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IDENTIFYING THE DRIVERS OF DIGITAL LITERACY IN INDONESIA'S DISTANCE LEARNING ERA

Selly Anastassia Amellia Kharis[1]*, Tri Wijayanti Septiarini[1], Arman Haqqi Anna Zili[2], Melisa Arisanty[3], Sri Maulidia Permatasari[4]
[1]Mathematics, Universitas Terbuka, Indonesia
[2]Mathematics, Universitas Indonesia, Indonesia
[3]Library and Information Science, Universitas Terbuka, Indonesia
[4]Statistics, Universitas Terbuka, Indonesia
selly@ecampus.ut.ac.id[1], tri.wijayanti@ecampus.ut.ac.id[1], armanhaz@sci.ui.ac.id[2], melisa.arisanty@ecampus.ut.ac.id[3] , srimaulidia@ecampus.ut.ac.id[4]

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ABSTRACT

In Indonesia's rapidly evolving distance learning landscape, digital literacy has become a critical competency for ensuring academic quality and ethical online engagement. However, existing assessments often focus narrowly on technical skills, overlooking behavioral and ethical dimensions that are equally essential in digital environments. This study aims to identify the key factors influencing digital literacy among students in Indonesia's distance learning environment, focusing on Universitas Terbuka. Utilizing a Random Forest algorithm, the research involves data preprocessing, model development and evaluation, and feature importance analysis to determine the most influential predictors. The findings reveal that digital ethics and behavioral aspects-such as academic integrity, proper citation practices, and responsible social media conduct- are the strongest indicators of digital literacy, whereas technical proficiency in e-learning platforms plays a less dominant role. This study's novel use of Machine Learning offers a methodological contribution to the assessment of digital literacy in educational settings. Based on these insights, the paper recommends a holistic approach to digital literacy education at Universitas Terbuka, advocating for programs that integrate technical training with robust digital ethics instruction, including awareness of citation, plagiarism, communication etiquette, privacy, and responsible information dissemination.

A. INTRODUCTION

Distance learning is fundamentally characterized by its ability to overcome spatial and temporal limitations in instruction (Bobyliev & Vihrova, 2021)The global landscape of education has been significantly reshaped by the COVID-19 pandemic, which necessitated a rapid transformation of student learning activities through technology (Purnama et al., 2021; Schneider & Council, 2021). In Indonesia, the implementation of distance learning continues to face considerable challenges (Azhari & Fajri, 2022; Churiyah et al., 2020). These challenges are particularly pronounced in rural and underserved communities, where deficiencies in infrastructure, limited device ownership, and high internet costs impede meaningful engagement in online education (Sholihah et al., 2023; Suni Astini, 2020). While the shift towards digitally-driven learning offers substantial opportunities, it simultaneously exposes systemic deficiencies in equipping both learners and educators with the requisite competencies for thriving in technology-enabled environments (Dziubaniuk et al., 2023; Masudah, 2021).

Strengthening digital literacy in Indonesia through collaboration, innovation, and sustainability education (G. I. Sari et al., 2024).

This pedagogical approach has gained increasing relevance amidst growing demands for educational flexibility and the ongoing expansion of digital infrastructure within Indonesia. Online learning not only facilitates broad access for students across diverse geographical regions but also necessitates adequate digital literacy skills for effective participation in the teaching and learning process (Hidayah, 2022). Digital literacy is increasingly critical due to the evolution of technology-based learning ecosystems in higher education (Tejedor et al., 2020). The demand for digital skills extends beyond mere device and application usage, encompassing crucial aspects of security and ethical conduct in online environments (Kabakus et al., 2023).

Numerous studies have explored the relationship between digital literacy and distance learning. For instance, a study developed and evaluated a predictive model using five machine learning algorithms to identify factors influencing digital literacy in distance education, revealing that learners' generation is a strong indicator, with Support Vector Machine (SVM) achieving up to 82.9% accuracy (Nadzir & Bakar, 2023). Furthermore, text mining applied to 1,037 articles (2000–2020) mapped the digital literacy research field, identifying three primary streams: digital literacy, digital learning, and twenty-first-century digital skills, all underpinned by informational and technological foundations (Audrin & Audrin, 2022). Additionally, research employing SEM-PLS on 300 students during the COVID-19 pandemic found that digital literacy, parental mediation, and self-control influenced online risk; however, parental mediation did not enhance self-control, underscoring the need for stronger digital literacy and parental guidance to ensure safe technology use (Purnama et al., 2021). A systematic review of 21 high-quality studies indicated that COVID-19 significantly altered teachers' professional roles, reduced career satisfaction, and highlighted the imperative for enhanced digital literacy to support future blended teaching models (Li & Yu, 2022). The roles and research trends of artificial intelligence in mathematics education have also been extensively analyzed, providing insights into technology-based learning models (Elnaffar & Fawey, 2024). Beyond identifying influencing factors, machine learning has also been employed to uncover effective pedagogical techniques in mathematics education, offering strategies for novice teachers to enhance their teaching (Elnaffar & Fawey, 2024).

The unique contribution of this study lies in its application of Machine Learning (ML), specifically the Random Forest algorithm, to precisely identify the primary variables that determine the level of digital literacy among students in Indonesia. This approach aligns with recent trends in educational research that leverage AI and ML to analyze learning processes and outcomes, particularly in mathematics education (Hwang & Tu, 2021). Furthermore, the use of machine learning to uncover effective pedagogical techniques in mathematics education is a growing area of research (Elnaffar & Fawey, 2024). The application of fuzzy mathematics and machine learning algorithms has also been explored in the context of educational quality evaluation models, demonstrating the broader utility of these advanced analytical tools in understanding and improving educational outcomes (Wang & Zhang, 2020). Consequently, this research advances the development of novel methodologies for measuring and analyzing digital literacy within educational contexts.

The aim of this study is to identify the key factors influencing digital literacy in Indonesia's distance learning environment and to provide evidence-based recommendations for enhancing digital literacy. To achieve this, the study employs Machine Learning algorithms to predict digital literacy levels based on available data and determine the most influential predictors of digital literacy. This finding formulates policy recommendations to enhance digital literacy, thereby supporting the effectiveness of online learning.

The remainder of this paper is structured as follows: Section B delineates the research methods, including data collection, pre-processing, feature selection, parameter tuning, and evaluation procedures. Section C presents and discusses the results, emphasizing key findings and their implications. Finally, Section D provides the conclusion, summarizing the main contributions and proposing directions for future research.

B. METHODS

1. Data collection

The data utilized in this study were acquired from a comprehensive digital literacy survey, which encompassed four critical aspects: digital skill, digital

ethics, digital safety, and digital culture. First, Digital Skills refer to the intelligence and proficiency in using digital media. This encompasses an individual's ability to utilize information and communication technology effectively. With proficient digital skills, a person is equipped to operate technological tools for various purposes, including educational, professional, and social activities. Such competencies allow for adaptability to the rapid changes experienced in the digital era. They serve as a foundation for further engagement in a society that increasingly relies on digital platforms for interaction, information dissemination, and productivity. Second, Digital Ethics denotes an individual's awareness and capability to act in accordance with established rules and norms during interactions in the digital realm. This ethical framework encourages individuals to develop communication habits that reflect politeness, responsibility, and respect for others in online environments. The cultivation of such ethical behaviors is essential for creating a healthy and productive digital ecosystem, as it fosters mutual respect and understanding among users. Third, Digital Safety refers to an individual's ability to protect oneself and personal data while engaging with technology. This capability encompasses awareness of potential threats, the establishment of safe usage patterns, and the implementation of preventive measures to mitigate risks such as data theft or online fraud. A robust understanding of digital safety is increasingly critical in an era where malicious activities on the internet are prevalent, necessitating proactive strategies for safeguarding personal information. Fourth, Digital Culture embodies an individual's capability to comprehend, appreciate, and enact national values within the framework of life in the digital age. It also implies the utilization of undertaken for the analysis are delineated as Figure 1.

technology to preserve and promote Indonesian culture through digitalization. This not only aids in the conservation of local cultural heritage but also enhances its visibility and accessibility to a global audience. This aspect of digital competency plays a crucial role in cultural exchange and education, allowing for diverse cultural representations in the digital sphere (Kharis et al., 2025; Nurwardani et al., 2024). Data collection for this study was conducted utilizing Google Forms, which contained an array of questions structured on a Likert scale from 1 to 4. The questions employed were rigorously tested for both validity and reliability to ensure the accuracy and consistency of the data gathered. (Permatasari et al., 2025). The survey respondents comprised 10,393 new students originating from diverse regions across Indonesia, specifically covering the Western, Central, and Eastern geographical areas. These participants represented various educational levels within the distance learning system.

2. Random forest

The analytical model implemented in this research is the Random Forest, a classification algorithm fundamentally based on decision trees. This algorithm is widely recognized for its robust accuracy in processing and classifying complex datasets (Hatwell et al., 2020; W. J. Sari et al., 2024). Each constituent decision tree within the Random Forest performs calculations to identify the most prominent class unit, thereby facilitating the classification of specific categories based on the provided training data input (Purwanto et al., 2023). Furthermore, the Random Forest algorithm significantly enhances both the robustness and predictive accuracy of the overall model (W. J. Sari et al., 2024). The sequential steps

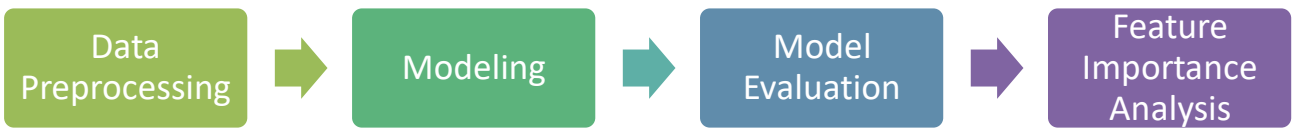

Figure 1. Illustration of the Use of 5-Fold Cross Validation

2.1 Data Preprocessing

This stage involved the transformation of categorical data into numerical values through the application of Label Encoding, a necessary step for compatibility with machine learning algorithms.

2.2 Modeling

The Random Forest model was trained using the preprocessed data to accurately identify the most influential factors contributing to digital literacy.

2.3 Model Evaluation

Model performance was rigorously assessed using a suite of standard metrics, including accuracy, precision, recall, and the confusion matrix, to ensure the reliability and validity of the findings.

2.4 Feature Importance Analysis

This crucial step involved determining the relative importance of each feature (factor) in predicting digital literacy levels, thereby highlighting the most impactful variables within the dataset.

3. Cross Validation

Cross validation is a technique that can be used to evaluate the performance of a model. Cross validation divides the dataset into two parts, namely the training data and the test data. One commonly used method of cross validation is k-fold cross validation. The procedure for k-fold cross validation, as described by Han, Kamber, and Pei (2006), is as follows:

a. **Dividing the Data:** The dataset is divided into k equal-sized parts.
b. Training and Testing**:** k-1 parts are utilized as the training data while one part is used as the test data.
c. Repetition of the Process**:** This process is repeated k times, each time with a different combination of training and test data, ensuring that every part of the dataset has been used once as the test data and k-1 times as training data.

The accuracy values obtained from each iteration are averaged to yield the final accuracy estimate. For example, in a scenario employing 5-fold cross validation, the dataset is divided into five parts, where one part serves as the test data while the remaining four parts are used for training. This process is conducted five times to ensure that every section of the dataset has been utilized once as the test data and four times as training data.

Illustration of 5-Fold Cross Validation: The utilization of 5-fold cross validation can be represented in the Figure 2, where each experiment indicates a distinct arrangement of training and test data.

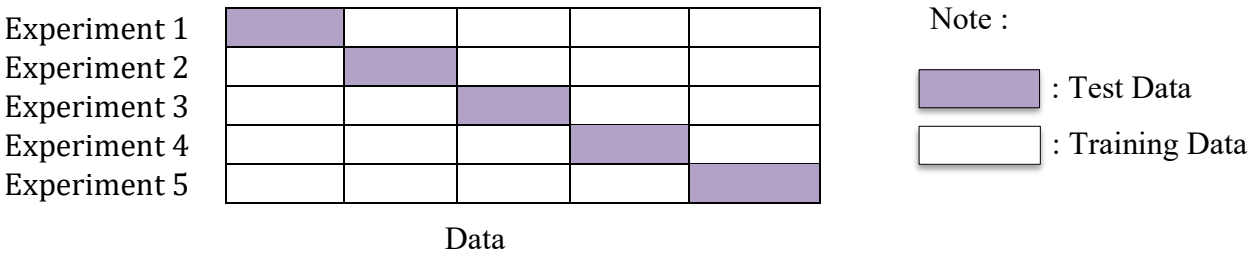

Figure 2. Illustration of the Use of 5-Fold Cross Validation

C. RESULT AND DISCUSSION

The collected data was subsequently analyzed using Random Forest to classify the level of digital literacy among students at the Universitas Terbuka. Table 1 presents the evaluation results obtained through the application of Random Forest and 5-fold cross validation. The evaluation results indicate that the model has an overall accuracy of 93.6%, demonstrating that the model is both consistent and stable. This finding provides a strong foundation for further exploring the factors influencing digital literacy, which, as it turns out, encompasses not only technical skills but also ethical dimensions, behavior, and social awareness in digital interactions. Furthermore, an analysis was conducted on the factors affecting the classification. The results of the feature analysis are illustrated in Figure 2.

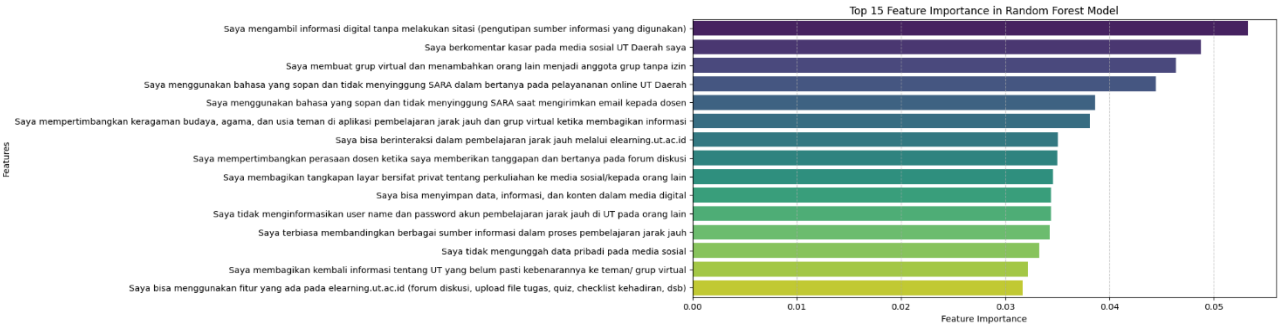

Figure 2. Top 15 Feature Importance in Random Forest Model

The analysis conducted using the Random Forest model reveals that the most significant factors influencing the digital literacy classification of Universitas Terbuka students extend beyond mere technical abilities, demonstrating a more pronounced dominance of digital ethics and behavioural aspects. The feature exhibiting the greatest influence is the statement: "I take digital information without citing it." This finding underscores the critical role of academic behaviour, particularly integrity in source citation, as a primary differentiator in students' digital literacy levels. Students who consistently practice proper citation tend to exhibit higher digital literacy, whereas those who neglect citation demonstrate lower levels of digital literacy. This suggests a strong correlation between academic diligence and digital competence.

Furthermore, social media conduct also contributes significantly to digital literacy. Indicators such as "I make rude comments on my regional UT social media" and "I create virtual groups and add other people without permission" are among the top ten most influential factors. This highlights that the capacity to uphold communication ethics, respect privacy, and maintain polite conduct in digital environments are essential components of students' overall digital literacy. Conversely, while technical proficiencies, such as the ability to interact through and utilize features on elearning.ut.ac.id, do play a role, their impact is comparatively less potent than that of digital ethics. Consequently, digital literacy is not solely quantifiable by technological skill; it is equally defined by how students demonstrate appropriate attitudes, responsibility, and integrity in their daily digital engagements.

Additional features affecting the classification of digital literacy using Random Forest include: "I use polite language and do not offend others based on ethnicity, religion, race, and inter-group relations (SARA) when inquiring about online services," "I employ polite language and do not offend SARA when sending emails to my lecturers," and "I consider the cultural, religious, and age diversity of my peers in distance learning applications." These three factors emphasize the importance of inclusive and ethical digital communication.

These factors have significant implications. Firstly, the use of polite and non-discriminatory language fosters a conducive distance learning environment. This practice reduces the potential for conflicts among students as well as between students and lecturers, enabling smoother academic interactions. Secondly, ethical communication strengthens healthy academic relationships among students, lecturers, and educational staff. As a result, a more supportive learning atmosphere is created, ultimately enhancing student motivation and engagement. Additionally, the awareness of considering cultural, religious, and age diversity in digital interactions has a substantial impact. This inclusive attitude plays a crucial role in fostering effective collaboration in virtual classrooms, particularly at Universitas Terbuka, which comprises students from diverse social and geographical backgrounds. When students are able to interact while being mindful of this diversity, the processes of group discussions, collaborative ssignments, and knowledge-sharing activities are likely to be more productive. These three factors not only serve as technical indicators in the classification of digital literacy but also reflect the significant role that ethical digital communication plays in supporting the effectiveness of distance learning. This indicates that good digital literacy encompasses not only the ability to operate technology but also includes attitude and behavior aspects that contribute to academic success.

A number of features with lower feature importance values are as follows: "I do not upload personal data to social media," "I share information about UT that has not been verified with friends/virtual groups," and "I can effectively use the features available on elearning.ut.ac.id (discussion forums, assignment uploads, quizzes, attendance checklists, etc.)." Although these features contribute less significantly, they remain relevant as they relate to data privacy protection, the dissemination of misinformation, and technical competence in utilizing e-learning features. These three features reflect digital literacy skills directly associated with self-protection, critical thinking, and technical mastery in distance learning. The ability to refrain from sharing personal data on social media signifies students' awareness of digital security. In distance education, this skill is essential for students to learn securely, without fear of information misuse. The capacity for information filtering (anti-hoaxes)

fosters students' critical thinking in utilizing digital sources. From an educational perspective, this contributes to the development of a healthy academic attitude, prevents misinformation, and cultivates a culture of responsible information sharing among students. Mastery of e-learning features, despite receiving a lower value in the model, remains important as a technical foundation for academic success. Students who can effectively engage in discussion forums, upload assignments, participate in quizzes, and independently monitor attendance will be more actively involved in the distance learning process.

Collectively, these results bear significant implications for digital literacy enhancement programs at Universitas Terbuka. The findings highlight that, although certain features such as personal data protection, information filtering, and mastery of e-learning tools have lower feature importance values, they remain crucial in shaping students' digital literacy competencies. These results align with previous studies, which emphasize that digital literacy is not solely determined by technical skills but also the ethical awareness and critical thinking in digital space (Kharis et al., 2025; Lawitta et al., 2025; Syafrida Putri et al., 2025). This comprehensive approach should encompass fostering correct citation habits, promoting courteous communication on social media platforms, instilling respect for privacy, and cultivating an awareness against the dissemination of unverified information. Through this integrated methodology, students are expected to not only achieve technical proficiency but also develop into intelligent, ethical, and responsible participants in the digital sphere.

D. CONCLUSION AND SUGGESTIONS

The analysis using the Random Forest algorithm demonstrates that the factors influencing the digital literacy of Universitas Terbuka students are predominantly shaped by aspects of digital ethics and behaviour, rather than solely by technical abilities. This finding underscores that digital literacy within the context of distance learning encompasses not only the operational skills of devices and applications but also critical dimensions of attitude, responsibility, and integrity in digital interactions. The most impactful feature in digital literacy classification is the statement: "I take digital information without citing it." This highlights that academic integrity, particularly the accurate citation of sources, serves as a primary indicator distinguishing students' digital literacy levels. Students who consistently practice proper citation tend to exhibit higher digital literacy, whereas those who disregard citation demonstrate comparatively lower digital literacy. This establishes a strong link between academic consciousness and digital proficiency. Furthermore, social media behavior significantly contributes to digital literacy. Indicators such as "I make rude comments on my regional UT social media" and "I create virtual groups and add other people without permission" are among the highest-weighted factors. This confirms that digital communication ethics, polite interaction, and respect for privacy are essential components in cultivating students' digital literacy. While technical factors, such as the ability to effectively use and interact with elearning.ut.ac.id, retain their relevance, their influence is notably less significant compared to the ethical dimension of digital engagement.

This finding suggests that the success of distance learning is not exclusively determined by technological aptitude but also by students' capacity to maintain digital conduct aligned with academic and social norms. Based on these findings, the primary implication is the necessity for Universitas Terbuka to develop digital literacy enhancement programs with a more holistic approach. Training initiatives should extend beyond merely focusing on the technical aspects of platform usage to comprehensively include digital ethics education. This involves instilling awareness regarding the importance of citation, fostering an understanding of plagiarism, promoting ethical communication on social media, emphasizing respect for privacy, and encouraging caution in disseminating unverified information. Through such an integrative approach, Universitas Terbuka students are expected to not only achieve technical mastery but also develop ethical competence in leveraging digital technology. Ultimately, this will elevate the quality of distance learning and cultivate graduates who are critical thinkers, responsible digital citizens, and possess integrity in navigating the challenges of the digital era.

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