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Student Digital Literacy Profile: Diagnostic Analysis and Its Implications for Learning

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ABSTRACT Digital literacy is a crucial competency for students in the 21st century, particularly in technology-driven learning environments. This study examines students' digital literacy profiles across five key aspects: information, communication, media, problem-solving, and digital security. A diagnostic analysis was conducted to identify students' strengths and challenges in these areas. The method used in this study is a descriptive research approach, providing a detailed portrayal of students' digital competencies. The research involved 269 students in Yogyakarta, with data collected through a validated multiple-choice digital literacy skills test aligned with predetermined indicators. The results indicate that students demonstrate the highest competence in searching for digital information, with 77% successfully formulating strategies for finding information online. However, digital communication remains the greatest challenge, as only 40% of students effectively design ways to share information using digital devices. These findings highlight the need to enhance digital literacy education, particularly in communication, information evaluation, cybersecurity, problem-solving, and collaboration. The study suggests implementing comprehensive strategies, including source evaluation, digital communication simulations, cybersecurity education, project-based learning, and digital collaboration. Strengthening these aspects will help students use digital technology more effectively, responsibly, and in line with 21st-century learning demands.

Keywords Digital literacy, Diagnostic analysis, Technology-integrated learning, Student digital competency, 21st-century education.

1. INTRODUCTION

In the digital era, the way we work has evolved, and many industries are experiencing digital disruption. The integration of the internet into daily life has reshaped how individuals access information and perceive literacy (Umut Zan et al., 2020). The widespread use of digital devices and the internet has brought significant changes at social, political, and economic levels, creating challenges in an increasingly globalized and ever-changing society (Gutiérrez-Ángel et al., 2022). As technological advancements continue to drive change, all industries, including the education sector, must adapt to evolving conditions. Digital technology has not only transformed work processes but also revolutionized how people learn (Promrub & Sanrattana, 2022).

The rapid development of digital technology has fostered a culture of connectivity, creativity, and online interaction. People's daily activities are increasingly intertwined with the virtual world, where they seek information and engage in activities such as blogging, online gaming, downloading music, digital transactions, and social media interactions (Rahayu & Mayasari, 2018). A survey by Hootsuite and We Are Social (2021) found that Indonesian respondents aged 16-64 spend an average of 7 hours and 52 minutes online daily, exceeding the global average of 6 hours and 54 minutes. Indonesia ranks 8th out of 42 surveyed countries for the longest internet usage, surpassing Singapore and Vietnam (Azzahra & Amanta, 2021). However, this increased internet usage does not necessarily equate to improved digital literacy.

Students often struggle to filter relevant content from the vast amount of online information, leading to information overload. Additionally, disparities in

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technology access contribute to a digital divide, limiting opportunities for digital literacy development. Overreliance on technology may also reduce students' learning focus if not managed effectively (Ervianti et al., 2023). Despite being digital natives, many students lack the ability to navigate, evaluate, and utilize digital resources effectively, impacting their readiness for the digital society (Erwin et al., 2022; Öncül, 2020).

Digital literacy is not only crucial for higher education but also for career readiness and social participation (Johnston, 2020). Strengthening digital literacy from an early age minimizes online risks and equips students with the skills necessary for meaningful internet use(Azzahra & Amanta, 2021). It is a foundational skill that enables students to compete in the workforce by effectively utilizing digital tools and content (Rini et al., 2022). Moreover, students with strong digital literacy are not only better prepared for workforce demands but are also capable of integrating technological advancements into their academic pursuits.

In today's rapidly evolving workplaces and educational environments, being digitally literate has become a crucial priority for enhancing knowledge and skills in both academic and professional settings (Arslantas & Gul, 2022). Digital literacy goes beyond the mere ability to use technology for social interactions; it requires individuals to critically analyze and integrate digital information. However, many students face challenges in this area, as they are often mistakenly labeled as 'digital natives' under the assumption that they inherently possess technological proficiency (Le et al., 2022; Margaryan et al., 2011). In reality, digital literacy is not just about searching for and identifying information but also about assimilating, evaluating, and applying it effectively. Beyond mastering basic technical skills, it involves the ability to use online information wisely and develop a deeper understanding of it (Ng, 2012; Peng & Yu, 2022; Tang & Chaw, 2016). As traditional skills that were once performed in analog environments transition into digital spaces, the definition of digital literacy has also expanded. It now encompasses not only proficiency in software and hardware but also the ability to develop, analyze, and interact with digital content (Amnie et al., 2021; Chetty et al., 2018; Farias-Gaytan et al., 2023). Digital literacy integrates both cognitive and technical skills, enabling individuals to understand information critically and engage in digital interactions responsibly (Nurhasanah et al., 2024). This competency includes not just technical expertise in using digital tools but also an awareness of digital security, ethical online interactions, and the critical evaluation of digital information.

The rapid advancements in information and communication technology have heightened the demand for digital literacy across various aspects of life. As a result, digital literacy has become a central focus for society, institutions, and policymakers (Audrin & Audrin, 2022), as it plays a key role in preparing individuals to adapt and compete in the era of digital transformation (Brata et al., 2022). Recognizing its significance, the Indonesian government has placed digital literacy among the five priorities in its national strategy to accelerate digital transformation (Sekertariat Kabinet Republik Indonesia, 2020). This highlights that digital literacy is not merely an additional skill but a fundamental necessity in navigating the digital era.

As technology continues to evolve, digital literacy must also progress. In education, it has been a crucial topic since the late 20th century, particularly in the context of open, distance, and digital learning (Marín & Castañeda, 2023). The digitalization of education represents a profound modernization and transformation of the learning system, ensuring it meets contemporary challenges (Abrosimova, 2020). Emerging digital trends have encouraged schools and educational institutions to integrate ICT into teaching and learning (Nguyen & Habók, 2022). Consequently, continuous education and training are essential to enhancing digital literacy, ensuring individuals remain relevant and competent in an increasingly digital world (Ervianti et al., 2023; Farias-Gaytan et al., 2022). Learners must not only master technology but also use it wisely and ethically (Yeyendra et al., 2025).

Strong digital literacy enables students to adapt to technology-based learning environments, access relevant information, develop critical thinking, and enhance communication skills (Ervianti et al., 2023). Improved digital literacy also fosters greater classroom engagement, as students can focus more on learning rather than technical difficulties. Given its numerous benefits, educators must design effective strategies to enhance students' digital literacy, not only to optimize learning outcomes (Peng & Yu, 2022) but also to equip them with the skills needed to thrive in the digital age—encouraging competitiveness, creativity, and active participation in an ever-evolving technological landscape (Firdaus et al., 2025).

To effectively prepare students for the digital era, appropriate evaluation strategies are essential. One effective approach is diagnostic testing, which helps assess students' learning outcomes and provides valuable feedback for improvement. Diagnostic tests are designed to identify specific learning difficulties, determine necessary interventions, and serve as a foundation for future learning (Juita et al., 2023; Rusilowati et al., 2024). The insights gained from these tests enable the design of tailored learning experiences that align with students' abilities and needs, leading to more effective instruction and improved learning outcomes (Asnawi et al., 2023). Therefore, conducting a diagnostic study is crucial to mapping students' digital literacy profiles and assessing their preparedness for digital challenges.

In addition to general competencies, digital literacy is particularly vital within STEM (Science, Technology, Engineering, and Mathematics) education, which emphasizes the integration of technology and critical thinking. Digital literacy is increasingly recognized as a foundational competency in the 21st-century education landscape, especially within the context of STEM learning. The integration of STEM education with digital literacy skills can foster students' cognitive development and logical thinking across various scientific disciplines (Rizaldi et al., 2020). However, despite its importance, previous studies have not fully explored the specific profiles and gaps of digital literacy skills among students in STEM-focused tracks, particularly at the secondary school level. Most existing research tends to focus on general digital usage or access to technology, rather than assessing students' competencies across specific aspects of digital literacy.

To address this gap, this study examines students' digital literacy in a more structured and diagnostic manner using the DigComp (Digital Competence Framework) developed by the European Commission. DigComp provides a comprehensive model for understanding digital competence across five key aspect: information and data literacy, communication and collaboration, digital content creation, safety, and problem-solving (Vuorikari et al., 2022). This study aligns and adapts the framework into five focused aspects: information, communication, media, problem-solving, and digital security, tailored to the educational context.

Furthermore, the analysis is situated within the theoretical lens of constructivist learning theory, which posits that learners actively construct knowledge based on their prior understanding and through social interaction with their surrounding environment (Mohammed & Kinyo, 2020), including engagement with digital tools and contexts. From this perspective, digital literacy is not merely a set of isolated technical skills, but rather a dynamic set of competencies that support deeper learning, collaboration, and critical thinking. The integration of DigComp and constructivist theory in this study offers a more robust pedagogical foundation for understanding students' readiness to engage in digital learning environments.

Based on these theoretical and practical frameworks, this study aims to analyze students' digital literacy across five key aspects: information, communication, media, problem-solving, and digital security. Information literacy involves searching for and identifying relevant digital information effectively, ensuring its accuracy and usefulness. Digital communication focuses on sharing ideas clearly and collaborating within digital environments, fostering knowledge exchange. Media literacy emphasizes assessing the credibility of digital content, including text, images, sound, and video. Additionally, problem-solving in digital contexts requires using digital tools strategically to address conceptual challenges and make informed decisions about appropriate technologies. Lastly, digital security encompasses protecting personal data, applying security measures, and ensuring the safe and sustainable use of digital applications. The findings are expected to provide a comprehensive overview of students' digital literacy levels and their implications for the learning process. By understanding these profiles, educators and policymakers can develop more effective strategies to enhance digital literacy, fostering meaningful and sustainable learning experiences tailored to students' needs.

2. METHOD

2.1 Research Design and Participants

This study employs a descriptive research method, which aims to provide a detailed depiction of the phenomenon under investigation without any treatment or intervention. This method was chosen because it is suitable for comprehensively describing students' digital literacy skills based on predetermined indicators. The subjects of this study consisted of 269 twelfth-grade science students from several high schools in Yogyakarta, aged 16–17 years. Academically, these students specialized in science and demonstrated varying levels of academic achievement, categorized as high, medium, and low. In terms of digital access, most students owned personal smartphones.

2.2 Data Collection

The data collection was conducted over a period of approximately four weeks, involving students from six schools. During this period, a digital literacy diagnostic test was distributed and administered under the supervision of teachers and researchers. Prior to data collection, official approval was secured from school authorities. Participants were informed about the objectives and procedures of the study. Informed consent was obtained, and participation was voluntary. Students were assured that their identities would be kept confidential and that the collected data would be used solely for academic and research purposes. Ethical standards were upheld throughout the research process by protecting personal data and ensuring that participants were not exposed to any form of harm.

2.3 Data Collection Tools

Data collection was carried out using a diagnostic multiple-choice test on digital literacy skills, which was developed based on relevant aspects and indicators of digital literacy. The test instrument was validated by experts, practitioners, and peer reviewers competent in their respective fields. The diagnostic test used to measure students' digital literacy skills in this study consists of nine questions that have been tailored to the aspects and indicators of digital literacy skills. The aspects covered in this test include information, communication, media, problem-solving, and digital security. Each question is designed to assess the extent to which students can

Table 1 Aspect and indicator of digital literacy skill

No.	Aspect	Indicator
1.	Information	Searching for digital information
		Identifying digital information effectively
2.	Communication	Communicating information in a digital environment
		Collaborating on information/knowledge in a digital environment
3.	Media	Assessing the accuracy of information from text, images, audio, or video in a digital environment
4.	Problem Solving	Solving conceptual problems through digital means
		Making informed decisions about the most appropriate digital devices based on objectives or needs
5.	Digital Security	Personal data protection and security measures
		Safe and sustainable application usage

understand and apply digital literacy skills in both learning contexts and everyday life. For example, in the information aspect, students are tested on their ability to search for and evaluate credible information sources. In the communication and media aspect, students are assessed on their skills in communicating ethically and responsibly through digital media. In the problem-solving aspect, students are evaluated on their ability to solve conceptual problems through digital means. Meanwhile, the digital security aspect measures students' awareness of personal data protection and online ethics.

2.4 Data Analysis

Data related to students' digital literacy skills were analyzed descriptively. The percentage calculation of students' response patterns can be determined using the following formula.

$$NP = \frac{PR}{n} x\ 100\%$$

Where NP represents the percentage of students selecting a specific answer option, PR is the number of students choosing that particular answer option, and N is the total number of students.

Based on the study findings, analysis, and relevance to the topic of physics learning, the aspects and indicators of digital literacy skills examined in this study are presented in Table 1.

The calculation results will be presented in percentage form, which will then be used to classify students' digital literacy skills into specific categories. After obtaining the percentage, the data will be analyzed by comparing each student's score with the digital literacy skill categories listed in Table 2.

Table 2 Percentage score interpretation criteria by Arikunto (2021)

Percentage (%)	Category
80-100	Excellent
60-80	Good
40-60	Fair
20-40	Poor
0-20	Fail

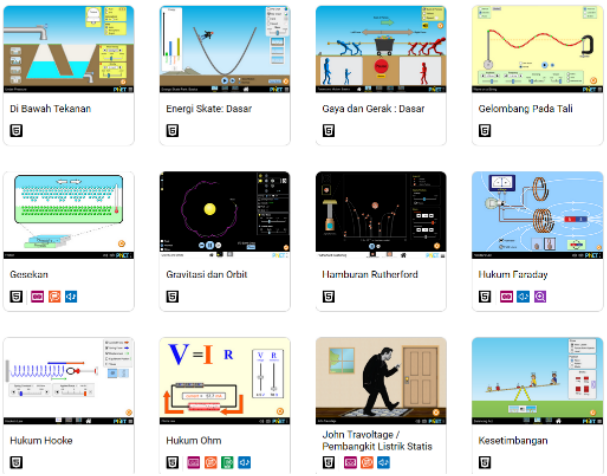
The interpretation criteria proposed by Arikunto (2021) are used to systematically and objectively describe students' level of digital literacy. These criteria align with the research objectives, namely providing accurate and valid interpretations in accordance with the descriptive method.

3. RESULT AND DISCUSSION

The rapid development of digital technology has brought significant changes to various aspects of life, including education. Digital literacy has become an essential skill that students must possess to effectively and responsibly utilize technology in learning. The ability to think critically about information obtained, protect personal data, and efficiently use information are crucial skills needed to navigate the 21st century (Suwanto & Lestari, 2024). Digital literacy not only includes the ability to use technological devices but also encompasses understanding digital information, ethical internet usage, and cybersecurity. However, there are differences in students' levels of digital literacy, which can be influenced by various factors such as access to technology, support from the surrounding environment, and experience in using digital media. Therefore, it is important to conduct a diagnostic analysis of students' digital literacy profiles to identify their strengths and weaknesses in this skill.

To better understand students' digital literacy profiles, this study analyzed responses to several diagnostic items based on five aspect: information, communication, media, problem-solving, and digital safety. Figure 1 illustrates an example of a question targeting the problem-solving aspect of digital literacy. This question is designed with the indicator of the ability to make informed decisions about the most appropriate digital device based on the user's goals or needs. Through this question, students are expected to analyze the given situation and develop effective steps to solve the problem digitally.

Endang will conduct an interactive simulation on wave interference using the PhET simulation.



PhET (Physics Education and Technology) is an interactive simulation of physics phenomena available as a free-access website.

The steps for conducting the simulation are as follows:

1. Recording the simulation results.
2. Selecting a topic that matches the intended simulation.
3. Clicking the play button on the simulation.
4. Observing the displayed simulation.
5. Adjusting the variable parameters.

The correct sequence of steps for conducting a physics simulation is:

a. 2-3-1-5-4
b. 2-3-5-4-1
c. 2-5-3-1-4
d. 3-2-5-4-1
e. 3-2-4-5-1

Figure 1 A test item related to the problem-solving aspect of digital literacy

3.1 Student Digital Literacy Profile: A Diagnostic Analysis

Diagnostic analysis was conducted by categorizing students based on their level of digital literacy into five categories: excellent, good, fair, poor, and failed. This categorization aims to understand the distribution of students' abilities in accessing, understanding, and effectively using digital technology. Thus, the analysis results can provide a clearer picture of the aspects of digital literacy that have been mastered and those that still require improvement, allowing learning interventions to be tailored to the needs of each student group.

Data analysis results indicate that students' digital literacy varies across the measured aspects. These differences reflect students' levels of understanding and skills in accessing, evaluating, and utilizing digital technology effectively. Figure 2 shows a graph related to the distribution of student' digital literacy skills. This graph serves as a basis for designing more effective learning strategies to enhance students' digital literacy.

In the Information aspect, there are two main indicators. The first indicator relates to searching for digital information, where 77% of students have been able to formulate effective ways to search for information using digital technology through the internet. This indicates that most students understand the necessary steps to obtain accurate information when conducting online searches. The second indicator focuses on effectively identifying digital information, with 45% of students successfully outlining an appropriate process for identifying information. This means that nearly half of the students understand the necessary steps to verify the accuracy and relevance of the information they obtain.

In the Communication aspect, digital literacy encompasses two key indicators: communicating information in a digital environment and collaborating on information or knowledge using digital tools. 40% of students have mastered the skill of sharing information digitally by designing effective ways to deliver information through online digital platforms. This indicates that they are proficient in using various digital communication platforms such as email, social media, or messaging applications. Additionally, 60% of students have demonstrated the ability to collaborate using digital tools to solve problems effectively. This highlights their capacity to utilize digital technology for teamwork and knowledge-sharing.

The Media aspect assesses students' ability to evaluate the accuracy of digital information. 52% of students have demonstrated proficiency in verifying the credibility of online information, which is crucial in today's digital era where misinformation is prevalent. Students who excel in this skill can systematically assess the accuracy and reliability of the information they receive.

In the Problem-Solving aspect, two indicators evaluate students' digital literacy. The first indicator measures the ability to solve conceptual problems using digital tools, with 46% of students successfully designing digital activities as solutions to problems they face. This reflects their ability to identify, analyze, and apply digital technology effectively in different problem-solving contexts. The second indicator assesses decision-making skills regarding the most appropriate digital tools for specific needs. 52% of students were able to outline structured steps for conducting simulations using digital devices, showing that more than half of the students can strategically identify, select, and use digital tools for problem-solving.

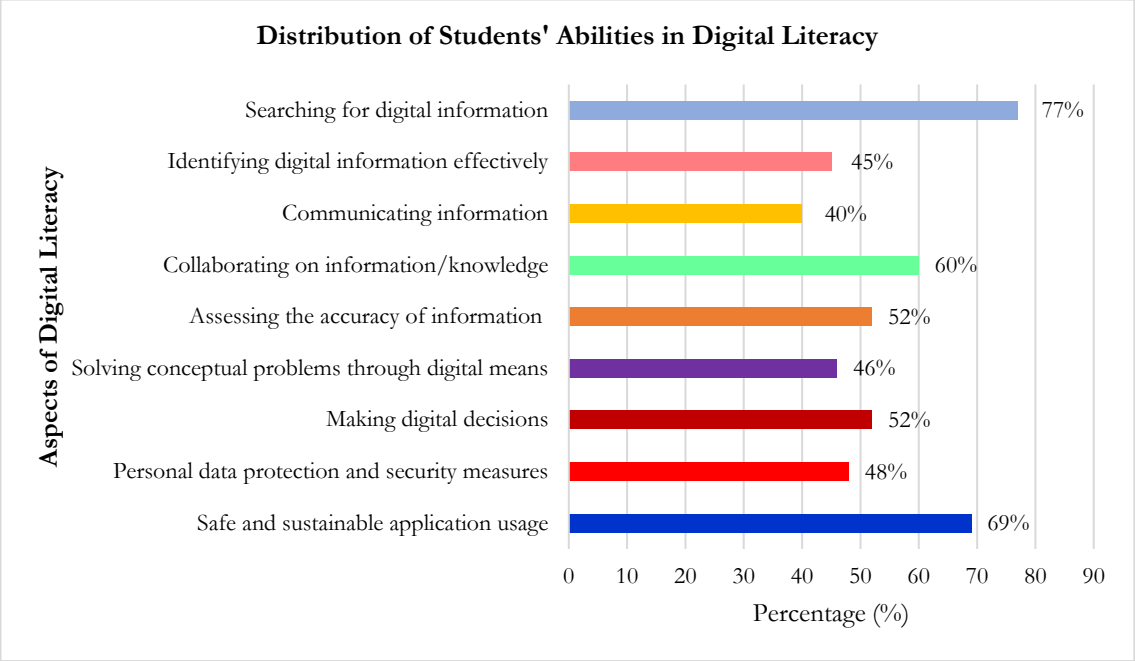


Figure 2 Distribution graph of students' abilities in digital literacy

The Security aspect evaluates students' awareness of data protection and digital safety. 48% of students understand how to safeguard personal data and implement security measures on digital devices, demonstrating awareness of the importance of privacy and online security. Additionally, 69% of students can select and use secure and sustainable applications, indicating their ability to assess security risks and consider sustainability in digital technology usage.

To comprehensively measure digital literacy skills, a clear mapping of aspects and indicators is essential in constructing assessment items. Each question must accurately reflect the designated indicators to effectively reveal students' levels of digital literacy. Digital literacy encompasses multiple aspects, including information, communication, media, problem-solving, and digital security. These aspects are further broken down into specific indicators that define expected digital literacy competencies. Each indicator is then translated into assessment items that measure the corresponding skills operationally.

Figure 3 illustrates the proportion of students who have achieved proficiency across various digital literacy indicators. The highest levels of proficiency are evident in the ability to search for digital information and in practicing safe and sustainable application usage. These results indicate that students are generally confident in navigating digital platforms to find information and demonstrate awareness of responsible technology use.

On the other hand, lower proficiency levels are observed in digital communication, collaboration, and personal data protection. These findings suggest a need for further emphasis on building students' interpersonal and ethical competencies in digital environments. Moderate levels of proficiency are noted in indicators related to evaluating the accuracy of digital information, making informed digital decisions, and solving conceptual problems using digital tools. These aspects highlight students' developing capacities in critical thinking and digital problem-solving. Overall, Figure 3 emphasizes the variation in students' digital literacy competencies. While foundational skills appear well established, more complex cognitive and ethical dimensions require targeted support to ensure a more balanced and holistic digital literacy development.

Diagnostic Analysis of Item 1: searching for digital information.

The diagnostic related to item number 1, which assesses the information aspect with the indicator of searching for digital information, shows that 77% of students are already capable of formulating ways to search for information using digital technology through the internet. Overall, the analysis results indicate variations in the students' accuracy and skills in searching for digital information. However, variations exist in their accuracy and effectiveness:

- A total of 5% of students are less meticulous in reading the steps of information searching,
- 12% of students have been able to formulate ways to search for information but are still inaccurate in selecting and evaluating the required information.
- 3% of students experience difficulties in the initial steps of searching for information on the internet.

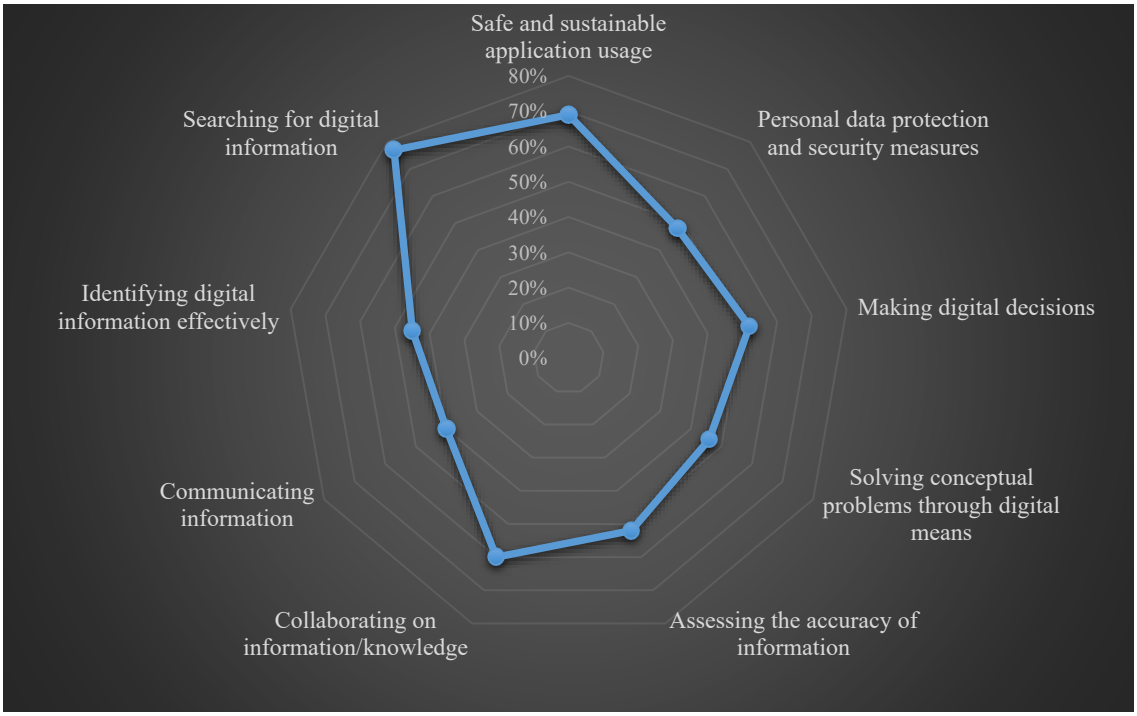


Figure 3 Proficiency rate across digital literacy indicators

Based on these findings, students are encouraged to be more mindful in understanding the steps of information searching, enhance their accuracy in selecting and evaluating information, and cultivate a habit of effectively utilizing digital technology to support their search for information. The ability to tag, search, filter, and manage information is a crucial component of digital literacy. Digital literacy goes beyond technical proficiency in using technology; it also encompasses the ability to locate, critically evaluate, select, and apply information effectively in the digital world (Vodă et al., 2022). In today's era of information overload, strong digital literacy empowers individuals to act as reliable gatekeepers of information. With these skills, they can differentiate between credible and reliable sources and misleading or false information. Therefore, digital literacy serves as a fundamental pillar for modern society in navigating the complexities of the digital age.

Diagnostic Analysis of Item 2: identifying digital information effectively.

The diagnostic related to item number 2, which assesses the information aspect with the indicator of effectively identifying digital information, shows that 45% of students have been able to structure the process of identifying information using digital technology accurately. However, some students still struggle to understand the credibility of information sources.

- A total of 18% of students do not yet understand that blogs cannot be fully relied upon as credible sources of information, so they are advised to pay more attention to the characteristics of blogs and distinguish between trustworthy and untrustworthy sources.
- 9% of students still do not understand that both blogs and social media are not always reliable references for information, so they are encouraged to be more critical in evaluating the sources of information obtained from these platforms.

The results of this analysis indicate the need to improve students' understanding of the credibility of digital information sources, especially in distinguishing valid information from less reliable ones. Therefore, learning should place greater emphasis on digital literacy skills, particularly in evaluating and identifying the reliability of information from various sources on the internet.

Diagnostic Analysis of Item 3: Communicating information in a digital environment.

The diagnostic analysis of item number 3, which measures the communication aspect with the indicator of communicating information in a digital environment, shows that 40% of students have been able to design ways to share information using digital devices online. However, some students still face difficulties in understanding various effective methods of sharing information.

- A total of 11% of students have not realized that sharing files via social media can be an effective method, so they are advised to try this approach.
- 20% of students do not yet understand that sharing files by providing keywords or article titles to be entered into a search engine is also an effective way to share information.

- 28% of students have not grasped that sending the source website address of an article can help in sharing information more accurately and efficiently.

The results of this analysis indicate the need for further strengthening of students' understanding of various digital information-sharing methods. Therefore, it is recommended to provide learning that emphasizes effective digital communication strategies so that students can optimize technology for sharing and disseminating information.

Diagnostic Analysis of Item 4: Collaborating on information/knowledge in a digital environment.

The diagnostic analysis of item number 4, which measures the communication aspect with the indicator of collaborating information or knowledge in a digital environment, shows that 60% of students have been able to design collaboration patterns using digital devices to solve problems effectively. However, some students still face difficulties in understanding the importance of initial discussions in the digital collaboration process.

- A total of 20% of students have not fully realized that initial discussions are a crucial step before carrying out collaboration, so they are advised to pay more attention to this stage to ensure more effective coordination.
- 18% of students face challenges in accuracy when designing collaboration patterns using digital devices. Therefore, they are encouraged to be more meticulous in planning collaboration strategies to ensure a smoother and more effective process.

The results of this analysis indicate that there is still a need to strengthen students' understanding and skills in digital collaboration, particularly in planning and accuracy. Therefore, learning should focus more on effective digital collaboration strategies, enabling students to work together more optimally in a digital environment.

Diagnostic Analysis of Item 5: assessing the accuracy of information in the form of text, images, audio, or video in a digital environment.

The diagnostic analysis of item number 5, which measures the media aspect with the indicator of assessing the accuracy of information in the form of text, images, audio, or video in a digital environment, shows that 52% of students have been able to evaluate the credibility of information sources effectively. However, some students still struggle to distinguish credible sources of information.

- A total of 20% of students have not yet understood that blogs and similar platforms cannot be fully relied upon as accurate sources of information. Therefore, they are advised to be more critical in evaluating the characteristics of these sources.
- 11% of students are still unaware that blogs and social media platforms such as YouTube have limitations in their credibility as sources of information, making it necessary for them to be more careful in assessing the validity of the information they obtain.
- 17% of students do not yet understand that social media, particularly YouTube, cannot always be considered an accurate reference. Thus, they are encouraged to pay closer attention to the credibility of the content they access.

The results of this analysis highlight the need to improve students' skills in evaluating the accuracy of digital information. Therefore, learning should place greater emphasis on media literacy, including strategies for identifying reliable sources and critically filtering and verifying information.

Diagnostic Analysis of Item 6: Solving conceptual problems through digital means.

The diagnostic analysis of item number 6, which measures the problem-solving aspect with the indicator of solving conceptual problems through digital means, shows that 46% of students have been able to formulate digital activities to address emerging issues. However, 54% of students are still unable to design digital solutions for solving conceptual problems. Therefore, it is recommended that students explore various digital learning resources, such as downloading and running simulations, to help them grasp concepts more concretely. The results of this analysis highlight the need to strengthen the application of digital technology as a tool for solving conceptual problems. Hence, students should be given more opportunities to explore various platforms and digital learning resources that can assist them in understanding and effectively solving problems.

Diagnostic Analysis of Item 7: Making informed decisions about the most appropriate digital devices based on objectives or needs.

The diagnostic analysis of item number 7, which measures the problem-solving aspect with the indicator of making decisions based on information about the most appropriate digital devices according to objectives or needs, shows that 52% of students have been able to accurately design the stages for conducting simulations using digital devices. However, some students still struggle with systematically executing simulations.

- A total of 15% of students do not pay enough attention to the step of adjusting variable quantities before recording simulation data, so they are advised to be more meticulous in following this procedure.
- 6% of students have not yet been able to structure the simulation steps correctly.

- 24% fail to properly consider the initial steps when conducting a simulation using digital devices. Therefore, they are encouraged to better understand and adhere to the correct procedures when running simulations to ensure more accurate results aligned with learning objectives.

The results of this analysis highlight the need to enhance students' skills in systematically and accurately conducting digital simulations. Hence, learning should place greater emphasis on procedural understanding in the use of digital devices, particularly in performing scientific simulations.

Diagnostic Analysis of Item 8: personal data protection and security measures.

The diagnostic analysis of item number 8, which measures the security aspect with the indicator of protecting personal data and security measures, shows that 48% of students have successfully designed methods to protect personal data on digital devices effectively. However, some students still struggle to understand various digital security risks.

- Total of 15% of students do not pay sufficient attention to the given instructions, so they are advised to be more careful when reading and understanding the questions.
- 6% of students are unaware that visiting websites potentially containing viruses can compromise digital device security.
- 14% of students do not understand the risks associated with transferring data through virus-infected storage devices.
- 17% have not realized the negative impact of downloading illegal files on device security.

The results of this analysis highlight the need to enhance students' understanding of digital security, particularly in protecting devices from threats such as viruses, malware, and risky cyber activities. Therefore, digital security education needs to be reinforced, including practical strategies for identifying dangerous websites, avoiding data transfers from untrusted sources, and understanding the risks of illegal downloads to safeguard data and digital devices.

Diagnostic Analysis of Item 9: safe and sustainable application usage.

The diagnostic analysis of item number 9, which measures the security aspect with the indicator of using safe and sustainable applications, shows that 69% of students have been able to select the appropriate type of application and use digital devices securely. However, some students still lack a complete understanding of security aspects in application usage.

- A total of 15% of students are unaware that requesting applications from friends can pose a security risk to digital devices. Therefore, they are advised to be more cautious and ensure that applications are downloaded directly from official sources.
- 14% of students understand digital security principles but are still unaware that conducting online simulations through official websites is a safer option. They are encouraged to utilize official platforms to minimize security risks.

These findings highlight the need to enhance students' awareness of safe application usage, including downloading apps only from trusted sources and utilizing official platforms for digital simulations. With better understanding, students can use digital devices more wisely, ensuring both security and sustainability.

Based on students' responses, it can be concluded that the highest digital literacy skill is in the aspect of information retrieval, where 77% of students have been able to develop methods for searching information using digital technology via the internet. Conversely, the lowest digital literacy skill is in the aspect of communication, particularly in the indicator of communicating information in a digital environment, with only 40% of students able to design ways to share information online using digital devices.

These results indicate that while most students have demonstrated strong skills in searching for digital information, there is still a need to strengthen their ability to communicate and share information effectively in digital environments. Therefore, digital literacy education should place greater emphasis on developing digital communication skills, such as sharing information safely, efficiently, and in alignment with the intended use of digital technology.

Efforts to enhance digital literacy should begin at the foundational level by improving general literacy, which involves developing the ability to understand, interpret, create, and communicate texts. This initiative must also incorporate critical thinking skills, as well as the ability to observe, analyze, and interpret information critically, while understanding the logical relationships between ideas to support rational decision-making processes. Based on a more specific definition of digital literacy, these efforts require the ability to find, evaluate, use, and create content on digital platforms (Azzahra & Amanta, 2021).

Digital Literacy Performance by School Context

Table 4 illustrates the digital literacy performance of students across six schools, assessed in five key aspects. The color coding highlights variations in proficiency, with green indicating higher scores and red representing lower scores.

Table 3 Digital literacy performance across schools

School	Information	Communication	Media	Problem Solving	Digital Security
School A	77%	60%	57%	50%	62%
School B	84%	71%	74%	67%	70%
School C	71%	53%	74%	47%	71%
School D	50%	57%	57%	36%	50%
School E	44%	38%	53%	35%	47%
School F	56%	29%	21%	31%	44%

The heatmap visualization provides insights into the variations in students' digital literacy performance across six different schools, based on five key aspects: information, communication, media, problem-solving, and digital security. The results indicate significant disparities between schools, influenced by various factors, including school ranking, location, and ownership status. Among the six schools, School B stands out as the highest-performing institution, particularly excelling in information literacy (84%), media literacy (74%), and digital security (70%). School B is a public school located in an urban area and is recognized as one of the top 60 high schools in Indonesia (Gramedia, 2024). This strong performance suggests that students in School B have better access to digital resources, structured learning environments, and potentially more exposure to digital literacy training.

In contrast, Schools E and F demonstrate the lowest overall digital literacy performance, with particularly weak scores in digital communication (38% and 29%) and media literacy (53% and 21%). School E is a public school, while School F is a private institution managed by a foundation, both of which are situated in rural areas. The lower scores in these schools may indicate limited access to digital infrastructure, fewer opportunities for digital learning, or a lack of emphasis on digital literacy in their curricula.

The information literacy aspect emerges as the strongest across all schools, with relatively high scores except in School E. On the other hand, communication and problem-solving appear to be the most challenging aspect, with several schools displaying lower proficiency levels, as indicated by the predominance of yellow and red shades in the heatmap.

These findings underscore the existing digital literacy gap between urban and rural schools, as well as between public and private institutions. The results highlight the need for contextual learning strategies, targeted interventions, and improved digital access in schools with lower performance. Strengthening digital communication and problem-solving skills should be a priority to ensure that all students, regardless of their school's location or status, can navigate the digital world effectively.

3.2 Implications in Learning

The analysis of students' digital literacy skills provides several important implications for learning, particularly in enhancing their understanding and ability to effectively utilize digital technology. The following are some key implications that can be applied in the learning process:

Strengthening Skills in Searching and Evaluating Digital Information

Although many students can search for information using digital technology, difficulties still exist in assessing the accuracy of the obtained information. Therefore, learning strategies should emphasize evaluating information sources, such as identifying credible sources, comparing information from multiple sources, and understanding potential biases in digital information.

Enhancing Digital Communication Skills

The ability to communicate information in digital environments still needs improvement. Learning can be directed toward teaching students how to share information safely and efficiently, such as using document-sharing platforms, copying source links, and understanding digital communication ethics. Simulating information-sharing through digital discussion forums can be one of the applied learning methods.

Strengthening Digital Security Awareness

Some students still lack an understanding of the importance of protecting personal data and digital security, including the risks associated with accessing unsafe websites, transferring data through virus-infected devices, and using unauthorized applications. Therefore, digital literacy materials should be integrated to cover cybersecurity risks, methods for securing personal data, and safe practices for using digital applications and media.

Developing Digital Problem-Solving Skills

Many students struggle with designing digital solutions to solve problems, particularly when using simulations and technology-based experiments. To address this challenge,

learning can be optimized through project-based learning (PBL), where students explore digital simulations to understand scientific concepts and apply technology-driven problem-solving approaches. Teaching digital literacy skills implicitly through student engagement in project-based work is considered an effective teaching and learning strategy, as it fosters student-centered learning and enhances students' ability to navigate digital environments (Churchill, 2020). By integrating PBL with digital literacy, students not only develop technical competencies but also critical thinking and problem-solving skills essential for the digital age.

Implementing Digital Collaboration-Based Learning

Some students do not fully understand the importance of initial discussions before collaborating in digital environments. Teachers can implement project-based learning models and online discussions, where students work in groups to complete digital-based tasks using collaborative platforms such as Google Docs, Padlet, or online discussion forums.

Overall, the results of this analysis emphasize the importance of integrating digital literacy into education through strategies such as information exploration, digital communication, cybersecurity, and technology-based problem-solving. With the right approach, students can be better prepared to face challenges in the digital era and utilize technology wisely to support their learning process.

Furthermore, the steps proposed by Azzahra & Amanta (2021) provide a strategic guide for enhancing digital literacy in Indonesia. The implementation of these steps can strengthen a more inclusive digital literacy ecosystem, particularly in the educational context. Some implications that can be applied in learning based on these steps include:

Integration of Digital Literacy into the Curriculum

Digital literacy should be incorporated into the curriculum at all educational levels, with an approach that not only emphasizes technical skills but also critical thinking in evaluating digital information.

Enhancing Teacher Competence

As the primary facilitators of learning, teachers need digital literacy training that covers technology utilization, cybersecurity, and strategies for teaching critical thinking to students.

Collaboration with the Private Sector and Government

The provision of relevant educational content, access to digital devices, and improvements in digital infrastructure should be carried out through synergy between the government, schools, and the private sector.

The Role of Parents in Children's Digital Literacy

Parents should also be equipped with basic digital literacy skills so they can guide their children in using technology safely and productively.

By implementing these steps in the education sector, digital literacy in Indonesian society is expected to improve, enabling individuals to use technology more wisely and responsibly.

4. CONCLUSION

Based on the analysis of students' digital literacy skills, the analysis revealedthat the highest skill aspect is in the ability to search for digital information, with 77% of students successfully formulating strategies for finding information on the internet. On the other hand, the lowest skill aspect is in digital communication, with only 40% of students able to effectively design ways to share information using digital devices. These findings indicate that although students have good competence in searching for digital information, challenges remain in developing communication skills and sharing information safely and efficiently in digital environments. Therefore, digital literacy education needs to place greater emphasis on strengthening digital communication, information evaluation, cybersecurity, digital problem-solving, and collaboration in digital environments.

The implications of these findings encourage the implementation of more comprehensive learning strategies, including the integration of information source evaluation methods, digital information-sharing simulations, cybersecurity education, project-based learning approaches, and the use of digital collaboration platforms. By doing so, students are expected to utilize digital technology more effectively, responsibly, and in alignment with the learning needs of the 21st century.

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