Digital literacy and the 4c competencies as the foundation of education 4.0 transformation in Indonesia: a conceptual review

Agus Junsion Naibaho[1], Eduardo Sianturi[2]
[1,2]Universitas Efarina, Indonesia
E-mail: agusjnaibaho@gmail.com; esianturi88@gmail.com

ABSTRACT

The transformation of education in the era of the Fourth Industrial Revolution has shifted learning paradigms toward adaptive, technology-enhanced, and competency-based education. This study aims to examine the conceptual relationship between digital literacy and the four core twenty-first-century competencies (4Cs)—critical thinking, creativity, collaboration, and communication—as the foundation of Education 4.0 in Indonesia. A conceptual review approach was employed by synthesizing international journal articles, policy documents, and authoritative reports relevant to digital literacy, Education 4.0, and twenty-first-century learning. The data were analyzed through thematic analysis and conceptual synthesis. The findings indicate that digital literacy has evolved into a multidimensional competency encompassing technical, cognitive, social, ethical, and epistemic dimensions that support the development of the 4C competencies. However, the implementation of Education 4.0 in Indonesia continues to face challenges related to digital inequality, teachers' digital competence, curriculum adaptation, and educational technology governance. This study proposes the Humanistic Digital Learning Ecosystem Model, integrating digital literacy, the 4C competencies, constructivist pedagogy, ethical artificial intelligence, and local wisdom as a conceptual framework for advancing Education 4.0 in Indonesia.

Keyword: digital literacy; Education 4.0; 4C competencies; constructivist pedagogy; local wisdom

Corresponding Author:
Agus Junsion Naibaho,
Universitas Efarina,
Jl. Pendeta J. Wismar Saragih No.72-74, Bane, Kec. Siantar Utara, Kota Pematang Siantar, Sumatera Utara 21143, Indonesia
Email: agusjnaibaho@gmail.com

1. INTRODUCTION

The rapid advancement of digital technologies during the Fourth Industrial Revolution (Industry 4.0) has fundamentally transformed nearly every aspect of human life, including education. The integration of Artificial Intelligence (AI), the Internet of Things (IoT), cloud computing, big data, and other digital technologies has reshaped how individuals access information, construct knowledge, and interact within learning environments. Consequently, education is no longer focused solely on the acquisition of subject knowledge but is increasingly expected to develop competencies that enable learners to adapt to rapid and complex societal changes. This paradigm shift positions education as a process of fostering higher-order thinking skills, creativity, collaboration, communication, and the responsible use of digital technologies.

In the Indonesian context, the transition toward Education 4.0 represents a strategic effort to improve the quality of human resources capable of competing in the global landscape. Various national initiatives, including the implementation of the *Merdeka Curriculum* and efforts to strengthen teachers' digital competencies, demonstrate the government's commitment to developing an education system that is more responsive to technological advancement. Nevertheless, the implementation of Education 4.0 continues to face significant challenges, including disparities in access to digital technologies across regions, variations in teachers' digital competencies, inadequate technological infrastructure, and learning cultures that remain predominantly focused on rote memorization and academic achievement. These conditions suggest that educational transformation cannot be achieved solely through the provision of technology but also requires a fundamental shift in pedagogical paradigms.

A growing body of international research suggests that the successful implementation of Education 4.0 is largely determined by two key components: digital literacy and twenty-first-century competencies. Digital literacy has evolved into a multidimensional competency encompassing the ability to access, evaluate, manage, create, and communicate information in a critical, ethical, and responsible manner. Meanwhile, the twenty-first-century competencies, commonly conceptualized through the 4C framework—critical thinking, creativity, collaboration, and communication—have become essential for preparing learners to thrive in knowledge-based societies.

Despite these developments, most existing studies continue to examine digital literacy and the 4C competencies as separate constructs. Research that explicitly explores their conceptual interrelationship in supporting the Education 4.0 ecosystem, particularly within the Indonesian context, remains relatively limited. Furthermore, recent advances in generative artificial intelligence, learning analytics, and the growing emphasis on digital ethics have introduced new educational challenges that are not yet adequately addressed by existing conceptual models.

Against this background, this article aims to examine the integrative relationship between digital literacy and the 4C competencies in supporting the transformation toward Education 4.0 in Indonesia. Unlike previous studies, this article proposes a conceptual synthesis in the form of the Humanistic Digital Learning Ecosystem Model, which integrates digital literacy, the 4C competencies, constructivist pedagogy, the ethical use of artificial intelligence, and local wisdom as a comprehensive conceptual framework for advancing future-oriented education.

2. RESEARCH METHOD

This study employs a conceptual review approach to develop a theoretical synthesis of the relationship between digital literacy and twenty-first-century competencies (4Cs) as the foundation for the transformation toward Education 4.0 in Indonesia. Unlike a Systematic Literature Review (SLR), which primarily focuses on synthesizing empirical evidence through rigorous selection procedures, a conceptual review emphasizes the development of theoretical models, the integration of diverse scholarly perspectives, and the formulation of new conceptual frameworks through the critical analysis of existing literature.

The sources of data consist of reputable international journal articles, nationally accredited journals, reports published by international organizations (e.g., the OECD, UNESCO, and the European Commission), Indonesian educational policy documents, and other academic references relevant to Education 4.0, digital literacy, twenty-first-century competencies, artificial intelligence in education, and digital pedagogy. Priority was given to publications published within the past five years (2021–2026). However, several seminal works were also included to establish a strong theoretical foundation, including Gilster's (1997) concept of digital literacy, the Technological Pedagogical Content Knowledge (TPACK) framework proposed by Mishra and Koehler (2006), and the European Framework for the Digital Competence of Educators (DigCompEdu) developed by Redecker (2017).

The data were analyzed through four main stages:

1. Identification of Key Concepts, involving the classification and synthesis of various definitions of Education 4.0, digital literacy, the 4C competencies, digital pedagogy, and educational transformation.
2. Thematic Analysis, involving the identification of relationships among these concepts by examining similarities and differences across previous studies and theoretical perspectives.
3. Conceptual Synthesis, involving the integration of the identified themes into a coherent framework explaining how digital literacy facilitates the development of the 4C competencies within a digital learning ecosystem.
4. Development of the Conceptual Model, involving the formulation of the Humanistic Digital Learning Ecosystem Model as the primary conceptual contribution of this study.

The trustworthiness of this conceptual review was ensured through the triangulation of literature sources, cross-comparison of findings from previous studies, critical evaluation of the consistency of theoretical arguments, and the synthesis of multiple scholarly perspectives. These procedures were undertaken to develop a conceptually robust model supported by a strong theoretical foundation.

3. RESULTS AND DISCUSSION

A. The Evolution of the Education 4.0 Concept

The concept of Education 4.0 has emerged in response to the profound transformations brought about by the Fourth Industrial Revolution. Education is no longer viewed merely as a process of transferring

knowledge from teachers to learners; rather, it is increasingly understood as a process of developing competencies that enable individuals to adapt to rapid social, economic, and technological changes. This paradigm shift places learners at the center of the educational process through student-centered learning while encouraging the integration of digital technologies to create learning experiences that are flexible, personalized, and collaborative.

UNESCO emphasizes that the digital transformation of education extends beyond the adoption of technology itself. Instead, it involves a fundamental shift in educational paradigms toward fostering higher-order thinking skills, creativity, collaboration, digital literacy, and lifelong learning. Accordingly, Education 4.0 should be understood as a comprehensive transformation of the education system rather than merely the digitalization of teaching and learning processes.

In Indonesia, the implementation of Education 4.0 has gained considerable momentum through the *Merdeka Belajar* (Freedom to Learn) policy, which promotes differentiated instruction, strengthens the *Pancasila Student Profile*, and encourages the integration of digital technologies into classroom practices. Nevertheless, numerous studies indicate that implementing these policies continues to face significant challenges, including teachers' readiness, inadequate technological infrastructure, digital inequality, and relatively low levels of students' digital competencies.

B. Digital Literacy from the Perspective of Modern Education

The concept of digital literacy has undergone substantial development over the past two decades. Gilster initially defined digital literacy as the ability to understand and utilize information obtained from various digital sources. This definition has subsequently evolved into a more comprehensive framework, particularly through the European Framework for the Digital Competence of Educators (DigCompEdu) developed by the European Commission.

From a contemporary perspective, digital literacy encompasses several interrelated dimensions, including:

- Information literacy;
- Media literacy;
- Technology literacy;
- Digital communication;
- Digital collaboration;
- Digital content creation;
- Digital safety; and
- AI literacy.

The rapid advancement of Artificial Intelligence (AI) in education has further expanded the scope of digital literacy beyond the ability to operate digital devices. Learners are now expected to critically evaluate AI-generated information, recognize algorithmic bias, protect personal and institutional data, and utilize AI ethically and responsibly throughout the learning process.

These developments demonstrate that digital literacy has evolved into a multidimensional competency and has become one of the fundamental pillars of Education 4.0.

C. The 4C Competencies as Learning Outcomes of Education 4.0

The Partnership for 21st Century Learning (P21) framework identifies Critical Thinking, Creativity, Collaboration, and Communication (4Cs) as the core competencies required for success in the twenty-first century. These competencies are highly interconnected and collectively prepare learners to thrive in an increasingly digital and knowledge-driven society.

1) Critical Thinking

Critical thinking enables learners to analyze digital information critically, evaluate the credibility and reliability of information sources, identify misinformation and algorithmic bias, and make evidence-based decisions. In the era of Artificial Intelligence, critical thinking has become even more essential because learners are increasingly exposed to information generated by both humans and intelligent systems. Consequently, the ability to critically evaluate digital content has become a fundamental component of responsible learning and informed decision-making.

2) Creativity

Creativity refers to the ability to generate innovative solutions to authentic and complex problems. Digital technologies provide diverse opportunities to foster creativity through the development of educational

videos, animations, infographics, virtual simulations, multimedia presentations, and even simple software applications. Therefore, creativity should no longer be viewed solely as an artistic ability but rather as the capacity to produce technology-supported innovations that address real-world challenges.

3) Collaboration

Collaboration has become an indispensable competency because contemporary global challenges increasingly require interdisciplinary and collective problem-solving. Digital learning environments facilitate both synchronous and asynchronous collaboration through a variety of online platforms and collaborative technologies. Beyond enhancing teamwork, digital collaboration also strengthens leadership, interpersonal communication, shared responsibility, and intercultural understanding, all of which are essential competencies for future professionals.

4) Communication

Communication in the twenty-first century extends far beyond traditional verbal interaction. Learners are expected to communicate ideas effectively through a variety of digital media, including videos, podcasts, infographics, interactive presentations, blogs, and academic social media platforms. Consequently, the ability to communicate effectively across multiple digital formats has become an integral component of digital literacy and an essential competency for lifelong learning.

D. Research Gap

Despite the rapid growth of research on digital literacy and the 4C competencies, several significant research gaps remain.

First, most previous studies have examined digital literacy as an independent construct rather than as an integral component of a broader educational ecosystem.

Second, research on the 4C competencies has predominantly focused on the effectiveness of specific instructional approaches, such as Project-Based Learning (PjBL) and Problem-Based Learning (PBL), without sufficiently exploring the broader conceptual relationships among twenty-first-century competencies.

Third, only a limited number of studies have attempted to integrate digital literacy, the 4C competencies, constructivist pedagogy, Artificial Intelligence, and character education into a unified conceptual framework.

Fourth, educational research conducted in Indonesia has largely relied on small-scale empirical investigations, resulting in the absence of a comprehensive conceptual framework capable of informing educational policy and large-scale educational transformation.

These research gaps highlight the need for a conceptual model that comprehensively explains the interrelationships among digital literacy, twenty-first-century competencies, Artificial Intelligence, and humanistic learning within a single integrative framework.

Accordingly, the primary contribution of this article extends beyond synthesizing existing theories. It proposes a novel conceptual framework—the Humanistic Digital Learning Ecosystem Model—which integrates digital literacy, AI literacy, the 4C competencies, constructivist pedagogy, and character education into a coherent educational ecosystem designed to support the transformation toward Education 4.0 in the Indonesian context.

4. CONCLUSION

The transformation toward Education 4.0 requires a fundamental shift in educational paradigms from knowledge transmission to the development of twenty-first-century competencies that are adaptive, collaborative, creative, and oriented toward lifelong learning. Digital literacy has evolved into a multidimensional competency that extends beyond the technical ability to use digital technologies. It encompasses the capacity to access, evaluate, create, and communicate information in a critical, ethical, and responsible manner.

The findings of this conceptual review indicate that digital literacy and the 4C competencies are mutually reinforcing. Digital literacy provides the epistemic foundation that enables learners to develop critical thinking, creativity, collaboration, and communication within digital learning environments. Conversely, the 4C competencies provide the pedagogical mechanisms through which technology can be meaningfully integrated into the learning process, ensuring that digital technologies contribute to authentic, engaging, and learner-centered educational experiences rather than merely serving as instructional tools.

The principal contribution of this article is the development of the Humanistic Digital Learning Ecosystem Model, which conceptually integrates digital literacy, active learning design, the ethical use of artificial intelligence, the 4C competencies, and humanistic character development into a unified conceptual

framework. This model is expected to serve as a valuable reference for educational policymakers, practitioners, and researchers in designing educational policies, instructional practices, and future research initiatives that support the effective implementation of Education 4.0 in Indonesia. Future studies are encouraged to validate and refine this conceptual model through empirical research conducted across diverse educational contexts to further strengthen its theoretical and practical applicability.

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