

Modeling Digital Literacy as a Pedagogical Ecosystem: The Interplay of Digital Skills, Ethics, Safety, and Culture in Secondary Education

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ABSTRACT:

Background: Digital literacy has evolved beyond technical competence into a multidimensional construct encompassing skills, ethics, safety, and culture, yet empirical studies often remain fragmented and descriptive, limiting their pedagogical relevance in secondary education contexts.

Aims: This study aims to model digital literacy as a pedagogical ecosystem by examining the interplay among digital skills, digital ethics, digital safety, and digital culture in shaping students' literacy practices.

Methods: A quantitative approach was employed with data collected from 93 secondary school students using structured questionnaires. Descriptive and inferential analyses were conducted to examine the distribution and interrelations of the four dimensions within a unified conceptual framework.

Results: The findings indicate that students demonstrate generally high levels across all dimensions, with digital skills functioning as the foundational driver, while digital ethics, safety, and culture operate as integrative components that shape responsible and critical engagement with digital environments. The interplay among these dimensions suggests a coherent ecosystem rather than isolated competencies.

Conclusion: This study advances a pedagogical ecosystem model of digital literacy, emphasizing that effective literacy development requires the integration of technical, ethical, and socio-cultural dimensions within educational practices. The findings highlight the need for instructional designs that move beyond skill acquisition toward critical, responsible, and context-aware digital participation. By reframing digital literacy as an interconnected system, this study offers a theoretically grounded and pedagogically relevant contribution to literacy education, particularly in preparing students for complex digital societies.

Keywords: Digital literacy ecosystem, pedagogical pathways, digital skills, digital ethics, digital safety, digital culture.

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INTRODUCTION

Digital literacy has become a central competence in contemporary education as digital environments increasingly mediate how knowledge is accessed, constructed, and shared. The rapid expansion of digital technologies has shifted literacy from a purely cognitive skill into a socio-technical practice that integrates critical thinking, ethical awareness, and cultural participation (Georgopoulou et al., 2025a). Recent scholarship highlights that digital literacy is no longer limited to operational skills but encompasses broader dimensions such as digital ethics, safety, and identity formation (Martínez-Bravo et al., 2022a). Educational systems, however, often struggle to adapt pedagogical approaches that reflect this multidimensional nature of literacy. Many secondary education contexts still prioritize technical proficiency while overlooking the ethical and cultural implications of digital engagement. This imbalance creates a gap between students' digital practices and their capacity for responsible and critical participation. Studies have shown that fragmented approaches to digital literacy fail to prepare students for complex digital ecosystems (Georgopoulou et al., 2025b). Consequently, there is an urgent need to reconceptualize digital literacy as an integrated construct within educational practice.

At the same time, the increasing risks associated with digital environments, including misinformation, cyber threats, and ethical dilemmas, demand a more holistic understanding of literacy. Digital safety and ethical awareness are becoming essential components of students' everyday interactions with technology. Research indicates that students often demonstrate high levels of digital usage but lack critical awareness and responsible behavior in online contexts (Sathy, 2025). This suggests that competence in digital skills alone is insufficient without corresponding development in ethical and cultural dimensions. Furthermore, the concept of digital culture emphasizes how individuals participate, communicate, and construct meaning within digital communities. Integrating these dimensions into a unified framework can provide a more accurate representation of students' digital experiences. Educational research increasingly calls for models that capture the interconnected nature of these competencies rather than treating them as isolated variables (Johnson & Christensen, 2024). Therefore, examining digital literacy as a pedagogical ecosystem becomes both timely and necessary.

Existing literature on digital literacy has made significant progress in identifying its core components, yet much of the research remains compartmentalized across different domains. Several studies focus primarily on digital skills as measurable competencies, often assessed through performance-based indicators or self-reported abilities (Pan et al., 2025). While these approaches provide valuable insights, they tend to neglect the relational dynamics between skills and other dimensions such as ethics and culture. Emerging frameworks suggest that digital literacy should be understood as a multidimensional construct involving cognitive, social, and ethical elements. For instance, recent models emphasize the role of critical literacy in navigating digital information environments and resisting misinformation (Panda & Kaur, 2024). However, empirical studies rarely integrate these dimensions into a cohesive analytical structure. This limitation reduces the explanatory power of digital literacy research in educational contexts. As a result, there is a growing call for more integrative approaches that can capture the complexity of students' digital engagement.

In addition, the pedagogical implications of digital literacy remain underexplored despite its recognized importance in education. Many studies highlight the need for instructional strategies that go beyond technical training and foster critical and ethical awareness (Iloka, 2025). Digital culture, in

particular, has gained attention as a dimension that reflects how learners interact within digital communities and construct shared meanings. Yet, this dimension is often treated descriptively rather than analytically within empirical research. The interplay between digital skills, ethics, safety, and culture has not been sufficiently examined in secondary education settings. Recent research suggests that understanding these interconnections is crucial for designing effective literacy interventions (Batool & Haleem, 2022). Without such integration, educational practices risk reinforcing fragmented learning experiences. Therefore, a more holistic perspective is needed to bridge theoretical frameworks and empirical findings. This study responds to this need by proposing a pedagogical ecosystem model of digital literacy.

Despite the expanding body of research on digital literacy, significant gaps remain in how its multidimensional nature is conceptualized and empirically examined. Existing studies tend to isolate digital skills, ethics, safety, and culture as separate constructs rather than exploring their interdependent relationships. This fragmentation limits the ability to understand how these dimensions collectively shape students' literacy practices (Nasiri, 2024). Moreover, many studies rely on descriptive approaches that do not capture the dynamic interactions among these variables. There is also a lack of research that frames digital literacy within a pedagogical ecosystem that reflects real-world digital engagement. In secondary education contexts, this gap becomes more pronounced due to the complexity of students' digital experiences. Without an integrative framework, it is difficult to design instructional strategies that address the full scope of digital literacy. Therefore, a study that models the interplay among these dimensions can provide a more comprehensive and theoretically grounded contribution (Rouse et al., 2025).

This study aims to conceptualize digital literacy as a pedagogical ecosystem by examining the interplay among digital skills, digital ethics, digital safety, and digital culture in secondary education. It seeks to move beyond fragmented approaches by providing a unified framework that reflects the interconnected nature of these dimensions. The study investigates how each component contributes to students' overall digital literacy and how they interact within a broader educational context. By adopting a quantitative approach, this research also aims to generate empirical insights into the relationships among these variables. The findings are expected to offer a more nuanced understanding of digital literacy as a multidimensional construct. In addition, the study intends to highlight the pedagogical implications of integrating these dimensions into teaching and learning practices. This includes informing curriculum design and instructional strategies that promote responsible and critical digital engagement. Ultimately, the study contributes to advancing digital literacy research by proposing a more holistic and contextually relevant model (Salimi et al., 2025).

METHOD

Research Design

This study employed a quantitative research design to examine digital literacy as a pedagogical ecosystem by analyzing the interplay among digital skills, ethics, safety, and culture in secondary education. A cross-sectional survey approach was adopted to capture students' perceptions and experiences within a specific educational context. Quantitative design was considered appropriate because it allows systematic measurement of multiple constructs and facilitates the identification of patterns across variables (Lim, 2025). The study was framed within an explanatory-descriptive orientation to move beyond simple measurement toward understanding the relationships among

dimensions. This approach aligns with recent calls for integrating multiple components of digital literacy into cohesive analytical frameworks (Martínez-Bravo et al., 2022b). The design also supports the conceptualization of literacy as a dynamic system rather than a static set of skills. By structuring the study around interconnected variables, the research reflects a pedagogical ecosystem perspective. This design provides a foundation for examining how different dimensions of digital literacy co-exist and interact within educational settings (Andalib & Monsur, 2024).

Participants

The participants of this study consisted of 93 secondary school students enrolled in a public high school setting. The selection of participants was based on purposive sampling to ensure that respondents had sufficient exposure to digital technologies in their learning environment. Secondary school students were chosen because they represent a critical stage in developing digital literacy competencies and identity formation. The sample reflects a context where digital tools are actively integrated into educational practices. This population is particularly relevant for examining the intersection of skills, ethics, safety, and culture in digital engagement. Prior research indicates that adolescents demonstrate diverse digital behaviors that require multidimensional analysis (Rossi et al., 2025). The participants provided responses based on their everyday interactions with digital platforms both inside and outside the classroom. This allows the study to capture authentic representations of digital literacy practices. Ethical considerations were maintained by ensuring voluntary participation and anonymity throughout the data collection process.

Instrument

Data were collected using a structured questionnaire designed to measure four key dimensions of digital literacy: digital skills, digital ethics, digital safety, and digital culture. The instrument was adapted from established digital literacy frameworks to ensure conceptual validity and relevance to contemporary educational contexts (Martínez-Bravo et al., 2022c). Each dimension was operationalized through multiple indicators reflecting both cognitive and behavioral aspects of digital engagement. A Likert-scale format was employed to capture the degree of students' agreement with each statement. The questionnaire was reviewed to ensure clarity, coherence, and alignment with the pedagogical ecosystem framework. Instrument development emphasized the integration of technical, ethical, and socio-cultural elements of literacy. This approach responds to the need for more comprehensive measurement tools in digital literacy research. Reliability was assessed using internal consistency measures to ensure stability across items. The instrument provides a holistic representation of students' digital literacy within a unified analytical structure (Avinç & Doğan, 2024).

Table 1. Dimensions And Indicators Of Digital Literacy.

Dimension	Indicators Description
Digital Skills	Ability to operate digital tools, access information, and solve technical problems
Digital Ethics	Awareness of ethical behavior, responsibility, and respect in digital environments
Digital Safety	Ability to protect personal data and manage online risks
Digital Culture	Participation in digital communities and understanding of digital norms

The table above illustrates how digital literacy is operationalized as a multidimensional construct within this study. Each dimension represents a critical component of the pedagogical ecosystem, emphasizing that literacy extends beyond technical competence. The inclusion of ethical, safety, and cultural indicators reflects a shift toward more holistic literacy frameworks. These

dimensions are not treated as isolated variables but as interconnected elements that shape students' digital experiences. By structuring the instrument in this way, the study aligns measurement with the conceptual model. This also enables a more integrated analysis of digital literacy practices. The framework supports the exploration of relationships among dimensions. Ultimately, it strengthens the validity of the research design.

Data Analysis Plan

Data analysis was conducted using descriptive and inferential statistical techniques to examine the distribution and relationships among variables. Descriptive statistics were used to identify general trends in students' digital literacy across all dimensions. Inferential analysis was employed to explore the interplay among digital skills, ethics, safety, and culture. This analytical approach allows for a more nuanced understanding of how different components interact within the ecosystem. The study emphasizes relational interpretation rather than isolated measurement of variables. Recent methodological discussions highlight the importance of examining interconnections in digital literacy research (Susanty, 2024a). Statistical procedures were performed to identify patterns that support the conceptual framework of a pedagogical ecosystem. The analysis also aims to provide empirical grounding for theoretical claims presented in the study. By integrating descriptive and relational insights, the analysis contributes to a more comprehensive understanding of digital literacy in educational contexts.

RESULTS AND DISCUSSION

Results

The analysis reveals that students demonstrate relatively high levels of digital literacy across all four dimensions, indicating strong engagement with digital environments. Digital skills emerged as the most dominant dimension, reflecting students' familiarity with accessing information and operating digital tools. However, the findings also show that digital ethics and safety, while present, are less consistently internalized compared to technical competencies. This suggests that students' engagement is more operational than reflective in nature. Digital culture appears as a bridging dimension that connects technical use with social participation in digital environments. The distribution of scores indicates a pattern where competencies are not isolated but interrelated. This supports the conceptualization of digital literacy as an interconnected system rather than separate constructs. The results highlight the need to interpret literacy as a dynamic ecosystem shaped by multiple dimensions.

Table 2. Descriptive Statistics of Digital Literacy Dimensions.

Dimension	Mean	Category
Digital Skills	4.21	High
Digital Ethics	3.98	High
Digital Safety	3.87	High
Digital Culture	4.05	High

The table above indicates that digital skills have the highest mean score, suggesting that students are more proficient in technical aspects of digital engagement. Digital culture also shows a relatively strong presence, indicating active participation in digital communities. In contrast, digital safety records the lowest mean, highlighting potential vulnerabilities in managing online risks. Digital ethics, while categorized as high, demonstrates variability that suggests inconsistency in responsible

digital behavior. These patterns reveal an imbalance between technical proficiency and critical awareness. The data reinforces the idea that digital literacy development is uneven across dimensions. This unevenness supports the need for an integrated pedagogical approach. Overall, the findings validate the multidimensional structure of digital literacy.

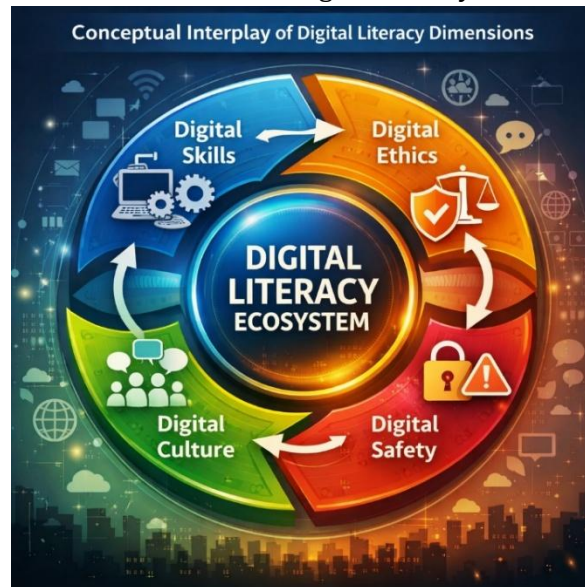


Figure 1. Conceptual Interplay of Digital Literacy Dimensions.

The figure illustrates the conceptual interplay among digital skills, ethics, safety, and culture as an ecosystem. Digital skills function as the foundational layer that enables interaction with digital environments. Digital ethics and safety act as regulatory dimensions that guide responsible and secure engagement. Digital culture operates as a contextual dimension that shapes how individuals participate and construct meaning. The interaction among these components suggests a dynamic system rather than a linear relationship. This visualization supports the empirical findings that dimensions are interconnected. It also reinforces the argument that literacy development requires integration across domains. The model provides a conceptual basis for interpreting the results within a pedagogical framework.

Further analysis indicates that the relationship among dimensions reflects a complementary rather than hierarchical structure. Students who demonstrate strong digital skills also tend to exhibit higher engagement in digital culture. However, this relationship does not automatically translate into stronger ethical or safety awareness. This suggests that technical competence alone does not guarantee responsible digital behavior. The interplay among variables highlights the importance of integrating ethical and safety education into digital learning environments. The findings align with the ecosystem perspective, where each dimension influences and is influenced by others. This interconnected pattern supports the argument that digital literacy should be understood holistically. The results provide empirical support for the proposed pedagogical ecosystem model. Ultimately, the findings contribute to a more nuanced understanding of digital literacy in secondary education.

Discussion

The findings of this study reinforce the growing consensus that digital literacy must be understood as a multidimensional construct rather than a singular skill set. The dominance of digital skills reflects broader trends in education where technical proficiency is prioritized over critical and

ethical dimensions. This pattern is consistent with previous studies showing that students often develop operational competencies faster than reflective capacities (Alt et al., 2022). However, the relatively lower consistency in digital ethics and safety indicates a critical gap in current educational practices. This imbalance suggests that students are well-equipped to use technology but less prepared to navigate its risks and ethical implications. The results highlight the limitations of skill-centered approaches to digital literacy. A more integrated pedagogical approach is needed to address this imbalance. These findings contribute to the ongoing discourse on redefining literacy in digital contexts.

The role of digital culture as a bridging dimension provides important insights into how students engage with digital environments. Digital culture reflects not only participation but also identity formation and social interaction within digital spaces. This aligns with research emphasizing the socio-cultural nature of digital literacy (Sari et al., 2025). The strong presence of digital culture suggests that students are actively engaged in digital communities, yet this engagement is not always accompanied by critical awareness. This disconnect raises concerns about the quality of participation in digital environments. Educational frameworks need to address not only how students participate but also how they interpret and evaluate digital content. Integrating cultural dimensions into literacy education can enhance students' critical engagement. This perspective supports the idea of literacy as a socially situated practice.

The interplay among digital skills, ethics, safety, and culture supports the conceptualization of digital literacy as an ecosystem. This finding resonates with recent calls for more integrative models that capture the complexity of digital engagement (Wu et al., 2024). The ecosystem perspective emphasizes that literacy development is not linear but dynamic and interdependent. Each dimension influences the others, creating a network of competencies that shape students' digital behavior. This approach challenges traditional frameworks that treat literacy components as separate variables. It also provides a more realistic representation of how students interact with digital environments. By adopting this perspective, the study contributes to advancing theoretical models of digital literacy. The ecosystem model offers a foundation for future research and pedagogical innovation.

The findings also have significant implications for instructional design in secondary education. Current practices often emphasize technical training without integrating ethical and safety considerations. This study highlights the need for curriculum designs that embed these dimensions into learning activities. Research suggests that effective digital literacy education requires a balance between skills and critical awareness (Susanty, 2024b). Teachers play a crucial role in facilitating this integration through reflective and inquiry-based approaches. Incorporating real-world digital scenarios into instruction can enhance students' understanding of ethical and safety issues. This aligns with pedagogical approaches that emphasize experiential learning. The study underscores the importance of aligning educational practices with the complexities of digital environments. Such alignment is essential for preparing students for responsible digital participation.

Furthermore, the findings contribute to the broader discourse on literacy education by emphasizing the importance of context. Digital literacy cannot be separated from the environments in which it is practiced. This aligns with studies highlighting the contextual and situated nature of literacy (Kilag et al., 2023). The ecosystem model reflects this perspective by integrating multiple dimensions into a unified framework. It also acknowledges the influence of social, cultural, and technological factors on literacy development. This approach provides a more comprehensive

understanding of students' digital experiences. It challenges reductionist views that focus solely on measurable skills. By emphasizing context, the study enhances the relevance of digital literacy research. This contribution is particularly important for developing context-sensitive educational strategies.

Implications

The study highlights the need for educational policies that integrate technical, ethical, and cultural dimensions of digital literacy. It suggests that curriculum design should move beyond skill acquisition toward holistic literacy development. Teachers should be supported in implementing pedagogical strategies that foster critical and responsible digital engagement. The findings also emphasize the importance of embedding digital safety education within everyday learning activities. Educational institutions can use the ecosystem model as a framework for designing literacy programs. This approach can enhance students' readiness for complex digital environments. The study provides practical insights for improving instructional practices. Ultimately, it supports the development of more comprehensive literacy education (Mhlongo et al., 2023).

Research Contribution

This study contributes to the field of literacy education by proposing a pedagogical ecosystem model of digital literacy. It provides empirical evidence supporting the interconnected nature of digital skills, ethics, safety, and culture. The study advances theoretical understanding by moving beyond fragmented approaches to literacy. It also offers practical insights for improving educational practices. By integrating multiple dimensions, the research enhances the relevance of digital literacy frameworks. The ecosystem perspective provides a foundation for future studies. This contribution is particularly significant in the context of rapidly evolving digital environments. Overall, the study strengthens the discourse on digital literacy in education.

Limitations

This study is limited by its sample size and focus on a single educational context. The findings may not be generalizable to other settings with different technological or cultural conditions. The use of self-reported data may also introduce bias in measuring students' competencies. Additionally, the study relies on descriptive and relational analysis without advanced modeling techniques. This limits the ability to establish causal relationships among variables. Future research could address these limitations by using larger and more diverse samples. Incorporating advanced statistical models could also strengthen the findings. Despite these limitations, the study provides valuable insights into digital literacy.

Suggestions

Future studies should explore the use of structural equation modeling to examine the relationships among digital literacy dimensions. Longitudinal research could provide insights into how digital literacy develops over time. Comparative studies across different educational contexts would enhance the generalizability of findings. Researchers should also investigate the role of teachers in shaping digital literacy ecosystems. Integrating qualitative approaches could provide deeper insights into students' experiences. Future research could also examine the impact of specific pedagogical interventions. Expanding the scope of variables may enrich the conceptual model. These directions can contribute to advancing digital literacy research.

CONCLUSION

This study repositions digital literacy as a pedagogical ecosystem by demonstrating that students' engagement with digital environments is shaped by the dynamic interplay of digital skills, ethics, safety, and culture. The findings reveal that while technical competence remains the most dominant dimension, it does not inherently translate into ethical awareness or safe digital behavior. This indicates a structural imbalance in how digital literacy develops within secondary education contexts. Rather than functioning as isolated competencies, the four dimensions operate as an interconnected system in which each component influences and constrains the others. The study therefore challenges reductionist approaches that prioritize operational skills while neglecting critical and socio-cultural aspects of literacy. By framing digital literacy as an ecosystem, this research offers a more comprehensive lens for understanding students' digital practices. It also highlights that meaningful literacy development requires alignment between technical capability, ethical reasoning, risk awareness, and cultural participation.

From a pedagogical perspective, the study underscores the need to move beyond fragmented instructional approaches toward integrated learning designs that reflect the complexity of digital environments. The ecosystem model proposed in this study provides a conceptual foundation for designing curricula that embed ethical, safety, and cultural dimensions within digital skill development. This approach enables educators to foster not only competent users of technology but also critical and responsible participants in digital society. Importantly, the findings suggest that digital culture plays a mediating role by connecting individual competencies with broader social practices. This insight contributes to expanding current digital literacy frameworks by incorporating the contextual and participatory nature of literacy. The study also provides empirical support for the argument that literacy education must evolve in response to the complexities of digitally mediated communication. By integrating multiple dimensions into a unified framework, this research advances both theoretical and pedagogical discussions in literacy education.

At a broader level, this study contributes to the ongoing redefinition of literacy in the digital age by emphasizing its systemic and context-dependent nature. It offers a conceptual shift from viewing literacy as a set of discrete skills to understanding it as a relational and adaptive process. This shift is particularly relevant for educational systems seeking to prepare students for uncertain and rapidly evolving digital futures. While the study is grounded in a specific context, its implications extend to wider discussions on curriculum design, digital citizenship, and educational transformation. The ecosystem perspective also opens new directions for research by encouraging the exploration of interactions among literacy dimensions across different contexts. Ultimately, this study strengthens the argument that effective digital literacy education requires holistic, integrative, and context-sensitive approaches. Such approaches are essential for developing learners who are not only digitally capable but also ethically aware and socially responsible in navigating digital environments.

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Finally, the authors affirm that this research was conducted independently without any conflict of interest, and no external funding influenced the design, analysis, or interpretation of the findings.

AUTHOR CONTRIBUTION STATEMENT

Irsyad Ismail was primarily responsible for conceptualization, research design, data collection, and the initial drafting of the manuscript. Hana Silvana contributed to the development of the theoretical framework, refinement of the research methodology, and critical revision of the manuscript to strengthen its academic rigor. Gema Rullyana was involved in data analysis, interpretation of results, and enhancing the analytical depth of the study.

All authors collaboratively reviewed and edited the manuscript to ensure coherence, clarity, and alignment with the pedagogical ecosystem perspective. Each author has read and approved the final version of the manuscript and agrees to be accountable for all aspects of the work, including the accuracy and integrity of the research.

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