

How Far Is Digital Technology Utilized in Biology Learning? Profile and Challenges in Higher Education

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Abstract: Digital technology utilization has become an essential component of biology learning in higher education as it supports more interactive, flexible, and student-centered learning processes. This study aimed to describe the profile of digital technology utilization in learning among lecturers of the Department of Biology, Faculty of Mathematics and Natural Sciences, State University of Makassar, based on students' perceptions. The study employed a quantitative descriptive method with a survey approach involving 110 fourth-semester students from the Biology Education, Biology, and Biotechnology study programs selected through purposive sampling. Data were collected using a Likert-scale questionnaire and analyzed using descriptive statistics, including mean scores and percentages. The results indicated that the utilization of digital technology was categorized as high, with an overall mean score of 4.14. The digital material delivery aspect obtained the highest score (4.35), while technology utilization in laboratory activities received the lowest score (3.68). It can be concluded that digital technology has been optimally utilized in biology learning; however, greater efforts are needed to enhance its application in practical laboratory activities.

Keywords: digital technology, biology learning, digital transformation, higher education, student perception

Abstrak: Pemanfaatan teknologi digital telah menjadi bagian penting dalam pembelajaran biologi di perguruan tinggi karena mampu mendukung proses pembelajaran yang lebih interaktif, fleksibel, dan berpusat pada mahasiswa. Penelitian ini bertujuan untuk mendeskripsikan profil pemanfaatan teknologi digital dalam pembelajaran oleh dosen Jurusan Biologi FMIPA Universitas Negeri Makassar berdasarkan persepsi mahasiswa. Penelitian menggunakan metode deskriptif kuantitatif dengan pendekatan survei terhadap 110 mahasiswa Program Studi Pendidikan Biologi, Biologi, dan Bioteknologi semester 4 yang dipilih secara purposive sampling. Data dikumpulkan melalui angket skala Likert dan dianalisis menggunakan statistik deskriptif berupa nilai rata-rata dan persentase. Hasil penelitian menunjukkan bahwa pemanfaatan teknologi digital berada pada kategori tinggi dengan rata-rata skor 4,14. Aspek penyampaian materi digital memperoleh skor tertinggi (4,35), sedangkan pemanfaatan teknologi dalam praktikum memperoleh skor terendah (3,68). Disimpulkan bahwa teknologi digital telah dimanfaatkan secara optimal dalam pembelajaran biologi, meskipun penguatan penggunaan teknologi pada kegiatan praktikum masih diperlukan.

Kata Kunci: teknologi digital, pembelajaran biologi, transformasi digital, pendidikan tinggi, persepsi mahasiswa

INTRODUCTION

Advances in information and communication technology have brought about significant changes in the field of education. The use of digital technology is now not only a learning aid but has become a necessity to support effective, interactive, and student-focused teaching and learning processes. The use of digital technology and innovation in education to improve learning and

school management can be defined as digital transformation in education. Various aspects of life have been transformed by digital transformation, including education at the elementary, secondary, and tertiary levels. The integration of digital technology into biology learning has significant potential to enhance conceptual understanding and develop 21st-century skills.

Digital transformation in higher education continues to advance in line with the increasing use of various online learning platforms, multimedia-based learning media, digital collaboration applications, and technology-based evaluation systems. The existence of digital technology serves not only as a tool for delivering material but also as a means to support student interaction, collaboration, and independent learning. According to Redecker (2017), the digital capabilities of teachers are a crucial element in determining the success of technology integration in learning, as lecturers are expected to be able to select, control, and use technology effectively in accordance with learning objectives.

Digital technology utilization in learning can be explained through the Cognitive Theory of Multimedia Learning (CTML) developed by Mayer (2021). This theory posits that learners process information through two separate channels, namely visual and auditory channels, each with limited processing capacity. Learning becomes more effective when information is presented through a combination of words, images, animations, videos, and other multimedia elements that facilitate meaningful cognitive processing. According to this theory, integrating verbal and visual information enables learners to construct more accurate mental representations and achieve deeper conceptual understanding than learning that relies solely on text-based materials.

In the context of biology education, the principles of CTML are particularly relevant because many biological concepts are abstract, complex, and difficult to observe directly. Topics such as cellular processes, genetics, physiological mechanisms, and ecological interactions often require visualization and simulation to support students' understanding. Therefore, the use of digital technologies such as instructional videos, animations, virtual simulations, digital laboratories, and online learning resources can facilitate the presentation of biological phenomena in ways that are more concrete, interactive, and meaningful for learners.

Based on this theoretical perspective, digital technology is expected to enhance the quality of biology learning by improving student engagement and conceptual understanding. Empirical evidence supports this assumption. Tang et al. (2021) found that the application of digital technology increases student participation, learning motivation, and meaningful learning experiences. Similarly, Makransky and Petersen (2021) reported that technology-enhanced science learning contributes positively to students' problem-solving skills, critical thinking abilities, and conceptual understanding. Nevertheless, the extent to which digital technology is utilized in biology learning may vary depending on several factors, including instructors' digital competencies, the availability of technological infrastructure, and institutional support. These factors influence how effectively digital technology can be integrated into teaching and learning practices. The use of digital technology can support students in understanding abstract concepts through animations, learning videos, and virtual laboratory simulations. The Biology Department as a provider of higher education must ensure that lecturers have implemented the optimal use of digital technology in the learning process. Assessment of the application of digital technology can be done from the perspective of students as direct users of learning services. The purpose of this study is to illustrate the profile of digital technology use in teaching by lecturers in the Biology Department according to students' views.

METHODS

This study employed a quantitative descriptive design using a survey approach to examine the profile of digital technology utilization in learning among lecturers in the Department of Biology, Faculty of Mathematics and Natural Sciences, Makassar State University. The study involved 110 fourth-semester students from the Biology Education, Biology, and Biotechnology Study Programs, who were selected through purposive sampling. The inclusion criteria were

students who had participated in biology courses utilizing digital technology during the learning process.

Data were collected using a structured questionnaire based on a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). The instrument consisted of six dimensions: digital material delivery, provision of digital learning resources, learning interaction and communication, digital learning evaluation, technology utilization in practicums, and perceptions of the benefits and consistency of digital technology use. Prior to data collection, the questionnaire was validated by experts in biology education and educational technology to ensure content validity. The validity test indicated that all questionnaire items met the required validity criteria, while the reliability test showed a Cronbach's alpha coefficient of 0,91, indicating that the instrument had good internal consistency.

The collected data were analyzed using descriptive statistics, including mean scores, percentages, standard deviations, and category distributions. To determine the level of digital technology utilization, the mean scores were interpreted using a five-level category scale based on the ideal score range. The categories were defined as follows: 4.21–5.00 = very high, 3.41–4.20 = high, 2.61–3.40 = moderate, 1.81–2.60 = low, and 1.00–1.80 = very low. These categories were established by dividing the scale range ($5-1 = 4$) by the number of desired categories (5), resulting in an interval width of 0.80. The categorized results were then used to describe the overall profile of digital technology utilization in biology learning.

RESULTS AND DISCUSSION

The profile of digital technology utilization in Biology learning was examined through six key dimensions: digital material delivery, availability of digital learning resources, learning interaction and communication, digital learning evaluation, technology use in practicum activities, and perceptions of the benefits and consistency of digital technology use (Table 1). The mean score for each dimension was used to represent students' perceptions of the extent to which digital technology supports the learning process. These dimensions were selected because they reflect the major components of technology integration in Biology education, ranging from content delivery and access to learning resources to assessment and practical learning experiences.

In the context of Biology learning, the integration of digital technology is particularly important because many biological concepts are abstract, dynamic, and difficult to observe directly. Digital resources such as videos, animations, virtual simulations, and digital laboratories can facilitate the visualization of biological structures and processes, thereby enhancing students' conceptual understanding. Therefore, examining technology utilization across these dimensions provides a more comprehensive understanding of how digital technology supports both theoretical learning and practical activities in Biology courses, while also identifying areas that may require further development to improve the quality of learning.

Table 1. Profile of Digital Technology Utilization in Biology Learning at the Department of Biology, State University of Makassar (n = 110)

No.	Aspect	Indicators	Mean	Standard Deviation (SD)	Category
1	Digital Material Delivery	Digital learning media, digital presentations, videos/animations/simulations	4.35	0.58	Very High
2	Provision of Digital Learning Resources	Learning materials in digital format	4.23	0.62	Very High
3	Learning Interaction and Communication	Online learning platforms, digital discussions, digital feedback	4.03	0.54	High

4	Digital Learning Assessment	Digital assignments and technology-based assessments	4.11	0.59	High
5	Technology Utilization in Laboratory Activities	Use of digital technology in laboratory practices	3.68	0.79	High
6	Perceived Benefits and Consistency of Use	Supporting content understanding and consistent use of digital technology	4.19	0.53	High
Overall Mean			4.14	0.42	High

Based on the data presented in Table 1, the overall utilization of digital technology in Biology learning was categorized as high, with an overall mean score of 4.14. The aspect of digital material delivery obtained the highest mean score (4.35), which falls within the very high category. This finding suggests that lecturers frequently utilize digital learning media, presentations, videos, animations, and simulations to support the learning process. In contrast, the utilization of technology in practicum activities received the lowest mean score (3.68), although it remained within the high category. These results indicate that digital technology has been integrated across various aspects of Biology learning; however, its application appears to be more extensive in content delivery than in practicum-related activities. Therefore, further efforts are needed to strengthen the integration of digital technology in practical learning experiences to achieve a more balanced implementation across all learning dimensions.

1. Delivery of Digital Material

The digital material delivery aspect received the highest score (4.35) and is categorized as very high. The results of this study indicate that lecturers have used various digital media such as electronic presentations, educational videos, animations, and simulations in learning activities. Effectively integrating digital technology into biology learning requires educators to have the necessary technological skills and pedagogical training. The use of interactive digital media helps create a learning environment that supports student engagement and intrinsic motivation, as learners can interact with dynamic visual content that makes abstract biological concepts more tangible and accessible (Mayer, 2021).

The use of digital media plays a significant role in supporting students in understanding complex and abstract biology concepts. Mayer (2021) stated that the use of multimedia that combines text, images, audio, and animation can improve students' cognitive processes, thus enhancing their understanding of the material. In delivering biology learning materials, lecturers can utilize various digital technologies such as presentation media (PowerPoint, Canva, and Prezi), online learning platforms (Google Classroom and Moodle), video conferencing applications (Zoom and Google Meet), learning videos, e-modules, virtual laboratories, interactive simulations, and artificial intelligence (AI)-based technology. The use of this technology allows the presentation of complex biological concepts to be more visual, interactive, and easier for students to understand.

In today's era of digital education, the learning process is required to utilize digital technology, one of which is through e-learning systems. Through e-learning, learning can be conducted online, eliminating the need for lecturers and students to be in the same room or location. Implementing e-learning requires electronic devices, such as computers or mobile devices, connected to the internet. With e-learning-based learning, students can access various resources and teaching materials tailored to their learning needs more flexibly. Furthermore, e-learning allows lecturers and students to interact in a virtual learning environment that can be accessed anytime and anywhere without the need for face-to-face meetings. Thus, e-learning is an effective solution to support a more flexible, interactive, and student-centered learning process (Takdir et al., 2021).

2. Provision of Digital Learning Resources

The digital learning resource provision dimension received an average score of 4.23, which is categorized as very high. This finding indicates that lecturers proactively provide learning materials in digital form that are easily accessible to students. The availability of digital learning resources allows students to study independently and gain broader access to various scientific references. This finding aligns with the results of a study by Tang et al. (2021), which revealed that access to digital learning resources positively influences student motivation and learning outcomes at university. The use of learning media significantly supports the efficiency of the learning process and the delivery of information and content. Media functions as a tool that can strengthen participation in the learning process. Because media have various characteristics, it is crucial to choose them carefully and appropriately so that they can be utilized effectively (Sari & Munir, 2024). Interactive digital media is a technology that enables direct interaction between users and flexible learning materials. The use of digital media in learning has experienced rapid development in line with advances in information and communication technology (Lestari & Suharto, 2022).

3. Learning Interaction and Communication

Interaction and communication in learning achieved an average score of 4.03, which is considered high. These results indicate that instructors have utilized online learning platforms and digital communication media to support discussion activities and academic interactions. The use of digital technology in learning interactions provides opportunities for students to be more actively involved and expand communication channels outside the classroom. This research finding is consistent with the results of Martin et al. (2020), who reported that the use of digital communication technology can strengthen student collaboration and participation in online and blended learning. Learning that focuses on student needs encourages them to be independent in learning rather than constantly dependent on the instructor. The advantages of online learning include increased interaction between students and instructors, flexibility of time and place, a wider reach of students, and more efficient delivery of teaching materials (Yuliani et al., 2020). Students can communicate through various applications such as Google Classroom, video conferencing, telephone or live chat, Zoom, or WhatsApp groups, which generally allow for sharing materials and submitting assignments. The success of a learning model or media depends on the characteristics of the teacher and students involved (Fitriyani et al., 2020).

Interaction and communication are crucial aspects of learning. Knowledge is easily conveyed if delivered appropriately and easily understood. The use of multimedia technology and the internet can transform information delivery methods and become a viable option for learning, including online learning. It is hoped that the presence of online learning will encourage the creation of innovative, technology-based learning models, with the hope of transforming face-to-face learning (teacher-directed learning) more efficiently (Saifuddin, 2017). Online learning is a distance learning process that utilizes various teaching methods. In practice, teaching activities are conducted separately from the learning activities of students and lecturers. Online learning places greater emphasis on student control of learning, thus emphasizing the student-centered learning approach.

4. Digital Learning Evaluation

The digital learning assessment aspect received an average score of 4.11, which is considered high. These results indicate that teachers have used digital technology in assessments, enabling a more effective evaluation process and facilitating the provision of feedback to students. This finding aligns with a study by Alruwais et al. (2018) which stated that a digital-based assessment system can increase the effectiveness of evaluation and expedite the process of providing feedback to students. Assessment of learning outcomes is a crucial aspect for measuring the extent of student competence in the material taught (Sumaryanto et al., 2025). Therefore, an appropriate method is needed in carrying out evaluations, starting from determining the instrument, compiling the instrument, analyzing the instrument, implementing the evaluation, drawing conclusions, and taking further steps based on the evaluation results. Digital-based assessment in this study

encompassed online quizzes, digital assignments, and technology-mediated feedback mechanisms that enabled more timely and efficient evaluation.

5. Utilization of Technology in Practicals

Although all aspects were classified as high to very high, the aspect of digital technology utilization in practicums received the lowest average score, at 3.68. These results indicate that the application of digital technology in practicum activities still requires strengthening. One factor is the limited use of virtual laboratories and simulation tools that support the practicum learning process. These results align with research conducted by Makransky and Petersen (2021), which stated that the use of virtual laboratories in science education still requires adequate infrastructure support and digital capabilities to be utilized optimally. Virtual Labs are not a total replacement for physical laboratories, but rather a complement to overcome tool limitations and deepen conceptual understanding, especially for abstract phenomena (Malan, 2025). The use of virtual laboratory models in the learning process is one element in developing students' attitudinal dimensions, resulting in student outcomes with the potential for international growth. A virtual laboratory is a form of laboratory through observation or experimental activities using software that operates on a computer; all the tools needed for a laboratory are contained within the software. Computer simulations offer opportunities to encourage students to learn in a dynamic and interactive manner. Virlab is an interactive simulation of an experiment in which all manipulations are performed on a computer (Špernjak & Sorgo, 2017). According to Abramov et al. (2016), Virlab is software that mimics experiments in a real laboratory. Virlab has become well-known in many science classrooms, primarily due to the increasing capabilities of computers in information processing (Špernjak & Sorgo, 2017).

6. Perceived Benefits and Consistency of Use

Students positively perceived the benefits and consistency of digital technology utilization in learning, as indicated by an average score of 4.19, which falls within the high category. This finding suggests that digital technology has become an integral component of the learning process and is consistently implemented by lecturers across biology courses. From the students' perspective, the regular use of digital technology facilitates access to learning materials, supports conceptual understanding, and promotes a more interactive and flexible learning environment.

These findings are consistent with previous studies highlighting the importance of digital competence and technology integration in higher education. Zhao et al. (2024) reported that lecturers' digital competence positively influences student engagement and learning effectiveness, while Bond et al. (2021) emphasized that sustained technology use enhances learning flexibility, access to educational resources, and student participation. Similarly, Sailer et al. (2021) found that lecturers' technology-based teaching skills contribute significantly to the quality of digital learning experiences and student satisfaction. Taken together, these studies suggest that the effectiveness of digital learning depends not only on the availability of technology but also on its consistent and pedagogically meaningful implementation.

The present study extends this body of literature by providing empirical evidence from biology education, a discipline characterized by abstract concepts and complex biological phenomena that often require visualization, simulation, and digital learning resources. While previous studies have primarily examined the general impact of digital technology in higher education, this study specifically maps the profile of digital technology utilization in Biology learning from students' perspectives. The findings reveal that students perceive digital technology not merely as a supporting tool but as an essential component that enhances learning experiences across multiple dimensions, including content delivery, communication, learning resources, assessment, and practical activities.

Therefore, this study contributes to the growing literature on digital learning by providing a comprehensive overview of how digital technology is utilized within Biology courses and identifying areas that require further improvement. The findings also offer practical implications for higher education institutions, highlighting the need for continuous enhancement of lecturers'

digital competencies and adequate technological infrastructure to ensure the sustainable and effective integration of digital technology in Biology learning.

CONCLUSION

The utilization of digital technology in Biology learning in the Biology Department, Faculty of Mathematics and Natural Sciences, Makassar State University is in the high category (4.14). Digital technology has been optimally utilized in delivering materials, providing learning resources, learning interactions, and evaluation, and has provided positive benefits for student understanding. However, the utilization of digital technology in practical activities still needs to be improved through the development of virtual laboratories and adequate infrastructure support to make Biology learning more effective and innovative. Further research is recommended to examine the influence of digital technology utilization on learning outcomes, 21st-century skills, and students' digital competencies, as well as explore factors that influence the effectiveness of digital technology use in Biology learning and practicals.

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