, the framework construction layer, and the application and extension layer. The theoretical foundation layer focused on the conceptualization and evolution of digital literacy, exploring how its meanings have expanded in parallel with technological and educational changes. The framework construction layer addressed the structural elements of digital literacy, including the identification of core components, the development of conceptual models, and the underlying principles guiding framework formation. The application and extension layer examined empirical studies conducted in specific educational contexts, with particular attention to research in higher and vocational education that investigated teachers' and students' digital literacy, influencing factors, and strategies for competence development. Across these layers, the literature was further analyzed along three primary analytical dimensions: theoretical evolution, framework construction, and practical application. The theoretical evolution dimension examined the expansion of digital literacy concepts and their integration with adjacent knowledge domains. The framework construction dimension focused on the mechanisms through which digital literacy has been structured into multidimensional frameworks, including approaches to dimension delineation and the development of assessment instruments. The practical application dimension emphasized the contextual enactment of digital literacy within educational settings, particularly the generative mechanisms, competency manifestations, and dynamic interactions between university students' digital literacy and broader processes of educational digital transformation. Through this structured and multidimensional synthesis of the literature, the analysis sought to clarify the overall structural characteristics and developmental tendencies of research on university students' digital literacy. This, in turn, provides a systematic theoretical foundation for the subsequent grounded theory-based framework construction undertaken in this study.

Coding Principles and Implementation Procedures

Following the operational paradigm of grounded theory, the coding process was implemented in three sequential stages: open coding, axial coding, and selective coding. This iterative approach enabled the systematic abstraction and conceptual aggregation necessary to transition from raw literature to a theoretically coherent framework.

During the open coding phase, the selected core literature was read and analyzed line by line, with continuous comparisons across sources to identify key concepts and terms related to "digital literacy definition," "competency dimensions," "educational application contexts," and "assessment mechanisms." Each literature unit was treated as an independent analytical unit, yielding initial concepts. To ensure methodological rigor and consistency, NVivo 14 software was employed for data management, coding visualization, and cross-validation, mitigating potential researcher bias. In the axial coding phase, preliminary categories derived from open coding were further analyzed to identify relationships among concepts, constructing conditions, contextual influences, and outcome linkages. For example, categories such as "information retrieval," "media literacy," and "technical operation skills" were consolidated under the core dimension of digital skills, while "critical thinking," "information ethics," and "digital citizenship awareness" were integrated into the digital awareness dimension. This stage aimed to establish stable category structures and clarify the interaction mechanisms among the components of digital literacy. In the selective coding phase, theoretical integration and framework construction were conducted around the core categories, leading to the identification of key propositions for the digital literacy framework for university students.

The selective coding phase focused on theoretical integration around the core category, culminating in the articulation of the central propositions for the “undergraduate digital literacy framework.” The execution of coding adhered to three fundamental principles: (1) systematicity, ensuring logical consistency from concept extraction to category integration; (2) iterativity, involving continuous verification and refinement to maintain alignment between theoretical construction and literature evidence; and (3) transparency, with detailed documentation of coding paths, operational procedures, and category generation to enhance traceability and academic reliability. Through comparative analysis across diverse literature sources and educational contexts, core components of digital literacy were distilled, further subdivided into secondary subdimensions, ultimately yielding a multi-level, dynamic framework that captures the structural and functional complexity of undergraduate digital literacy.

Construction of the Undergraduate Digital Literacy Framework

Open Coding: Aggregation of Initial Concepts

Open coding constitutes the initial stage of grounded theory analysis and focuses on identifying, labeling, and conceptualizing analytically meaningful units from a large body of literature in order to uncover latent patterns and conceptual structures (Walker & Myrick, 2006). Based on systematic literature collection and screening, 126 core studies published between 2000 and 2025 and closely related to digital literacy, undergraduate students, and higher education were selected. These studies were retrieved from Scopus, Web of Science, Scopus, Google Scholar, ERIC, IEEE Xplore, CNKI, and Wanfang, and collectively addressed cognitive, skill-based, ethical, safety-related, and creative dimensions of digital literacy. All selected articles were imported into NVivo 14 and subjected to qualitative coding to ensure procedural consistency and analytical rigor. Following line-by-line analysis, paragraph comparison, and the constant comparative method (Charmaz, 2017), statements, phrases, and paragraphs explicitly describing university students’ digital literacy characteristics were systematically examined. Initial concepts were inductively generated as the smallest analytical units grounded directly in the literature. This process resulted in 162 initial concepts. For example, literature focusing on academic learning outcomes emphasized students’ capacity to evaluate the credibility of digital information and adapt learning strategies in online environments, whereas studies on emerging technologies highlighted competencies such as human–AI collaboration awareness and ethical engagement with intelligent systems. To enhance methodological transparency and directly address concerns regarding the concreteness of the coding process, Table 1 presents representative examples of literature-based open coding. The table illustrates how specific textual extracts from prior studies were translated into corresponding initial concepts, thereby demonstrating the direct linkage between empirical literature evidence and concept generation.

Table 1
Examples of Literature-Based Open Coding in the Construction of the Digital Literacy Framework

Literature Extract	Initial Concept	Author(s)
Digital literacy significantly predicts college students' academic achievement through their ability to evaluate online information and regulate learning in digital environments.	Information Filtering Platform Adaptation	Chen (2025)
The integration of artificial intelligence into educational contexts requires learners to develop new competencies, including adaptive interaction with intelligent systems and reflective judgment of AI-supported outcomes.	Cross-Platform Interaction Content Quality Evaluation	Benvenuti et al. (2023)
AI literacy emphasizes not only technical understanding but also ethical reasoning, particularly in relation to data use, algorithmic transparency, and responsible decision-making.	Algorithmic Fairness AI Ethics	Chiu et al. (2024)

Note. Literature extracts were paraphrased to preserve original meaning while ensuring analytical clarity and consistency with the coding process.

To ensure coding reliability, a dual independent coding strategy was adopted. Two researchers with expertise in educational technology and qualitative methodology conducted the open coding independently. Intercode agreement was assessed using Cohen's kappa coefficient, yielding an initial agreement value of $\kappa = 0.82$, which exceeds the commonly accepted threshold for substantial agreement (Fleiss et al., 1979). Discrepancies were subsequently resolved through iterative discussion and consensus meetings, during which coding definitions were refined and unified. This procedure strengthened the reliability and stability of the coding outcomes while maintaining theoretical sensitivity and grounding concept generation in the data rather than in pre-existing theoretical assumptions. Subsequent inductive aggregation condensed the 162 initial concepts into 48 preliminary categories through conceptual grouping based on semantic similarity and conceptual relevance. These categories represent distinct yet interrelated dimensions of undergraduate digital literacy (Table 2). For instance, the category Digital Cognition integrates concepts such as information awareness, technological understanding, and data comprehension, whereas Digital Ethics encompasses privacy protection, responsible information sharing, and normative online behavior. To assess theoretical saturation, an additional 20 studies published between 2023 and 2025 were analyzed. No new conceptual units emerged, indicating that theoretical saturation was achieved at the open coding stage.

Table 2
Open Coding Results: Initial Concepts and Sub-Categories

Serial Number	Sub-Categories	Initial Concept	Serial Number	Sub-Categories	Initial Concept
1	Digital Cognition Awareness	Digital Technology Perception Digital Environment Sensitivity Technology Acceptance Attitude Digital Cognition Interest	25	Media Literacy	Media Identification Cross-Media Understanding
2	Digital Comprehension Ability	Understanding Tool Functionality Analyzing Resource Value Information Authenticity Recognition Systematic Logical Understanding	26	Intercultural Awareness	Global Perspective Cultural Difference Awareness
3	Digital Thinking Patterns	Systematic Thinking Data-Driven Thinking Innovative Thinking Logical Reasoning	27	Digital Learning Strategies	Platform Selection Time Management
4	Digital Evaluation Competence	Information Filtering Reliability Assessment Content Quality Evaluation	28	Digital Collaboration Competence	Task Collaboration Cloud Tools
5	Digital Information Acquisition	Active Information Search Keyword Retrieval Multi-Channel Search Information Capture	29	Digital Feedback Awareness	Data Tracking Feedback-Based Revision
6	Digital Resource Selection	Platform Selection Resource Matching Evaluation Authority Recognition	30	Self-Efficacy	Technology Confidence Task Belief
7	Digital Communication and Expression	Digital Communication Cross-Platform Interaction Multimedia Expression	31	Technology Anxiety Regulation	Coping Strategies Psychological Regulation
8	Digital Application Transfer	Learning Platform Operation Cross-Context Application Real-Life Scenario Transfer	32	Critical Thinking	Content Analysis Logical Reasoning
9	Digital Knowledge Mastery	Software Knowledge Platform Familiarity Operational Procedure Comprehension	33	Information Re-Creation	Resource Re-Editing Content Re-Creation
10	Digital Skills Operation	Data Processing Document Editing Video Processing Data Analysis	34	Interdisciplinary Integration	Integrative Innovation Knowledge Integration
11	Problem-Solving Ability	Problem Analysis Digital Solution Design Problem Reasoning	35	Digital Environment Adaptability	Virtual Environment Navigation Platform Adaptation
12	Digital Innovation Capability	Creative Generation Content Creation Innovative Expression	36	Systematic Learning	Stage Planning Holistic Optimization
13	Digital Identity Recognition	Online Identity Awareness Digital Persona Management	37	Lifelong Learning Awareness	Continuous Learning Self-Renewal

14	Digital Ethics Awareness	Integrity Awareness∥Intellectual Property Awareness∥AI Ethics	38	Online Culture Cognition	Online Language Recognition∥Understanding Cultural Phenomena
15	Digital Safety Awareness	Cybersecurity∥Privacy Protection∥Data Protection	39	Digital Rights Protection	Rights Awareness∥Sharing Norms
16	Digital Behavioral Norms	Legal Resource Use∥Online Behavior Norms	40	Digital Citizenship Awareness	Public Participation∥Responsible Expression
17	Learning Motivation Enhancement	Learning Interest∥Learning Motivation∥Self-Directed Learning Motivation	41	Digital Emotional Management	Emotion Regulation∥Conflict Management
18	Learning Strategy Utilization	Task Planning∥Self-Regulation∥Learning Feedback	42	Data Ethics Awareness	Algorithmic Fairness∥Privacy Protection
19	Learning Adaptability	Adaptation to New Technology∥Continuous Learning	43	Digital Aesthetic Competence	Visual Design∥Interface Aesthetics
20	Instructional Interaction Participation	Classroom Interaction∥Peer Collaboration∥Teacher Communication	44	Technology Learning Transfer	Transfer of New Knowledge∥Cross-Task Application
21	Learning Performance Improvement	Learning Efficiency∥Outcome Transfer	45	Platform Recognition Ability	Platform Familiarity∥Selection Strategies
22	Information Integration Ability	Data Compilation∥Information Summarization∥Integrative Judgment	46	AI Tool Application	Chat GPT Utilization∥AI-Based Image Generation∥Intelligent Writing
23	Data Analytical Thinking	Data Statistics∥Result Interpretation∥Data-Based Decision Making	47	Element Integration and Innovation	Multimodal Information Integration∥Innovative Expression
24	Technical Operation Proficiency	Multi-Device Operation∥Platform Switching	48	Feedback and Iteration Awareness	Data-Driven Feedback Optimization∥Reflective Improvement

The resulting 48 preliminary categories comprehensively capture the core characteristics of undergraduate digital literacy, spanning cognition, behavior, competence, and ethics. These categories reflect four underlying dimensions: (1) Cognitive dimension, including awareness, understanding, evaluation, and digital thinking; (2) Behavioral dimension, encompassing information acquisition, digital communication, tool use, and resource application; (3) Competency dimension, covering knowledge mastery, skill application, creative production, and problem-solving; and (4) Ethical dimension, including digital identity, data ethics, rights awareness, and behavioral norms. Collectively, open coding reveals the dynamic development of undergraduate digital literacy from cognitive awareness to behavioral practice, competency formation, and ethical orientation, laying a systematic theoretical foundation for subsequent axial coding and the integrated construction of the comprehensive digital literacy framework.

Axial Coding: Integration of Primary Categories

The core objective of axial coding is to systematically compare and relate preliminary categories, uncover their intrinsic relationships, and integrate them into higher-order primary categories (Urcia, 2021). In this stage, the 48 preliminary categories derived from open coding were aggregated, analyzed for semantic connections, and examined for causal relationships to construct the core dimensions of undergraduate digital literacy. Axial coding extends beyond simple concept classification; it functions as a mechanism for theoretical linkage, employing the “conditions, interactions, and consequences” analytical framework to reveal the underlying logical structure among concepts (Rakhmawati, 2019).

The process involved the combined application of constant comparative analysis and semantic association analysis, assisted by NVivo 14 software, to assess semantic similarity, co-occurrence frequency, and contextual consistency among preliminary categories. Through iterative synthesis, the 48 preliminary categories were ultimately consolidated into 16 primary categories. This progression exemplifies the movement from empirical data to theoretical abstraction, consistent with grounded theory’s inductive “bottom-up” logic for theory generation (Lindqvist & Forsberg, 2023). For instance, preliminary categories such as information awareness, technological understanding, and data comprehension were integrated into the Digital Cognition primary category, constituting a core element of the Digital Transformation dimension. Similarly, categories such as information selection, resource retrieval, and multimodal communication demonstrated overlapping functional characteristics and were aggregated under the Digital Use dimension, encompassing subcategories like digital acquisition and digital communication. Comparative analysis of the intrinsic relationships among categories further delineated cognitive transformation pathways, including digital cognition, digital thinking, digital understanding, and digital evaluation, as well as practical usage pathways, including digital acquisition, digital selection, digital communication, and digital application. Collectively, axial coding transformed 48 preliminary categories into 16 coherent primary categories, establishing a structured network of undergraduate digital literacy dimensions (Table 3).

Table 3
Correspondence between Initial Subcategories and Main Categories

Serial Number	Main Category	Subcategory
1	Digital Cognition	Digital Awareness Formation∥Digital Environment Cognition∥Digital Information Comprehension
2	Digital Thinking	Logical Thinking Structure∥Critical Analysis∥Systematic Thinking
3	Digital Understanding	Information Filtering∥Concept Differentiation∥Semantic Understanding
4	Digital Evaluation	Information Credibility Assessment∥Source Evaluation∥Outcome Reflection
5	Digital Acquisition	Information Retrieval∥Multi-source Search∥Data Access
6	Digital Selection	Content Selection∥Resource Comparison∥Tool Matching
7	Digital Communication	Online Communication∥Collaborative Expression∥Cross-platform Interaction
8	Digital Application	Tool Utilization∥Resource Integration∥Knowledge Transfer
9	Digital Knowledge	Information Organization∥Technical Comprehension∥Operational Knowledge
10	Digital Skills	Software Skills∥Data Analysis∥Content Editing
11	Problem Solving	Problem Identification∥Solution Design∥Strategy Implementation
12	Digital Creation	Innovative Thinking∥Creative Expression∥Output Publication
13	Digital Identity	Account Management∥Privacy Protection∥Identity Recognition
14	Digital Ethics	Cyber Ethics∥Ethical Judgment∥Value Alignment
15	Digital Rights	Copyright Awareness∥Data Ownership∥Digital Equity
16	Behavioral Norms	Self-discipline Awareness∥Civil Expression∥Responsible Behavior

Selective Coding: Determining Core Categories

In grounded theory research, selective coding represents the critical stage that transitions empirical data into theoretical construction. Its purpose is not merely to summarize existing categories but to integrate the results of axial coding, identifying core categories capable of encompassing various concepts and explaining the overall structure of the phenomenon under investigation (Urcia, 2021). Following open and axial coding, this study entered the theoretical refinement phase, conducting continuous comparison and longitudinal backtracking across literature to reveal the intrinsic relationships among primary categories and their underlying generative logic.

1. Identification and Theoretical Focus of Core Categories

In the previous axial coding stage, preliminary primary categories were established, including technical operations and cognition, information evaluation and security, creative application and innovation awareness, ethical values and responsibility, and social interaction and collaborative ability. At this stage, rather than examining these categories in isolation, the focus shifted to analyzing their interactions and the overarching theoretical focus they collectively signify. Comparative analysis of textual references to “competence,” “literacy,” “value,” and “responsibility” revealed that these categories are not merely parallel constructs but converge toward a higher-order theme: how undergraduates, situated in digitally mediated environments, achieve progressive development from technical adaptation to skill growth and ultimately value internalization through reflective practice. Accordingly, the study identified the “Mechanisms of Undergraduate Digital Literacy Development in Digital Technology Contexts” as the core category. This core category encompasses not only technical proficiency but also the conception of digital literacy as a contextually generated, practice-based educational value. Theoretical stability of this core category was verified through supplementary literature sampling, yielding no new concepts or relationships, indicating theoretical saturation.

2. Integration of Subcategories and Construction of Generative Pathways

A key task in selective coding is clarifying how subcategories relate to the core category, forming an explanatory structure. Analysis revealed that undergraduate digital literacy development is non-linear, unfolding along several interwoven pathways:

(1) From Technical Cognition to Practical Adaptation – emphasizes the transition from operational familiarity to reflective understanding and rational use of digital technologies.

(2) From Information Judgment to Value Internalization – highlights the symbiotic relationship among information evaluation, security awareness, and ethical reasoning, demonstrating the progression from competence to value-driven literacy.

(3) From Innovative Application to Social Collaboration – captures the externalized form of digital literacy in real-world contexts, emphasizing collaboration, civic engagement, and creative practice.

These pathways are interconnected under the core category, forming a dynamic evolutionary whole that represents the progression from “responding to technology” to “understanding technology” and ultimately to “leveraging technology for personal and societal development.”

3. Emergence of a Preliminary Framework

Building on the core category and its pathways, a preliminary theoretical framework was developed, conceptualizing undergraduate digital literacy across three interrelated levels: external drivers, internal regulation, and outcome manifestation. The external drivers include the digital technology environment, higher education digital policies, and availability of learning resources, providing contextual conditions and pressures for literacy development. The internal regulation level mediates through cognitive structures, learning motivation, and value orientation, shaping students’ understanding and engagement with digital technologies. The outcome level reflects the integrated manifestation of creative application, social collaboration, and ethical responsibility, capturing the transformation of potential literacy into actualized competence. Continuous comparative analysis and theoretical saturation checks confirmed the framework’s clarity in illustrating conditions, subcategory relations, and evolutionary logic, addressing previous limitations of digital literacy research that overemphasized skill lists while neglecting generative mechanisms.

4. Theoretical Implications and Category Integration

The finalized core category demonstrates a theoretical shift from “technical competence” to “educational value.” Within digitally pervasive learning environments, undergraduate digital literacy is no longer limited to tool proficiency; it constitutes a composite structure integrating

technological understanding, cognitive regulation, innovative practice, and ethical reasoning (Zhou et al., 2025). This aligns with UNESCO’s digital competency perspective emphasizing sustainable development, critical application, and social responsibility, providing empirical guidance for localized digital literacy frameworks in higher education. Applying Strauss and Corbin’s (1998) conditions-relations model, four principal relationships were identified: causal conditions, contextual conditions, interaction strategies, and outcome variables. These relationships form a progressive chain from cognitive comprehension to behavioral practice, culminating in ethical elevation. Accordingly, the 16 primary categories derived from axial coding were integrated into four overarching dimensions: Digital Transformation Literacy, Digital Use Literacy, Digital Competency Literacy, and Digital Safety Literacy (Table 4). This structure elucidates the generative mechanisms and developmental pathways of undergraduate digital literacy, highlighting its nature as a holistic educational competence encompassing cognition, skill, and value dimensions.

Table 4
Correspondence between Core Category and Main Categories

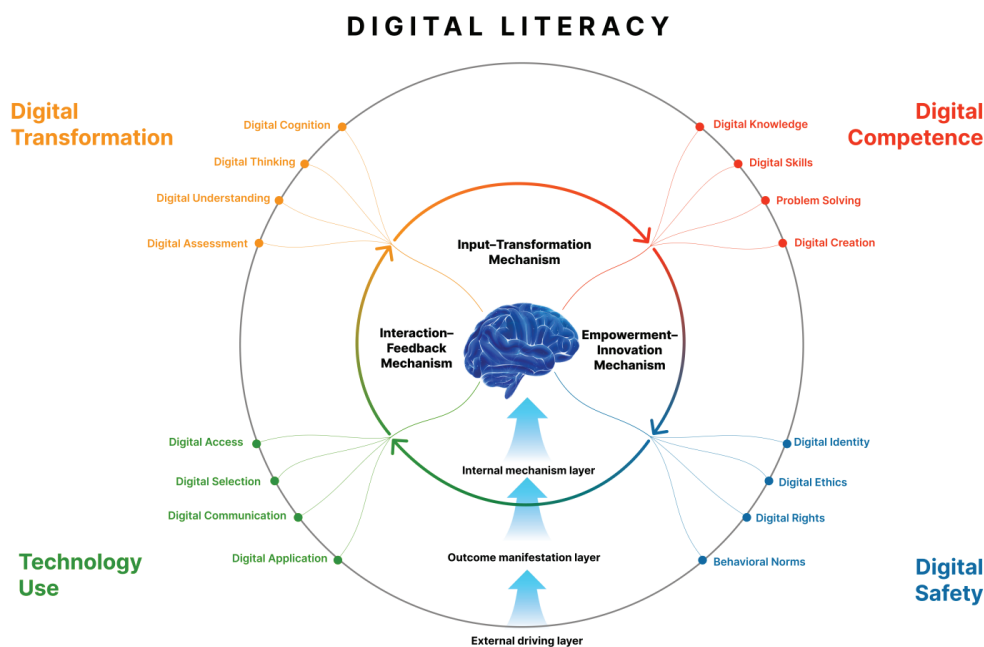
Core Category	Main Category
Digital Literacy	Digital Cognition
	Digital Thinking
	Digital Understanding
	Digital Evaluation
	Digital Acquisition
	Digital Selection
	Digital Communication
	Digital Application
	Digital Knowledge
	Digital Skills
	Problem Solving
	Digital Creation
	Digital Identity
	Digital Ethics
	Digital Rights
	Behavioral Norms

Proposed Framework of Undergraduate Digital Literacy

The theoretical understanding of digital literacy has evolved from focusing primarily on technical operational skills to encompassing critical comprehension and social participation competencies. Early information literacy models and frameworks such as the European Digital Competence Framework (DigComp) primarily emphasized functional dimensions, including information acquisition, technology use, and problem-solving, while paying limited attention to learners' value judgment and contextual adaptability. In contemporary higher education, where digital technologies are deeply embedded in teaching and learning, undergraduate digital literacy exhibits new structural characteristics: first, technical understanding has shifted from mere tool operation to cognitive awareness of intelligent systems' logic and human-computer interaction; second, learner agency is markedly enhanced, with digital technologies serving as key enablers of autonomous learning and creative practice; third, value reasoning and ethical awareness are increasingly prominent, with digital behavior guided by social responsibility and public value considerations. Building on these theoretical shifts and the categorical structures derived from open, axial, and selective coding, this study proposes a comprehensive framework of undergraduate digital literacy (Figure 3), with the generative mechanisms of digital literacy as the analytical core. The framework systematically represents the overall developmental trajectory of undergraduate digital literacy within digitally mediated learning ecosystems, spanning cognitive comprehension, skill construction, and value internalization.

Figure 3

Digital literacy Framework for University Students



1. Structural Dimensions of Undergraduate Digital Literacy

Integration of categories resulted in a framework consisting of four interrelated primary dimensions: Digital Transformation Literacy, Digital Use Literacy, Digital Competency Literacy, and Digital Safety Literacy, encompassing 16 secondary categories. Digital Transformation Literacy forms the foundational layer, reflecting students' cognitive processing

and transformation of digital information, including digital cognition, digital thinking, digital understanding, and digital evaluation. This dimension highlights the progression from perceiving digital information to forming judgment and reflective thinking, underscoring that digital literacy is not passive technical reception but a structured, higher-order cognitive process. Digital Use Literacy addresses the practical application of digital tools and resources in specific contexts, encompassing digital acquisition, selection, communication, and application. It emphasizes context-driven and purposeful use, illustrating students' capacity to embed digital technologies into learning, daily life, and social interactions, thereby translating cognition into action. Digital Competency Literacy refers to integrative abilities for problem-solving, knowledge construction, and innovative practice in digital environments, including digital knowledge, technical skills, problem-solving, and digital creation. This dimension captures the core functional capacity of digital literacy, supporting enhanced learning performance and innovative development. Digital Safety Literacy defines the boundary of digital literacy from value and normative perspectives, encompassing digital identity, ethics, rights, and behavioral norms. It highlights students' conscious recognition of security, responsibility, and ethical conduct, reflecting the social and public value dimensions of digital literacy. These four dimensions are interdependent, forming a progressive structure across cognitive comprehension, practical application, and value orientation, representing the holistic composition of undergraduate digital literacy.

2. Three-Tier Generative Structure

From the perspective of generative mechanisms, the framework is structured into three interconnected layers: external drivers, internal mechanisms, and outcome manifestations. (a) The external driver layer comprises the digital technology environment, higher education policy orientation, learning resources, and campus culture, providing contextual conditions and practical incentives. Intelligent learning platforms, AI-assisted tools, and data analytics systems facilitate frequent interaction and personalized learning; policy frameworks integrate digital competencies into core higher education objectives; infrastructure and innovation-oriented culture subtly shape students' digital behavior patterns. (b) The internal mechanism layer represents the core of digital literacy generation, encompassing four interacting subsystems: technological cognition, information ethics, innovation awareness, and social collaboration. Technological cognition underpins understanding and use of digital tools; information ethics reflects value judgment and responsibility; innovation awareness drives problem-solving and creative expression; social collaboration represents students' knowledge co-construction and social innovation in hybrid learning spaces. These dimensions interact continuously via cognitive regulation and contextual adaptation, forming intrinsic drivers of digital literacy development. (c) The outcome manifestation layer represents the practical and societal expression of digital literacy, manifested in creative outputs, learning transfer, and social value realization. This layer illustrates the transformation of potential competencies into observable practices, highlighting the sustainable development of digital literacy within digitally empowered learning ecosystems.

3. Operational Mechanisms and Theoretical Contributions

The operational mechanism of undergraduate digital literacy can be summarized as three interrelated processes: (a) Input–Transformation – external drivers (policy, technology, culture) are mediated through internal cognitive and value mechanisms to generate initial digital competencies. (b) Interaction–Feedback – continuous engagement with digital systems provides immediate feedback, facilitating dynamic enhancement of technical understanding, information judgment, and innovation awareness. (c) Empowerment–Innovation – digital literacy is ultimately transformed into enhanced learning performance, innovative outcomes, and social responsibility, representing a transition from technical adaptation to self-empowerment.

This framework conceptualizes undergraduate digital literacy as a dynamic, contextually and cognitively mediated system rather than a static aggregation of discrete skills. Theoretically, the study advances three dimensions: (a) integrating digitally mediated learning ecosystems,

moving beyond tool-centric paradigms; (b) employing a grounded-theory-based three-tier structure (external drivers–internal mechanisms–outcomes), elucidating generative logic; (c) emphasizing value orientation and social responsibility, aligning with higher education's shift from technical rationality to human-centered pedagogy. Practically, the framework provides guidance for curriculum design, digital tool integration, and faculty professional development, facilitating systematic and sustainable cultivation of undergraduate digital literacy.

Building on a systematic grounded-theory approach, this study modeled the conceptualization and structural formation of undergraduate digital literacy. Through sequential open, axial, and selective coding of high-quality literature, the analysis progressively abstracted initial concepts into core categories, ultimately constructing a structural framework comprising four primary dimensions and sixteen main subcategories. The findings indicate that undergraduate digital literacy is not merely a collection of technical skills. Rather, it constitutes a complex, dynamically generated competence system within digitally empowered learning contexts, where Digital Transformation, Digital Use, Digital Competency, and Digital Safety interact synergistically to shape comprehensive literacy. Further theoretical integration elucidates a three-tier generative logic: the external driver layer provides technological, policy, and contextual support; the internal mechanism layer facilitates competence development through cognitive regulation, value internalization, and innovation awareness; and the outcome layer manifests as learning transfer, creative application, and social responsibility. This framework transcends traditional tool-centric perspectives of digital literacy research, highlighting the interconnections among cognitive deepening, practical engagement, and ethical awareness. The proposed framework provides a robust theoretical foundation for the development of assessment instruments and educational interventions, while offering universities a clear structural reference and practical guidance for systematically cultivating students' digital competencies and holistic literacy in digitally mediated learning environments.

Discussion

Drawing on a literature-grounded theory approach, this study constructs an analytical framework for undergraduate digital literacy situated within digitally mediated societies. Rather than organizing digital literacy around predefined competency lists or modular skill taxonomies, the framework is inductively derived from high-quality international literature through systematic coding procedures. Through successive stages of open, axial, and selective coding, four core domains are identified and integrated into a coherent conceptual structure: digital transformation, digital use, digital competence, and digital safety. This coding-driven analytical process clarifies not only the internal composition of undergraduate digital literacy but also the mechanisms through which it emerges, develops, and is sustained over time. In doing so, the framework addresses a persistent theoretical limitation in digital literacy research, namely the fragmentation of conceptual dimensions and the lack of explanatory coherence, and advances an understanding of digital literacy as a dynamic and generative educational process rather than a static aggregation of discrete abilities. From a theoretical standpoint, a central contribution of this study lies in situating undergraduate digital literacy within a digitally empowered learning ecosystem. Digital literacy is conceptualized as an evolving system shaped by the interaction between external conditions, internal learning mechanisms, and educational outcomes. This perspective departs from tool-centered and function-oriented paradigms by foregrounding learners' agency, adaptive capacity, and processes of self-empowerment in digitally mediated environments. Importantly, value rationality and ethical orientation are incorporated as constitutive dimensions of digital literacy rather than supplementary considerations. Digital safety, ethical responsibility, and rights awareness are positioned as integral to competence development, responding to a widely acknowledged tension in higher

education between the rapid advancement of digital technologies and the comparatively slower development of normative and ethical guidance. Accordingly, undergraduate digital literacy is framed as a comprehensive form of literacy encompassing cognition, capability, practice, and responsibility.

Although the framework is derived from international literature, its characterization as “international” does not imply cultural uniformity or normative standardization. Instead, its international applicability resides in its structural logic and generative orientation. By conceptualizing digital literacy as a dynamic system composed of external drivers, internal mechanisms, and outcome manifestations, the framework analytically distinguishes between structurally robust dimensions and context-sensitive expressions. This distinction enables the framework to maintain theoretical stability across diverse cultural and institutional settings while allowing flexible interpretation and localized implementation. At the structural level, the four core domains reflect challenges commonly faced by higher education systems worldwide, including technological transformation, pedagogical digitalization, competence formation, and ethical governance. These domains correspond to recurrent concerns identified across different educational systems, indicating a substantial degree of cross-cultural robustness. At the same time, the framework explicitly acknowledges that the interpretation, prioritization, and operationalization of digital literacy are shaped by sociocultural norms, institutional arrangements, and policy environments. Variations in the emphasis placed on digital safety, ethical responsibility, or rights awareness are therefore understood not as limitations of the framework but as contextually grounded expressions within a stable conceptual structure. This capacity to accommodate contextual sensitivity while preserving theoretical coherence constitutes a core strength of the framework and enhances its adaptability across national and cultural contexts. From a practical perspective, the framework provides an operational theoretical reference for curriculum design, competence assessment, and educational intervention in higher education. By differentiating domains and developmental pathways of digital literacy, institutions are better positioned to articulate progressive learning objectives and coherent instructional strategies. This approach helps to avoid an overreliance on short-term tool training or fragmented skill instruction and instead supports the systematic and sustained development of students’ digital literacy across the undergraduate curriculum.

In comparison with existing international frameworks, DigComp 2.1 conceptualizes citizens’ digital competence across five domains—information and data literacy, communication and collaboration, digital content creation, safety, and problem solving—with a strong emphasis on proficiency levels and competence progression (Carretero et al., 2017). DigCompEdu, developed from a teacher professional development perspective, foregrounds instructional practice, assessment, and learner empowerment (Redecker, 2017). While both frameworks have exerted substantial international influence, they primarily adopt functional and checklist-oriented approaches to competence classification. By contrast, the framework proposed in this study addresses a key explanatory limitation of these models by focusing on how digital competencies are activated, internalized, and translated into educational practice. Through a grounded analytical process, cognition, application, competence development, and ethical orientation are organized into a progressive and interrelated structure, thereby shifting attention from the possession of competencies to the processes through which digital literacy is formed and enacted. Recent research has further noted that DigComp-based applications in higher education may be overly tool-oriented and insufficiently inclusive of ethical and contextual dimensions (Abubakari et al., 2025). By systematically integrating digital ethics, rights awareness, and behavioral norms into its core domains, the present framework responds directly to these critiques and extends the value dimension of digital literacy research.

Similarly, the UNESCO Institute for Statistics’ Digital Learner Global Framework (DLGF), derived from DigComp 2.0, emphasizes performance in information processing,

communication, content creation, safety, and problem solving and plays an important role in international benchmarking for the Sustainable Development Goals (Law et al., 2018). While DLGF offers substantial macro-policy relevance, its primary function lies in assessment and benchmarking rather than in explaining learning processes at the micro-educational level. The present study complements this limitation by providing a theoretically grounded account of how digital literacy evolves within specific learning ecologies. Beyond employability and civic participation, the framework foregrounds learning transfer, creative practice, and social responsibility, thereby extending the educational value attributed to digital literacy. By explicitly recognizing the influence of policy environments, technological conditions, and institutional resources, the framework also offers conceptual guidance for contextualizing global digital literacy standards within national and institutional settings.

Recent international scholarship reflects a broader shift from skill-based models toward more holistic and integrative conceptions of digital literacy in higher education (Zhao et al., 2021). Although dimensions such as critical thinking, creativity, and ethical awareness are increasingly emphasized, many existing models remain at the level of dimensional aggregation and provide limited explanatory depth. Studies have highlighted the close relationship between digital literacy and self-regulated learning, underscoring the role of reflective and metacognitive processes in higher-order digital competence (Anthonysamy et al., 2020), while emerging research has identified human–AI collaboration as an expanding dimension of digital literacy (Benvenuti et al., 2023). Distinct from approaches that extend predefined frameworks, the present study adopts a bottom-up, literature-grounded strategy to generate conceptual categories. By integrating external drivers, internal mechanisms, and outcome manifestations into a coherent analytical structure, the framework offers a systematic explanation of how undergraduate digital literacy operates in authentic educational contexts. Emerging technologies, including artificial intelligence, are thus treated not merely as instructional tools but as contextual conditions shaping cognition, value judgment, and social responsibility. Collectively, these features demonstrate the methodological and theoretical value of a literature-grounded theory approach and provide a replicable analytical paradigm for future cross-cultural research on digital literacy in higher education.

Conclusions and Implications

This study employed a literature-grounded approach to systematically construct a theoretical framework for undergraduate digital literacy within digitally mediated societies. The findings indicate that digital literacy has evolved beyond instrumental skills such as information retrieval or technical operation, developing instead into a multi-layered, composite competence encompassing cognitive transformation, practical application, capability development, and ethical regulation. Specifically, Digital Transformation captures the processes by which students reinterpret technologies and information, reconstructing cognitive structures and thought patterns; Digital Use reflects the contextualized application of digital technologies in learning, communication, and task completion; Digital Competency emphasizes higher-order abilities, including knowledge integration, problem solving, and innovative practice; and Digital Safety addresses digital identity, ethical responsibility, and behavioral norms, responding to the demands of individual sustainability and public accountability in the digital society. These four dimensions are structurally interconnected and functionally progressive, collectively forming the comprehensive profile of undergraduate digital literacy.

At the theoretical level, the study overcomes the limitations of prior digital literacy research, which often suffered from conceptual fragmentation and juxtaposed frameworks, revealing the internal logic through which digital literacy evolves from technical adaptation to cognitive transformation, value internalization, and innovative empowerment. Compared with

existing frameworks based on competency checklists or performance indicators, the proposed model emphasizes the generative mechanisms and developmental pathways of digital literacy, highlighting the critical role of individual cognitive regulation, contextual interaction, and ethical constraints in the formation of digital competencies. This perspective offers a novel lens for understanding the dynamic characteristics of digital literacy in digitally mediated educational contexts. From a practical standpoint, the framework provides direct implications for higher education. It offers a structured reference for designing digital literacy curricula and developmental objectives. At the curricular level, instruction should shift from isolated technical training toward the integrated cultivation of cognitive understanding, practical application, and ethical reflection. At the instructional level, project-based learning, authentic problem-solving scenarios, and human–technology collaborative tasks can promote the generation and internalization of digital competencies. At the assessment level, the framework supports a transition from purely operational metrics toward process-oriented and developmental evaluation, aligning evaluation practices with the dynamic and integrative nature of digital literacy. Furthermore, the framework can guide higher education institutions in integrating digital learning tools and enhancing faculty digital pedagogical competence, providing a clear theoretical foundation for systemic development.

Nevertheless, the study has limitations. First, the framework is derived primarily from high-quality literature, and its structure has not yet been empirically validated. Second, variations in technological infrastructure, educational systems, and cultural contexts across countries and regions may affect the framework’s applicability. Future research could extend this framework by employing survey instruments, interviews, or structural equation modeling to examine structural validity and cross-context applicability, as well as exploring practical implementation across different disciplines and educational levels.

Suggestions

Based on the systematic analysis of the structural composition and generative mechanisms of undergraduate digital literacy, higher education institutions are encouraged to enhance digital literacy education through targeted curriculum design and concrete instructional implementation. Rather than treating digital literacy as an isolated skill set, curriculum planning should align with the developmental logic of the proposed framework and translate its core domains into explicit learning experiences. First, digital literacy curricula should be organized according to a progressive competency structure that corresponds to the four core domains of the framework: digital transformation, digital use, digital competence, and digital safety. At the foundational level, general education courses can emphasize digital transformation by introducing students to the social, cultural, and technological implications of digitalization, such as datafication, algorithmic governance, and artificial intelligence in everyday life. At the intermediate level, disciplinary courses can focus on digital use and digital competence by embedding domain-specific digital tools, data analysis methods, and problem-solving tasks into subject learning. For example, students in social sciences may engage in data visualization and digital research projects, while engineering or design students may apply AI-assisted tools to address authentic professional problems. At the advanced level, capstone courses or integrative modules should foreground digital safety by explicitly addressing ethical reasoning, data privacy, academic integrity, and responsible technology use through case analysis and reflective assessment. Second, pedagogical strategies should prioritize task-driven and context-rich learning activities that promote the internalization and transfer of digital competencies. Project-based learning, scenario simulation, and inquiry-oriented tasks can be systematically incorporated to connect digital skills with real-world problem contexts. For instance, students may be asked to complete an AI-generated content (AIGC) project that requires not only

technical production but also critical evaluation of algorithmic bias, authorship, and ethical responsibility. Assessment in such tasks should move beyond technical performance to include reflective reports or learning portfolios that document students' decision-making processes and value judgments. These approaches help prevent superficial or passive technology use and support the development of higher-order digital literacy. Third, the sustainable development of digital literacy requires supportive institutional learning ecosystems. Universities should strengthen faculty development programs focused on digital pedagogy, enabling instructors to design meaningful digital learning tasks and guide students' reflective engagement with technology. At the institutional level, digital platforms, learning analytics systems, and interdisciplinary teaching teams can be leveraged to support continuous practice and feedback. In addition, incentive mechanisms and normative guidance should be established to foster responsible and self-directed digital learning behaviors, encouraging students to view digital tools as resources for learning enhancement rather than mere efficiency instruments.

Overall, digital literacy education should be systematically embedded within higher education talent cultivation frameworks through coordinated optimization of curriculum structure, instructional strategies, and learning environments. By translating the conceptual framework into concrete curricular practices and pedagogical actions, institutions can better support the integrated development of digital competence and ethical responsibility, preparing university students to navigate and contribute meaningfully to digitally mediated societies.

Declaration of Interest

The authors declare no competing interests.

References

- Abubakari, M. S., Zakaria, G. A., & Musa, J. (2025). Validating the DIGCOMP framework among university students across different educational systems. *Discover Education*, 4, Article 200. <https://doi.org/10.1007/s44217-025-00652-x>
- Anthonyamy, L., Koo, A. C., & Hew, S. H. (2020). Self-regulated learning strategies in higher education: Fostering digital literacy for sustainable lifelong learning. *Education and Information Technologies*, 25(4), 2393–2414. <https://doi.org/10.1007/s10639-020-10201-8>
- Baber, H., Fanea-Ivanovici, M., Lee, Y.-T., & Tinmaz, H. (2022). A bibliometric analysis of digital literacy research and emerging themes pre-during COVID-19 pandemic. *Information and Learning Sciences*, 123(3/4), 214–232. <https://doi.org/10.1108/ils-10-2021-0090>
- Basilotta-Gómez-Pablos, V., Matarranz, M., Casado-Aranda, L.-A., & Otto, A. (2022). Teachers' digital competencies in higher education: A systematic literature review. *International Journal of Educational Technology in Higher Education*, 19, Article 8. <https://doi.org/10.1186/s41239-021-00312-8>
- Benvenuti, M., Cangelosi, A., Weinberger, A., Mazzoni, E., Benassi, M., Barbaresi, M., & Orsoni, M. (2023). Artificial intelligence and human behavioral development: A perspective on new skills and competences acquisition for the educational context. *Computers in Human Behavior*, 148, Article 107903. <https://doi.org/10.1016/j.chb.2023.107903>
- Carretero, S., Vuorikari, R., & Punie, Y. (2017). *DigComp 2.1: The digital competence framework for citizens with eight proficiency levels and examples of use*. Publications office of the european union. <https://data.europa.eu/doi/10.2760/38842>
- Carlin, A. P., & Kim, Y. H. (2019). Teaching qualitative research: Versions of grounded theory. *Grounded Theory Review*, 18(01), 29–43. <https://groundedtheoryreview.org/index.php/gtr/article/view/296>
- Charmaz, K. (2017). Constructivist grounded theory. *The Journal of Positive Psychology*, 12(3), 299–300. <https://doi.org/10.1080/17439760.2016.1262612>
- Chen, F. (2025). The relationship between digital literacy and college students' academic achievement: The chain mediating role of learning adaptation and online self-regulated learning. *Frontiers in Psychology*, 16, Article 1590649. <https://doi.org/10.3389/fpsyg.2025.1590649>

- Chiu, T. K., Ahmad, Z., Ismailov, M., & Sanusi, I. T. (2024). What are artificial intelligence literacy and competency? A comprehensive framework to support them. *Computers and Education Open*, 6, Article 100171. <https://doi.org/10.1016/j.caeo.2024.100171>
- Connor, J., Flenady, T., Dwyer, T., & Massey, D. (2023). Application of classic grounded theory in nursing studies: A qualitative systematic review protocol. *BMJ Open*, 13(7), Article e068588. <https://doi.org/10.1136/bmjopen-2022-068588>
- Cutcliffe, J. R. (2000). Methodological issues in grounded theory. *Journal of Advanced Nursing*, 31(6), 1476–1484. <https://doi.org/10.1046/j.1365-2648.2000.01430.x>
- Demeshkant, N., Trusz, S., & Potyrała, K. (2022). Interrelationship between levels of digital competences and technological, pedagogical and content knowledge (TPACK): A preliminary study with polish academic teachers. *Technology, Pedagogy and Education*, 31(5), 579–595. <https://doi.org/10.1080/1475939x.2022.2092547>
- Dunne, C. (2011). The place of the literature review in grounded theory research. *International Journal of Social Research Methodology*, 14(2), 111–124. <https://doi.org/10.1080/13645579.2010.494930>
- Eshet-Alkalai, Y., & Chajut, E. (2010). You can teach old dogs new tricks: The factors that affect changes over time in digital literacy. *Journal of Information Technology Education: Research*, 9(1), 173–181. <https://doi.org/10.28945/1186>
- Eshet, Y. (2012). Thinking in the digital era: A revised model for digital literacy. *Issues in Informing Science and Information Technology*, 9(2), 267–276. <https://doi.org/10.28945/1621>
- Falloon, G. (2020). From digital literacy to digital competence: The teacher digital competency (TDC) framework. *Educational Technology Research and Development*, 68(5), 2449–2472. <https://doi.org/10.1007/s11423-020-09767-4>
- Farias-Gaytan, S., Aguaded, I., & Ramirez-Montoya, M. S. (2023). Digital transformation and digital literacy in the context of complexity within higher education institutions: A systematic literature review. *Humanities and Social Sciences Communications*, 10, Article 386. <https://doi.org/10.1057/s41599-023-01875-9>
- Feerrar, J. (2019). Development of a framework for digital literacy. *Reference Services Review*, 47(2), 91–105. <https://doi.org/10.1108/rsr-01-2019-0002>
- Ferrari, A., Punie, Y., & Bre, B. N. (2013). *DIGCOMP: A framework for developing and understanding digital competence in Europe*. <https://data.europa.eu/doi/10.2788/52966>
- Fleiss, J. L., Nee, J. C., & Landis, J. R. (1979). Large sample variance of kappa in the case of different sets of raters. *Psychological Bulletin*, 86(5), 974–977. <https://doi.org/10.1037/0033-2909.86.5.974>
- Gkrimpizi, T., Peristeras, V., & Magnisalis, I. (2023). Classification of barriers to digital transformation in higher education institutions: Systematic literature review. *Education Sciences*, 13(7), Article 746. <https://doi.org/10.3390/educsci13070746>
- Gutiérrez-Ángel, N., Sánchez-García, J. N., Mercader-Rubio, I., García-Martín, J., & Brito-Costa, S. (2022). Digital literacy in the university setting: A literature review of empirical studies between 2010 and 2021. *Frontiers in Psychology*, 13, Article 896800. <https://doi.org/10.3389/fpsyg.2022.896800>
- Hammoda, B., & Foli, S. (2024). A digital competence framework for learners (DCFL): A conceptual framework for digital literacy. *Knowledge Management & E-Learning*, 16(3), 477–500. <https://doi.org/10.34105/j.kmel.2024.16.022>
- Heath, H., & Cowley, S. (2004). Developing a grounded theory approach: a comparison of Glaser and Strauss. *International Journal of Nursing Studies*, 41(2), 141–150. [https://doi.org/10.1016/s0020-7489\(03\)00113-5](https://doi.org/10.1016/s0020-7489(03)00113-5)
- Kaplan, O., & Kara, T. M. (2025). The effect of digital technology integration on students' creative thinking skills: Pisa evidence using propensity score matching. *Problems of Education in the 21st Century*, 83(3), 403–423. <https://doi.org/10.33225/pec/25.83.403>
- Karakuş, İ., & Kılıç, F. (2022). 'Digital' overview at the profiles of pre-service teachers: Digital awareness, competence and fluency. *Problems of Education in the 21st Century*, 80(2), 324–338. <https://doi.org/10.33225/pec/22.80.324>
- Karchmer, R. A. (2001). The journey ahead: Thirteen teachers report how the Internet influences literacy and literacy instruction in their K-12 classrooms. *Reading Research Quarterly*, 36(4), 442–466. <https://doi.org/10.1598/RRQ.36.4.5>

- Koltay, T. (2011). The media and the literacies: Media literacy, information literacy, digital literacy. *Media, Culture & Society*, 33(2), 211–221. <https://doi.org/10.1177/0163443710393382>
- Kuzu, Ç. I., & Kayabasi, K. E. (2025). Determining the digital literacy levels of mathematics pre-service teachers. *Problems of Education in the 21st Century*, 83(4), 563–578. <https://doi.org/10.33225/pec/25.83.563>
- Law, N., Woo, D., Torre, J. D. L., & Wong, G. (2018). *A global framework of reference on digital literacy skills for indicator 4.4.2*. UNESCO Institute for Statistics. <http://www.uis.unesco.org>
- List, A. (2019). Defining digital literacy development: An examination of pre-service teachers' beliefs. *Computers & Education*, 138, 146–158. <https://doi.org/10.1016/j.compedu.2019.03.009>
- Li, F., Cheng, L., Wang, X., Shen, L., Ma, Y., & Islam, A. Y. M. (2025). The causal relationship between digital literacy and students' academic achievement: a meta-analysis. *Humanities and Social Sciences Communications*, 12, Article 108. <https://doi.org/10.1057/s41599-025-04399-6>
- Lindqvist, H., & Forsberg, C. (2023). Constructivist grounded theory and educational research: Constructing theories about teachers' work when analysing relationships between codes. *International Journal of Research & Method in Education*, 46(2), 200–210. <https://doi.org/10.1080/1743727X.2022.2095998>
- Mohammadyari, S., & Singh, H. (2015). Understanding the effect of e-learning on individual performance: The role of digital literacy. *Computers & Education*, 82, 11–25. <https://doi.org/10.1016/j.compedu.2014.10.025>
- Morgan, A., Sibson, R., & Jackson, D. (2022). Digital demand and digital deficit: Conceptualising digital literacy and gauging proficiency among higher education students. *Journal of Higher Education Policy and Management*, 44(3), 258–275. <https://doi.org/10.1080/1360080X.2022.2030275>
- Nathaniel, A. K. (2022). When and how to use extant literature in classic grounded theory. *Grounded Theory Review*, 21(02), 33–48. <https://groundedtheoryreview.org/index.php/gtr/article/view/417>
- Niasse, N. (2022). Dealing with literature review and epistemological underpinnings in grounded theory methodology. *International Journal of Qualitative Research*, 2(2), 159–164. <https://doi.org/10.47540/ijqr.v2i2.683>
- Na, M., Lee, S. S. J., Md Noor, H., Fu, J. Q., & Ying, W. (2024). A pre-service art teacher digital literacy framework for digital literacy in pre-service art teacher education in china. *Asian Journal of University Education (AJUE)*, 20(2), 235–247. <https://ajue.uitm.edu.my/>
- Öncül, G. (2021). Defining the need: digital literacy skills for first-year university students. *Journal of Applied Research in Higher Education*, 13(4), 925–943. <https://doi.org/10.1108/JARHE-06-2020-0179>
- Pan, L., Haq, S. U., Shi, X., & Nadeem, M. (2024). The impact of digital competence and personal innovativeness on the learning behavior of students: Exploring the moderating role of digitalization in higher education quality. *Sage Open*, 14(3), 1–19. <https://doi.org/10.1177/21582440241265919>
- Pangrazio, L. (2016). Reconceptualising critical digital literacy. *Discourse: Studies in the Cultural Politics of Education*, 37(2), 163–174. <https://doi.org/10.1080/01596306.2014.942836>
- Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., ... & Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ*, 372, Article n71. <http://dx.doi.org/10.1136/bmj.n71>
- Pool, C. R. (1997). A new digital literacy: A conversation with paul gilster. *Educational Leadership*, 55(3), 6–11. <http://www.discovery.com/area/travel/travel.htm>
- Tavakol, M., Torabi, S., & Akbar Zeinaloo, A. (2006). Grounded theory in medical education research. *Medical Education Online*, 11(1), Article 4607. <https://doi.org/10.3402/meo.v11i.4607>
- Taib, A., Awang, Y., Mohamed Shuhidan, S., Zainal Zakaria, Z. N., Sri Sulistyowati, S. S., & Luluk Muhimatul Ifada, L. M. I. (2023). Digitalization of the accounting profession: An assessment of digital competencies in a Malaysian comprehensive university. *Asian Journal of University Education (AJUE)*, 19(2), 365–380. <https://ajue.uitm.edu.my>
- Tinmaz, H., Lee, Y. T., Fanea-Ivanovici, M., & Baber, H. (2022). A systematic review on digital literacy. *Smart Learning Environments*, 9, Article 21. <https://doi.org/10.1186/s40561-022-00204-y>
- Trilling, B., & Fadel, C. (2012). Tactics for success. *RSA Journal*, 158(5550), 10–15. <https://www.jstor.org/stable/26204110>

- Van Audenhove, L., Vermeire, L., Van den Broeck, W., & Demeulenaere, A. (2024). Data literacy in the new EU DigComp 2.2 framework how DigComp defines competences on artificial intelligence, internet of things and data. *Information and Learning Sciences*, 125(5-6), 406–436. <https://doi.org/10.1108/ILS-06-2023-0072>
- Urcia, I. A. (2021). Comparisons of adaptations in grounded theory and phenomenology: Selecting the specific qualitative research methodology. *International Journal of Qualitative Methods*, 20, 406–436. <https://doi.org/10.1177/16094069211045474>
- Urquhart, C., & Fernández, W. (2013). Using grounded theory method in information systems: The researcher as blank slate and other myths. *Journal of Information Technology*, 28(3), 224–236. <https://doi.org/10.1057/jit.2012.34>
- Wang, C., & Si, L. (2023). A bibliometric analysis of digital literacy research from 1990 to 2022 and research on emerging themes during the COVID-19 pandemic. *Sustainability*, 15(7), Article 5769. <https://doi.org/10.3390/su15075769>
- Wang, X., Wang, Z., Wang, Q., Chen, W., & Pi, Z. (2021). Supporting digitally enhanced learning through measurement in higher education: Development and validation of a university students' digital competence scale. *Journal of Computer Assisted Learning*, 37(4), 1063–1076. <https://doi.org/10.1111/jcal.12546>
- Walker, D., & Myrick, F. (2006). Grounded theory: An exploration of process and procedure. *Qualitative Health Research*, 16(4), 547–559. <https://doi.org/10.1177/1049732305285972>
- Wolfswinkel, J. F., Furtmueller, E., & Wilderom, C. P. (2013). Using grounded theory as a method for rigorously reviewing literature. *European Journal of Information Systems*, 22(1), 45–55. <https://doi.org/10.1057/ejis.2011.51>
- Wu, D., Sukumaran, S., Zhi, X., Zhou, W., Li, L., & You, H. (2025). Categories, themes and research evolution of the study of digital literacy: A bibliometric analysis. *Education and Information Technologies*, 30(4), 4907–4931. <https://doi.org/10.1007/s10639-024-12955-x>
- Yang, F., Yao, R., Ren, Y., & Guo, L. (2025). Harmony in diversity: Digital literacy research in a multidisciplinary landscape. *Computers & Education*, 230, Article 105265. <https://doi.org/10.1016/j.compedu.2025.105265>
- Yu, Z. (2022). Sustaining student roles, digital literacy, learning achievements, and motivation in online learning environments during the COVID-19 pandemic. *Sustainability*, 14(8), Article 4388. <https://doi.org/10.3390/su14084388>
- Rakhmawati, W. (2019). Understanding classic, straussian, and constructivist grounded theory approaches. *Belitung Nursing Journal*, 5(3), 111–115.
- Redecker, C. (2017). *European framework for the digital competence of educators: DigCompEdu*. publications office of the european union. <https://doi.org/10.2760/159770>
- Reddy, P., Chaudhary, K., & Hussein, S. (2023). A digital literacy model to narrow the digital literacy skills gap. *Heliyon*, 9(4), Article e14878. <https://doi.org/10.1016/j.heliyon.2023.e14878>
- Reynolds, R. (2016). Defining, designing for, and measuring “social constructivist digital literacy” development in learners: A proposed framework. *Educational Technology Research and Development*, 64(4), 735–762. <https://doi.org/10.1007/s11423-015-9423-4>
- Seker, O., Kwon, K., & Kocak, O. (2025). Exploring researchers' artificial intelligence (AI) literacy: The mediating role of digital literacy and data literacy between 21st century skills and AI literacy. *Information Development*. <https://doi.org/10.1177/026666669251336368>
- Setyadi, A., Pawirosumarto, S., Damaris, A., & Dharma, R. (2025). Risk management, digital technology literacy, and modern learning environments in enhancing learning innovation performance: A framework for higher education. *Education and Information Technologies*, 30, 15095–15123. <https://doi.org/10.1007/s10639-025-13380-4>
- Smith, E. E., & Storrs, H. (2023). Digital literacies, social media, and undergraduate learning: what do students think they need to know? *International Journal of Educational Technology in Higher Education*, 20, Article 29. <https://doi.org/10.1186/s41239-023-00398-2>
- Sosa-Díaz, M. J., & Valverde-Berrocoso, J. (2022). Grounded theory as a research methodology in educational technology. *International Journal of Qualitative Methods*, 21, 1–13. <https://doi.org/10.1177/16094069221133228>

Xueyi CAI, Aidah ABDUL KARIM. Constructing a digital literacy framework for university students: A literature-grounded theory approach

- Zhao, Y., Llorente, A. M. P., & Gómez, M. C. S. (2021). Digital competence in higher education research: A systematic literature review. *Computers & Education*, 168, Article 104212. <https://doi.org/10.1016/j.compedu.2021.104212>
- Zhou, X., Sun, K., Zhu, K., Feng, L., Sun, Q., & Zhong, D. (2025). The impact of digital literacy on university students' innovation capability: Evidence from Ningbo, China. *Frontiers in Psychology*, 16, Article 1548817. <https://doi.org/10.3389/fpsyg.2025.1548817>

Received: December 18, 2025 Revised: January 28, 2026 Accepted: February 06, 2026

Cite as: Cai, X., & Abdul Karim, A. (2026). Constructing a digital literacy framework for university students: A literature-grounded theory approach. *Problems of Education in the 21st Century*, 84(1), 46–74. <https://doi.org/10.33225/pec/26.84.46>

Xueyi Cai

EDD, Faculty of Education, National University of Malaysia (Universiti Kebangsaan Malaysia), Malaysia.
Lecturer, School of Economics and Management, Jiangsu College of Engineering and Technology, P. R. China.
mail: P125441@siswa.ukm.edu.my
ORCID: <https://orcid.org/0009-0003-2074-121X>

Aidah Abdul Karim
(Corresponding author)

Professor, Faculty of Education and Faculty of Human and Social Science, National University of Malaysia (Universiti Kebangsaan Malaysia), Malaysia.
mail: eda@ukm.edu.my
ORCID: <https://orcid.org/0000-0002-1115-1205>