



Digital literacy of biology education students: Trends and differences based on semester level

Sri Wahyuni ⁽¹⁾, Nurhayati B ⁽²⁾, Faisal ⁽²⁾ *

⁽¹⁾ Doctoral Program of Biology Education, Postgraduate Program, Universitas Negeri Makassar, Makassar, South Sulawesi, Indonesia
⁽²⁾ Department of Biology Education, Faculty of Mathematics and Natural Science, Universitas Negeri Makassar, Makassar, South Sulawesi, Indonesia

* Corresponding Author Email: faisal8401@unm.ac.id

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Abstract

Twenty-first century skills are an important aspect in developing student competencies, one of which is digital literacy competency. Proficient digital literacy is needed in education, especially to support the technology-based learning process. This study aims to identify differences in the level of digital literacy of Biology Education students based on semester level. The research method used is a quantitative survey with a cluster random sampling technique. The sample of this study was biology education study program students in semesters 2, 4, and 6, with a total sample of 232 students. Data were analyzed using descriptive and inferential statistics, namely the ANOVA test, to determine whether there were significant differences in students' digital literacy skills between semesters. The results showed that the average digital literacy skills of students increased from semester 2 to semester 6, with consecutive scores of 41.20, 44.32, and 45.21. Despite the increase, the overall average is still very low. The results of the inferential statistical test, namely the ANOVA test, obtained a significance value of $p = 0.000$ ($p < 0.05$), which shows that there are differences in the digital literacy skills of students in different semesters. Therefore, a more optimal technology integration strategy in learning is needed, as well as lecturer competence in utilizing digital technology to strengthen student digital literacy.

Abstrak. Keterampilan abad 21 merupakan aspek penting dalam pengembangan kompetensi mahasiswa, salah satunya yaitu kompetensi literasi digital. Literasi digital yang mumpuni sangat diperlukan dalam dunia pendidikan, terutama untuk mendukung proses pembelajaran berbasis teknologi. Penelitian ini bertujuan untuk mengidentifikasi perbedaan tingkat literasi digital mahasiswa Pendidikan Biologi berdasarkan tingkat semester. Metode penelitian yang digunakan adalah survei kuantitatif dengan teknik random sampling. Sampel penelitian ini adalah mahasiswa program studi pendidikan biologi semester 2, 4 dan 6, tahun akademik 2023/2024 dengan jumlah sampel sebanyak 232 mahasiswa. Data dianalisis menggunakan statistik deskriptif dan inferensial yaitu uji anova untuk menentukan terdapat perbedaan signifikan keterampilan literasi digital mahasiswa antar semester. Hasil penelitian menunjukkan bahwa rata-rata keterampilan literasi digital mahasiswa mengalami peningkatan dari semester 2 ke semester 6 dengan perolehan nilai berturut-turut sebesar 41,20, 44,32, dan 45,21. Meskipun terjadi peningkatan, rata-rata keseluruhan masih tergolong sangat rendah. Hasil uji statistik inferensial yaitu uji anova diperoleh nilai signifikansi $p = 0,000$ ($p < 0,05$) yang menunjukkan bahwa terdapat perbedaan keterampilan literasi digital mahasiswa pada semester yang berbeda. Oleh karena itu, diperlukan strategi pengintegrasian teknologi yang lebih optimal dalam pembelajaran, serta kompetensi dosen dalam pemanfaatan teknologi digital guna memperkuat literasi digital mahasiswa.

A. Introduction

The rapid development of information and communication technology has opened up opportunities to improve learning effectiveness and facilitate access to information sources (Allo et al., 2021). This is supported by the increasing level of public use of digital devices, particularly smartphones and the internet, including in the education sector. Data released by the Indonesian Internet Service Providers Association (APJII) shows that in the 2022-2023 period, the number of internet users in Indonesia reached 215,626,156 people (APJII, 2023). However, higher education institutions also face challenges in implementing changes in educational practices due to the explosion of digital information (Ginting et al., 2021), particularly in equipping students with digital literacy skills (Trilling & Fadel, 2009) so that they can adapt and compete in an increasingly digitized world.

Digital literacy is a very important skill in accessing, disseminating, and managing information from digital sources (Gutierrez-Angel et al., 2022; Hobbs, 2021). This skill enables individuals to understand new concepts and solve various problems in the fields of science and technology (Grunwitz, 2019). Digital literacy encompasses not only technical skills in using digital devices but also a critical understanding of information and the ability to adapt to ever-evolving innovations. As a dynamic social practice, digital literacy continues to change in line with technological advances and digital culture, so educators should not simply assume that the younger generation already possesses these skills automatically, but must teach them systematically in the curriculum (McDougall et al., 2018). This is increasingly important in the context of biology education, where students are required to access scientific literature, analyze data, and report research results effectively through various digital platforms (Gui & Argentin, 2011; Sabon et al., 2022).

Digital literacy in the context of higher education enables students to access various scientific references and use technology-based learning resources. The lecture process needs to be designed to encourage students' digital literacy skills and encourage students to utilize literacy through the availability of digital technology. Therefore, higher education must incorporate digital literacy into the curriculum to equip students with skills relevant to the demands of 21st-century skills (Van Laar et al., 2017). Students with strong digital literacy skills are more adept at engaging in collaborative projects, participating in online discussions, and efficiently disseminating digital content (Koh et al., 2022). Previous studies have shown that digital literacy has a very significant impact in higher education because it facilitates access to a wider range of learning resources and increases student motivation to learn (Tinmaz et al., 2022; Smith & Storrs, 2023).

Digital literacy skills are very important for college students and can be observed at various semester levels. Research has proven that the level of digital literacy among students can increase along with academic development. For example, students in their final semester tend to demonstrate higher digital skills than students in their early semesters, such as proficiency in the use of digital technology. This research is clarified by Hasibuan and Hasibuan (2023), who found that students in their seventh semester achieved higher digital literacy scores than students in their fifth semester. Similarly, Fathia et al. (2022) emphasize that students' digital literacy develops in line with the academic experience they have gained during their studies. Academic experiences that can support students' digital literacy include the use of digital platforms in learning (Cao et al., 2023), the use of digital technology in accessing information (Rezeqy et al., 2024), and involvement in a series of practices involving digital devices and media, such as computer operation (Tinmaz et al., 2022).

Previous studies have also shown that digital literacy levels are often influenced by various factors, including education level and access to technology. The study's results revealed that first-semester students generally demonstrated a poor understanding of technology applications in an academic environment, whereas advanced students showed greater proficiency in using digital tools in the learning process (Bond et al., 2020; Saefurrohman, 2021). The proposed solution emphasizes improving digital literacy training in the education curriculum. Other studies reveal that continuous digital skills training can help students overcome barriers in accessing and utilizing information effectively (Dang et al., 2024). In addition, programs aimed at improving digital literacy through social media, e-learning, and other digital resources have been shown to improve students' ability to understand relevant information (Alenezi, 2023). Given the importance of digital literacy in education, there is a need for evaluation to measure the digital literacy of students, especially biology education students.

Students, especially those studying Biology Education, must have adequate digital literacy skills in order to use technology effectively in learning, teaching, and research. The development of these skills is not only the responsibility of the students themselves but also requires active support from lecturers, educational institutions, and the government, according to findings from various universities around the world (Ng, 2012; Tinmaz et al., 2022; Bond et al., 2020; Budiman & Syafroni, 2023). Previous research shows that students' digital literacy is influenced by their educational background, experience in using technology, availability of digital infrastructure, and the learning strategies applied by lecturers (Koh et al., 2022). By understanding the

digital literacy profile of students at various semester levels, lecturers can adjust teaching strategies and curriculum materials to suit student needs, so that digital literacy skills can develop optimally and gaps between students can be minimized.

Inferential statistical methods will be used to determine the factors that influence students' digital literacy levels over several semesters. This study focuses on measuring digital literacy by comparing students in their early semesters with those in their later semesters. The hypothesis is that there is a significant difference in digital literacy levels between students in their early semesters and those in their later semesters, with the expectation that students in their later semesters will demonstrate better digital skills.

B. Material and method

This study is a quantitative descriptive study using a survey research design. The researcher used a questionnaire to describe the digital literacy of students in three different semesters. The research sample was selected using cluster random sampling by randomly selecting two classes at each semester level (semesters 2, 4, and 6). The total sample consisted of 232 students from six different classes in the Biology Education Study Program at the Faculty of Teacher Training and Education, Tadulako University.

The instrument used in this study was a digital literacy questionnaire adapted from Naufal (2021). The questionnaire consisted of 15 items, comprising 8 positive statements and 7 negative statements. The scale used is a 5-point Likert scale, consisting of "strongly agree," "agree," "unsure," "disagree," and "strongly disagree." The digital literacy indicators used consist of: a) knowledge assembly, b) ability to present information, c) ability to read and understand, d) awareness of the importance of media, e) awareness of network access, f) use of information filtering, and g) comfort and ease of access.

The validity of the instrument was tested using construct validity with the Pearson Product-Moment correlation method. The results of the analysis showed that all items in the instrument had a Pearson Product-Moment correlation coefficient above 0.70 with a significance value (p-value) of 0.000 (< 0.05). Thus, all items in the instrument were declared valid. In addition, the reliability test results obtained a Cronbach's Alpha (α) value of 0.981, indicating that the instrument has very high reliability. This means that all items on the questionnaire are reliable for use in data collection.

Data analysis of research results used descriptive statistics by calculating the average digital literacy score of students, the standard deviation, the highest score, and the lowest score. The categories of student digital literacy are shown in Table 1. In addition, to see the differences in digital literacy among students based on their semester level, inferential

statistical analysis was used, namely the ANOVA test, to see the statistical significance of the differences in the average scores of the three groups of students with different semester levels.

Table 1 Categorization of student digital literacy

Value range	Category
62-75	Very high
50-61	High
38-49	Currently
26-37	Low
< 25	Very low

(Source: Sahabuddin et al., 2021)

C. Results and discussion

Data on the digital literacy skills of students in the biology education study program at FKIP UNTAD was obtained based on the results of data analysis that had been carried out. Table 2 shows the digital literacy skills scores of students each semester.

Table 2 Students digital literacy skills profile

Descriptive statistics	Semester II	Semester IV	Semester VI
N	79	71	75
Mean	41.39	44.38	45.43
Median	41.00	44.00	46.00
Std. deviation	3.63	3.42	3.21
Variance	13.16	11.73	10.28
Range	15	15	16
Maximum	50	52	53
Minimum	35	37	37

The average digital literacy skills of students in the biology education study program at FKIP UNTAD in semesters 2, 4, and 6 can be categorized as moderate. This indicates that it is necessary to review the implementation of the learning process and the obstacles encountered so that students' digital literacy skills can improve.

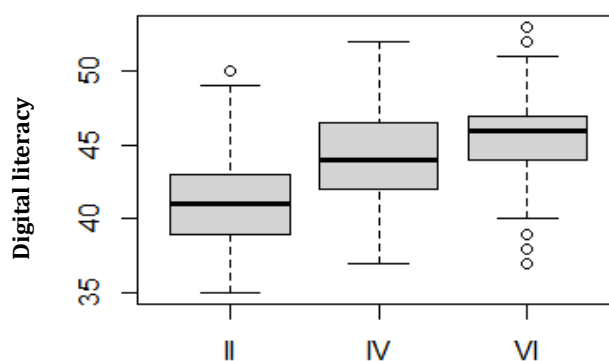


Figure 1
Box plot of student digital literacy by semester

The digital literacy boxplot (see Figure 1) illustrates the distribution of digital literacy skills

among students in the Biology Education Study Program according to semester (Semester II, IV, VI). Although there is a tendency for the average digital literacy score to increase each semester, this boxplot shows significant variation among students. At each semester level, there are students with very low scores and some with very high scores, creating a wider distribution and outliers. In higher semesters, students' digital literacy scores tend to be more

scattered, with some semester VI students showing more deviant scores, both lower and higher, compared to semester II and IV students. This shows that despite the improvement, the gap in digital skills among students is still quite large, indicating the need for greater integration of technology in digital literacy learning and training. The results of this study show the contribution of each indicator of the student digital literacy questionnaire presented in Table 3.

Table 3 Differences in students' digital literacy levels based on semester level (semesters 2, 4, and 6)

Anova					
Questionnaire					
	Sum of squares	df	Mean square	F	Sig.
Between groups	687.120	22	343.560	29.747	.000
Within groups	2644.793	229	11.549		
Total	3331.914	231			

Table 4 Results of the Tukey HSD digital literacy test

Comparison	Average difference	Lower limit	Upper limit	Integrated p-value
IV-II	2.987877	1.6653610	4.310392	0.0000007
VI-II	4.034262	2.7305423	5.338071	0.0000000
VI-IV	1.046385	-0.2927197	2.385490	0.1578678

Table 3 shows that based on the results of the inferential statistics of the ANOVA test in different semesters on students' digital literacy skills, a significance value of $p = 0.000$ ($p < 0.05$) was obtained, indicating that there are differences in students' digital literacy skills in different semesters, namely semesters 2, 4, and 6. The F value obtained was 29.747, which is quite high, indicating that the variation in digital literacy skills between semesters is quite large.

To determine which treatment (which semester) had a significant effect on digital literacy skills, a further test was conducted, namely the Tukey HSD (Tukey Honest Significant Difference) test. The results of the Tukey HSD test can be seen in Table 4. It can be concluded that the semesters with the best scores are semesters IV and VI. These two semesters are not significantly different. Therefore, after entering semester IV and above, students' digital literacy is the same. The most significant increase in students' digital literacy occurs when they reach semester IV, and after that, digital skills tend to stabilize until semester VI. This means that students have optimally developed their digital literacy skills in the middle semesters, and additional experience in the following semester (semester VI) does not cause a significant difference. The findings of this study are very important as a basis for consideration for learning strategies that optimize the integration of technology and digital literacy from the early semesters, so that students are ready to achieve an optimal level of ability in the middle semesters.

Although the Tukey HSD test showed significant differences between semesters, overall, students' digital literacy skills were still in the moderate

category. This can be seen from the average scores for each indicator, which, although varied, still showed that digital literacy improvement still needed to be optimized. These results were obtained from descriptive data analysis. The research results found different data scores for each indicator, although the differences were not significant and all were in the moderate category. If all indicators are carefully observed, it is important to improve students' digital literacy skills. At the university level, a literacy movement is also needed to avoid the negative impacts of media and technology on society (Fuad & Hamid, 2019).

In general, second-semester students have the lowest average digital literacy skills percentage at 53.94%, while fourth-semester students show slightly better results (57.13%) compared to second-semester students, although this is still considered low. Among the three different semester levels, sixth-semester students have a higher average digital literacy skill percentage than the other two, at 58.18%, but it is still in the low category. These results show that there is an increase in digital literacy skills as the semester progresses. This is in line with research conducted by Rezeqi et al. (2024), which reports that although students are able to adapt digital technology well, especially in the aspects of communication, collaboration, and digital content creation, their critical thinking and evaluation dimensions are still not optimally developed. This indicates that students tend to use digital technology more as a means of accessing information than as a tool for critical reflection in learning. These findings are also in line with research conducted by Liza and Andriyanti (2020) and Rizal et

al. (2020), which states that a higher level of education has an influence on a person's digital literacy skills, as well as research by Ng (2012), which explains that students who have studied and used technology for longer have more experience in utilizing digital resources. To improve students' digital literacy more effectively, digital literacy can be achieved through the collection of assigned tasks, such as the implementation of a flipped classroom that uses digital video conferencing media as an active communication tool. This approach can create a more dynamic and engaging learning environment, especially for students who are at an age of high curiosity, such as those aged 16-18, who have a high level of curiosity (Amina & Susilo, 2022). Therefore, support from lecturers and parents is important to facilitate the development of students' interest in learning. In this context, further research is needed to explore the use of different digital media and technologies in each class meeting to optimize learning and build students' motivation to learn using technology more effectively.

The findings of this study become even clearer when viewed from the perspective of digital literacy as an evolving social practice. McDougall et al., (2018) emphasize that digital literacy should not be understood merely as a technical skill, but rather as a form of literacy that is bound to social, cultural, and academic contexts. The differences in achievement between semesters in this study show that new students utilize digital literacy more for basic functions, such as searching for information or uploading assignments, while advanced students have used it for more in-depth, critical, and collaborative academic activities. This view is in line with the results of a systematic review by Tinmaz et al. (2022), which formulates four main dimensions of digital literacy, namely literacy, competence, skills, and digital thinking. This framework shows that digital literacy is multidimensional, encompassing the ability to manage information, communicate and collaborate, create content, maintain digital security, and solve problems, as emphasized in the Digital Competence Framework (DigComp). Therefore, the variation in digital literacy skills between semesters among Biology Education students can be understood as a form of increasingly complex capability development: early students are more prominent in operational skills and basic ICT use, while senior students show excellence in information literacy, collaboration, and critical thinking skills in managing and producing academic content.

One of the causes of low digital literacy is the lack of technology integration in the learning process. Previous studies explain that the effectiveness of digital literacy in higher education depends on the learning strategies applied by lecturers (Setyaningsih et al., 2018; Shuhidan et al., 2022; Smith & Stors, 2023). Another cause is the gap in students' digital literacy skills, where students who have extensive experience using technological devices tend to have higher levels

of digital literacy (Aslan, 2020; Nguyen & Habók, 2024).

The analysis results show differences between students in semesters 2, 4, and 6. The digital literacy skills of students in the biology education study program at UNTAD increased from semester 2 to semester 6. There was a decline in these skills among fourth-semester students. This was due to the increasing academic workload as the semester level increased, causing students to focus more on academic assignments rather than independently exploring digital technology (Ririen & Daryanes, 2022; Subroto et al., 2023). Other studies also reveal that high academic pressure can hinder students in effectively developing digital literacy skills (Sestiani et al., 2022). These findings also indicate that even though students have access to digital technology during their studies, it is still difficult for them to utilize it optimally.

The development of students' digital literacy skills from the beginning of the semester to the end of the semester can be influenced by several factors, namely that students in their final semester or semester 6 have more learning experience, which makes them accustomed to accessing scientific journals, utilizing data analysis software, and interacting in a digital-based academic environment. The strengthening of these skills is also influenced by the frequency of use of digital learning resources, where students who more frequently utilize technology in academic assignments and research tend to have better digital competencies (Ferrari, 2013; Tang & Chaw, 2016). One example is that final year students are more often involved in research and community service activities, so they have more experience in this area. Although there was an increase in digital literacy between semesters, the results of this study show that students' digital literacy is in the moderate category. These results are reinforced by inferential statistical tests that show differences in digital literacy between students in semesters 2, 4, and 6. Final-year students have gained experience in using digital technology, which shows that there is a significant difference in digital literacy competencies. Ng (2012) states that advanced students are more accustomed to using technology for academic purposes than early-stage students. In the context of biology learning, Ramaila and Molwele (2022) reveals that the integration of technology in biology education can improve students' digital skills, especially in understanding complex scientific concepts.

In today's digital age, digital literacy skills are an important topic for discussion. Digital literacy is necessary for students because it can help develop digital cognitive skills and foster independent learning (Techataweewan & Prasertsin, 2018). Digital literacy is needed for students to actively and independently engage in digital learning, including choosing applications that are suitable for learning (McDougall et al., 2018). Furthermore, research conducted by

Budiman and Sayfrony (2023) shows that student engagement with digital media can help students develop (cognitively and in terms of skills), make significant contributions, and develop their careers. Another study by (Getenet et al., 2024) explains that students in their final semester have a more positive attitude towards digital technology and better digital literacy compared to students in their early semesters. This correlates with greater student engagement in online learning, thereby improving learning outcomes.

Improving students' digital literacy can be achieved by integrating technology into the learning process, such as providing internet access and implementing blended learning methods with digital learning platforms (Amina & Susilo, 2022). The learning process implemented in biology education study programs during the pandemic marked the beginning of technology-based learning, such as the availability of LMS (Learning Management System). However, it has not been able to work optimally. This is influenced by the readiness of lecturers in terms of implementing online or LMS-based learning processes, resulting in low levels of student digital literacy. The COVID-19 pandemic has forced lecturers and students to adapt to circumstances that require them to carry out the learning process online.

Findings from previous studies show that educational equity and technology availability play an important role in shaping students' digital literacy skills. For example, a study in Jeneponto Regency found that students in urban areas are more likely to develop their existing digital literacy skills, while students in rural areas need additional facilities and technology to support the learning process (Bahri et al., 2022). These results are in line with the findings of the current study, in which first-semester students had lower digital literacy scores than advanced students, possibly influenced by their previous experience with technology and access to digital facilities in their educational environment. The differences in abilities between semesters observed are also similar to the variations between grade levels in student research, emphasizing that learning experiences and gradual exposure to digital technology consistently improve digital literacy competencies. These findings underscore the importance of implementing adaptive technology integration strategies in higher education, taking into account students' backgrounds and readiness to utilize learning technologies.

The findings of this study have several implications for the development of higher education policy, particularly in improving students' digital literacy. Here are some implications to consider:

1) Technology integration curriculum.

The results of the study show that despite an increase in digital literacy, the results are still relatively low. Therefore, the integration of technology into the curriculum needs to be strengthened, one of which is through Learning

Management System (LMS)-based learning (Setiadi et al., 2022; Alenezi, 2023).

2) Digital literacy training (students and lecturers).

The role of lecturers is very important in efforts to improve digital literacy as facilitators. Training programs for lecturers and students in the use of digital technology can help improve the quality of technology-based learning (Nguyen & Habók, 2024; Dang et al., 2024).

3) Provision of technology infrastructure.

Students have access to digital technology, but not all students have the same opportunities to utilize technology for academic purposes. Providing access to digital libraries, e-learning, and other infrastructure support can significantly improve students' digital skills (Bond et al., 2020).

4) More adaptive learning strategies

Lecturers need to adopt more adaptive and technology-based learning strategies so that students become more accustomed to utilizing technology in the learning process. The use of the flipped classroom and blended learning methods can be effective solutions for improving students' digital literacy skills (Graham & Metcalf, 2020).

This study also has limitations that need to be considered in interpreting the results, namely the quantitative approach. The method used to analyze data in this study is inferential statistics. It would be better to use a qualitative approach such as interviews or case studies so that it can provide deeper insights into the factors that influence students' digital literacy.

D. Conclusion

Based on the analysis results, although students' digital literacy skills improve as they progress through their semesters, the level is still relatively low. There is a significant difference in students' digital literacy skills based on semester level, indicating that students in higher semesters have better skills than those in earlier semesters. Therefore, more innovative and technology-based learning strategies are needed to improve students' digital literacy at all semester levels, along with recommendations for developing relevant curricula and training programs to enhance students' digital skills in facing the challenges of the digital era.

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