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Digital and Botanical Literacy Profiles for Sustainability: A Study on Biology Students

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Abstract: Higher education plays a crucial role in promoting sustainability, particularly in establishing professional individuals who able to apply sustainable knowledge and ideas. The awareness of the importance of botany is hampered by student's low interest and knowledge about plants. The low relationship between botany and humans is an obstacle in achieving sustainable development. Digital literacy plays an important role in increasing botanical literacy conversely. ICT technology can help increase botanical literacy and reduce the level of plant awareness disparity due to digital literacy serves access to extensive botanical information and online interaction. This research method is quantitative and qualitative method with survey to biology students and interview with botanical lecturers at several universities in Malang, East Java. The research instrument consists digital literacy questionnaire refers to Carretero et al. (2017), botanical literacy test refers to Uno (2009) level model, and interview guidelines and survey about botanical learning in higher education. The data analysis used is quantitative and qualitative descriptive analysis. The findings suggest that digital literacy among students in Malang Raya is generally adequate but varies by aspect, with particularly weaknesses in information and data literacy. Group A shows the highest botanical literacy across all levels, though lower multidimensional scores highlight challenges in applying this knowledge broadly. Integrating digital and botanical literacies through project-based learning and meaningful assignments can enhance engagement and support students' understanding of sustainability issues. Future research should focus on designing and evaluating innovative curriculum models that integrate botanical literacy with digital technology to foster student engagement and sustainability awareness.

Keywords: Digital literacy; botanical literacy; science education; sustainability; learning

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Introduction

Sustainability has become a pressing global agenda, with issues such as climate change, biodiversity loss, and environmental degradation posing significant threats (Clémençon, 2021; Shrivastava et al., 2020). Amidst these challenges, higher education institutions bear the responsibility of equipping students with the essential skills and knowledge to contribute effectively to environmental conservation efforts (Aleixo et al., 2021; Reimers, 2021; Van Luong & Hong Van, 2021; Žalėnienė & Pereira, 2021). Thus, the higher education plays a crucial role in promoting sustainability, particularly in establishing professional individuals who able to apply sustainable knowledge and ideas (Adams et al., 2018). Digital literacy and

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botanical knowledge are two crucial components, that when developed synergistically, can enhance a deeper understanding of ecosystems and the role humans play in maintaining the balance of nature. ICT as digital tool can help increases botanical literacy and reduce the level plant blindness due to digital literacy serves access to extensive botanical information and online interaction (Dimon et al., 2019; Pettit et al., 2014).

Digital literacy has become foundational knowledge and a basic skill in modern society for information retrieval and media navigation (Peiffer et al., 2020; Ulfert-Blank & Schmidt, 2022). Digital literacy encompasses the ability to utilize information technology across various aspects, including data collection and analysis, as well as the dissemination of information relevant to sustainability issues (Radovanović et al., 2020). Digital literacy is a critical competency for students, as it is related to the effective use of digital resource (Le et al., 2022; Saputra & Siddiq, 2020). It is essential as it encompasses the ability to skillfully use digital tools to explore, retrieve, organize, evaluate, research, and integrate digital materials, gain new insights, create multimedia representations, and engage in interactions (Cohen et al., 2020; Lukitasari et al., 2022). However, student digital literacy is relatively low, particularly in indicators such as information seeking and media production for information sharing (Kahar, 2018; Nugroho & Nasionalita, 2020).

Botanical literacy involves an understanding of plants and their ecosystems, serving as a crucial foundation in environmental conservation efforts. Students tend to lack interest in botanical subjects and are unfamiliar with local plants (Pany, 2014). The inability of individuals to recognize and describe plants in their environment is referred to as "plant blindness" or "plant awareness disparity (PAD)" (Parsley, 2020a). Several educational studies have identified the phenomenon of PAD or plant blindness in society (Balding & Williams, 2016; Jose et al., 2019; Wulandari et al., 2023). Low botanical literacy leads to a decrease in educators or botanists, which subsequently affects conservation efforts (Ahrends et al., 2011) and directly hinders the achievement of several Sustainable Development Goals (SDGs) (Amprazis & Papadopoulou, 2020).

The integration of digital literacy and botanical literacy equips students with the ability to scientifically understand the environment while applying technological tools to address environmental issues creatively. The importance of integrating botanical knowledge with technology to combat plant blindness and foster a deeper understanding of the environment (Jose et al., 2019). However, there is still a gap in students' mastery of digital (Buchholz et al., 2020; Chan, 2017; Kemenkominfo, 2022; Nugroho & Nasionalita, 2020; Radovanović et al., 2020b; Reddy et al., 2020; Youssef et al., 2022) and botanical literacy (Balding & Williams, 2016; Chien et al., 2019; Hemingway et al., 2011; Pongsophon & Jituafua, 2021; Sari et al., 2018, 2023).

Many students are proficient in using digital technology (Napal et al., 2020) but do not fully understand the potential of botany in the context of sustainability (Stroud et al., 2022). Based on the field study, 53.57% of biology college students in Malang, East Java chose botany as the most difficult subject/scientific subject and 39% of students chose flower structure as the most difficult material, fill the second rank after genetics. Emphasis and experience with plant content helps students, especially to develop a deeper understanding of botany and the importance of preserving nature's sustainability (Pedrera et al., 2023). This study aims to identify effective ways to enhance digital and botanical literacy among students, as well as to understand the important of these literacies to promote the sustainability in higher education. The research questions were what are the levels of student's digital literacy and botanical literacy? This research also identifies how is the effective way to enhance digital literacy and botanical literacy in higher education to in sustainable era.

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Method

Research Design

The research applied survey and interview research design. The main objective of this study was to identify the students' digital literacy, botanical literacy, and the factors influencing their understanding of these two literacies. Data collection was conducted using an online questionnaire survey created in Google Forms. The research instruments included a digital literacy questionnaire based on Carretero et al. (Carretero et al., 2017), a botanical literacy test based on Uno's (Uno, 2009) level model, and interview guidelines and a survey concerning botanical learning in higher education.

Before conducting the survey, instrument validation and reliability testing were performed to ensure that the measurement tools used could produce accuracy and consistent of the data. Validation was carried out through a Pearson Product Moment formula, in which experts in digital and botanical literacy evaluated the alignment of the instrument's items with the concepts being measured. The questionnaire survey was pre-tested by a group of students, and the feedback provided was used to refine the instrument. Reliability testing was conducted using Cronbach's Alpha coefficient to assess the internal consistency of the questionnaire items. The data collection procedure involved participants completing the questionnaire online.

Data collection and sample

This study employed a quantitative approach through a survey conducted with 149 undergraduate students majoring in biology or biology education at universities in Malang Raya (N=149) and 4 biology lecturers. The subjects participated from four universities in Malang, East Java, including Universitas Negeri Malang, Universitas Islam Malang, Universitas Islam Negeri Maulana Malik Ibrahim, and Universitas Insan Budi Utomo. The students who participated in this survey were those enrolled in botany courses, and the lecturers were those teaching botanical sciences. Data collection took place from May to June 2024. The survey was designed to measure the level of digital and botanical literacy among students and to identify the factors influencing their understanding of these two literacies.

Instrument

The research instruments consist of 1) botanical literacy was developed in test according to indicators/levels from (Uno, 2009), 2) digital literacy was developed in questionnaire according to aspect and indicators form (Carretero et al., 2017) or DigComp 2.1, and 3) learning need aspect instrument was developed in open ended and closed questionnaire and interview guidelines (Table 1). The instrument could be accesed by subjects via Google Form.

The digital literacy questionnaire consisted of 24 items and the botanical literacy test consisted of 8 multiple choice and 3 essay questions. Before the instrument used in data collection, instruments was analyzed to measure the validity and reliability. The validation results showed that all item in the digital and botanical literacy instrument were considered valid by expert, with minor adjustment to some items to improve clarity and relevancy. The reliability test results showed that the digital literacy questionnaire was confirmed reliable with a value of 0,798 and the botanical literacy instrument test confirmed reliable with a value of of 0,91. Both of these values indicate a high level of reliability, so the instruments is considered consistent in measuring digital and botanical literacy.

Data Analysis

The collected data were then analyzed using both quantitative and qualitative descriptive statistics to describe the data distribution about digital literacy index and the level of botanical literacy. The quantitative data were analyzed using descriptive analysis with the help of Microsoft Excel and SPSS software. Thus, to identify the effective way to enhance digital literacy and botanical literacy in higher education use triangulation analysis. To analyze student's answer about botanical and digital literacy, researcher utilized scoring rubrics to show botanical and

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digital literacy index, as presented in Table 2. The digital literacy and botanical literacy results are analyzed descriptively use SPSS program according to the mean of result.

Table 1. Level and Aspect in Research Instrument

Botanical Literacy Level	Digital Literacy Aspect	Learning Need
Nominal Functional Structural Multidimensional	Information and data literacy Communication and collaboration Digital content creation Safety Problem solving	Learning activities in class Perception of botanical course Perception of current education development

Table 2. The Item Number of Instrument and Scoring

Botanical Literacy Level	Digital Literacy Aspect	Learning Need
11 botanical literacy test questions in the form of multiple choices with a score of 1 true, 0 false and 4 essay questions with a score of 1-4	24 digital literacy items question with a score of 1-4 adapted from DigComp 2.1	10 open ended question

Result

Student's Digital Literacy Score

Digital literacy has become an increasingly essential skill for students, particularly in this advancing digital era. The integration of digital and botanical literacies enables students to comprehend their environment through a scientific lens while utilizing technology to develop innovative solutions for environmental challenges. The results of this study are presented in a bar chart, displaying the percentage scores of four groups of students, labeled as A, B, C, and D.

Figure 1 presents the results of a digital literacy survey conducted among biology students from four universities in Malang Raya. According to (Carretero et al., 2017) digital literacy indicators are categorized into five main aspects: information and data literacy, collaboration and communication, digital content creation, security, and problem-solving. The data indicate that Group A achieved the highest percentage across all aspects of digital literacy, except in digital content creation, where Group B slightly surpassed Group A with a score of 65.43% compared to 65.39%. In the information and data literacy aspect, Group A attained the highest score at 55.81%, while the other groups ranged between 42.48% and 44.10%. For the communication and collaboration aspect, all groups showed higher scores, ranging from 67.88% to 74.01%, indicating stronger proficiency in collaboration and communication compared to information and data literacy. Students are less able to choose valid and credible digital sources, it shown by students not being able to sort digital sources according to their credibility as sources of information and data.

In the safety aspect, Groups A and B recorded relatively high scores, with 73.37% and 71.30% respectively, suggesting a greater awareness of digital security compared to Groups C and D. Last, in problem-solving aspect, Group B achieved the highest score of 78.26%, followed closely by Group D with 78.30%, indicating that problem-solving is one of the strongest areas of digital literacy among biology students in Malang Raya.

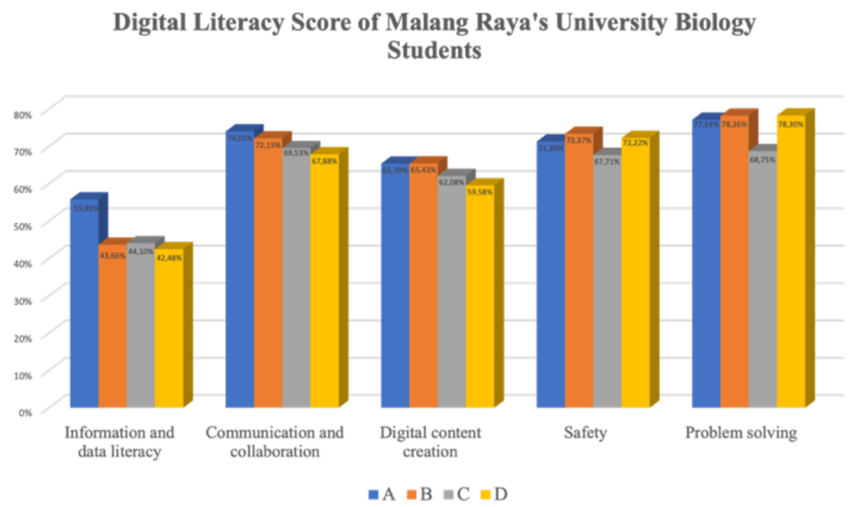

Figure 1. Digital Literacy Score of Malang Raya's University Biology Students

Student's Botanical Literacy Score

This study was conducted to assess the level of botanical literacy among biology students from four universities in Malang Raya, with a total of 149 participants. Botanical literacy is categorized into four levels consist of nominal, functional, structural, and multidimensional, each representing different aspects of the students' understanding of botany.

According to Figure 2, at the nominal level, which represents a basic understanding of botany, Group A demonstrated the highest score at 67.01%, followed by Group D with 47.92%, Group C with 42.71%, and Group B with 35.87%. At the functional level, which indicates the ability to understand the basic functions of botanical concepts, Group A also led with a score of 58.85%, while Group D scored 42%, Group C scored 42.71%, and Group B scored 32.07%. At the structural level, reflecting an understanding of the interrelationships between botanical concepts, Group A achieved the highest score of 54.86%, followed by Group B at 42.71%, Group D at 36.46%, and Group C with the lowest score at 35.42%. Finally, at the multidimensional level, which demonstrates the ability to apply botanical concepts in various contexts, Group A remained the highest with a score of 49.83%, followed by Group B at 42.01%, Group D at 31.25%, and Group C with the lowest score of 30.21%.

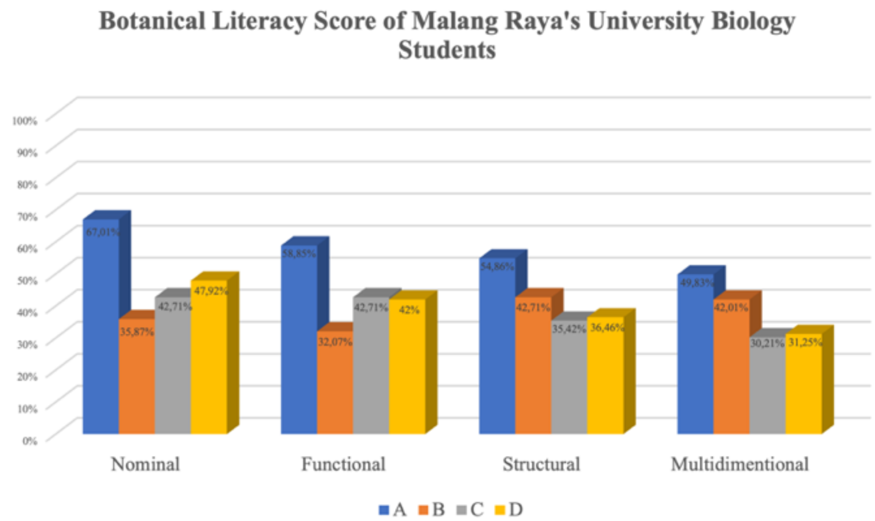

Figure 2. Botanical Literacy Score of Malang Raya's University Biology Students

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Foster digital and botanical literacy by lecturers perception

In the context of sustainable education, integrating digital literacy with botanical literacy empowers students to engage actively in environmental efforts. By incorporating digital tools in botanical learning, educators can enhance students' understanding of plant biology and ecology to fostering a deeper appreciation for sustainability. The combination of digital and botanical literacies equips students with the skills necessary to analyze environmental data and make informed decisions that promote sustainable practices.

The interview with lecturer held to identify how is lecturer perspective about botanical learning in promoting sustainability. The learning need aspect consist learning activities in class, perception of botanical course, perception of current education development, botanical literacy tasks, and digital literacy tasks.

Regarding learning model used during class in botany or biology course, interviewee 1 shared "*I actually use group assignments include practical reports, projects describing plants in the surrounding environment, and social media posts. I think that I had too combined the other tasks to foster student's skill so they can stan with the digital and society 5.0 right now*".

Concerning to content obstacle in botanical course, interviewee 2 said that "*In botanical course, there are many terms that are difficult for students to understand, students are confused about how to apply them when observing plants. Probably, group work improves understanding of the material. Live project that direct practice in the field, it allows for a deeper understanding when it is related to everyday life, i often use Project Based Learning such collecting plant surrounding or making product from plant potential* ".

Thus, according to the development of current education development in 21st century, spefically in botanical and digital literacy, interviewee 3 said that "*developing botanical and digital literacy among students not only supports their academic success, but also equips them with relevant skills and knowledge for everyday life and future careers. Botanical literacy helps create individuals who are more environmentally aware, healthier, more engaged in communities, and better prepared to face global challenges such as climate change, food security, and biodiversity loss. perhaps it is necessary to add assignments that are more meaningful for students, by exposing them to contextual problems that can be solved with botanical concepts and then approach them to digital ecosystem to share their knowledge further to construct their knowledge*". The integration of botanical and digital literacy through contextually relevant assignments prepares students to navigate the complexities of environmental challenges. It fosters a holistic educational experience that equips them with the skills necessary for personal and professional success in an increasingly interconnected world.

Students need to be faced with meaningful contextual problems that can be solved using botanical concepts example ESD. The interviewee 4 said "*regarding the suitable model that could use the project learning that students have carried out in learning based on local wisdom material in botany can be improved by social media assignments or technology to make learning more meaningful and appropriate to current developments, such as diving into social media to share knowledge and sustainability campaigns in the global world*".

Discussion

Student's Digital Literacy Profile

The slight edge of Group B in digital content creation highlights a competitive aspect of student engagement, suggesting that targeted interventions could enhance this critical skill across all groups (Nkomo et al., 2021). As digital content creation becomes increasingly vital in various fields, fostering an understanding of copyright and intellectual property rights is essential for responsible digital citizenship. Integrating these concepts into the curriculum may not only enhance students' digital literacy but also prepare them to navigate the ethical dimensions of digital content production. Further, students do not know much about copyright and have minimal knowledge regarding the process of creating digital

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content (Kahar, 2018; Nugroho & Nasionalita, 2020). The challenge of selecting valid and credible digital sources is echoed in recent literature, emphasizing the need for explicit instruction on evaluating digital information (Damico et al., 2018). This gap in information literacy may hinder students' ability to engage critically with digital content, thereby limiting their academic success and future employability (Peiffer et al., 2020; Ulfert-Blank & Schmidt, 2022).

In the safety aspect, Groups A and B recorded relatively high scores, with 73.37% and 71.30% respectively, suggesting a greater awareness of digital security compared to Groups C and D. Last, in problem-solving aspect, Group B achieved the highest score of 78.26%, followed closely by Group D with 78.30%, indicating that problem-solving is one of the strongest areas of digital literacy among biology students in Malang Raya. This aligns with the current educational paradigm that emphasizes project-based learning, which fosters critical thinking and creativity (Kimani, 2024). Encouraging students to engage in problem-solving activities can further enhance their digital literacy, making them more competent and adaptable in an ever-evolving digital landscape. Overall, this data suggests that digital literacy among students in Malang Raya varies across different aspects, with certain groups demonstrating particular strengths in specific areas.

Student's Botanical Literacy Profile

All things considered, these findings indicate that Group A exhibits a higher level of botanical literacy across all levels compared to the other groups. Nevertheless, the lower scores observed at the multidimensional level suggest challenges in applying botanical knowledge comprehensively, which may require further educational interventions to enhance students' abilities to utilize botanical understanding across diverse contexts. Multidimensional level is the highest level of botanical literacy (Beasley, 2023), unfoturnately students tend not to be able to explain the role of botany and its position in life clearly.

The results of the qualitative research underscore the disparities in botanical literacy among the groups, particularly highlighting Group A's superiority in basic and functional understanding of botanical concepts. However, the relatively low scores at the multidimensional level signal a significant challenge in applying this knowledge to real-world situations, which is essential for fostering environmental awareness and practical problem-solving skills in the context of sustainability (Beasley et al., 2021). This indicates a need for instructional strategies that promote deeper engagement with botanical concepts, possibly through an essential learning that encourages students to tackle real-life issues using their botanical knowledge (Colon et al., 2020; Zhu et al., 2024). Moreover, integrating interdisciplinary approaches that combine botany with technology could further enhance students' capabilities to transfer their learning to complex, multifaceted situations (Bowcutt & Caulkins, 2020; Cil, 2016; Zhu et al., 2024). As such, educational programs should aim to not only improve foundational botanical literacy but also to cultivate the skills necessary for students to effectively navigate and contribute to the challenges of their environments.

Foster digital and botanical literacy by lecturers perception

An enjoyable and interactive learning approach to build students' interest in botany in the 21st Century is important (Pedrera et al., 2023). Learning with social media integration which is currently trending has become an interesting new method for students, especially for utilizing social media to share knowledge and science. Through digital literacy, students can search, filter, and process, evaluate, and use information wisely, communicate effectively, and continue learning in an environment that increasingly demands digitalization. So far, it has only been limited to searching for information.

Students experience difficulties in understanding the terminology used in botanical courses and in applying it during plant observations. However, their

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comprehension can be enhanced through group work and project-based learning that involves direct practice and is connected to everyday life. This opposite to (Sari et al., 2018) stated that there is still a need for other integrations in Project Based Learning to increase botanical literacy. Yustina et al., (2020) Project based learning can improve student skills supported by ICT (Information Communication and Technology).

The critical role that botanical and digital literacy play in shaping well-rounded students capable of addressing contemporary environmental issues. In the 21st century, education must evolve to meet the complex challenges posed by climate change, food security, and biodiversity loss. By fostering botanical literacy, educators can cultivate a generation of students who are not only knowledgeable about plant biology and ecology but also understand the significance of sustainable practices in their daily lives (Sanders et al., 2018; Stroud et al., 2022b; Ward et al., 2014).

Furthermore, integrating digital literacy into botanical education allows students to leverage technology as a powerful tool for environmental advocacy and engagement. Digital platforms can facilitate collaborative projects where students investigate local ecological problems, propose solutions rooted in botanical knowledge, and share their findings with a broader audience (Pettit et al., 2014; Sanders et al., 2018). This approach aligns with the principles of experiential learning, which emphasize the importance of real-world applications and critical thinking in the learning process (Colon et al., 2020; Kizi, 2024).

Moreover, the suggestion to incorporate more meaningful assignments resonates with the concept of project-based learning which encourages students to engage with authentic issues relevant to their communities (Adinugraha, 2022; Børresen et al., 2023). By tackling contextual problems, students can see the direct application of botanical concepts, enhancing their understanding and appreciation for the subject matter. This strategy not only reinforces botanical literacy but also promotes digital literacy as students utilize various technologies to research, collaborate, and present their work (Pedrera et al., 2024).

Students need to be faced with meaningful contextual problems that can be solved using botanical concepts example ESD (Education of Sustainable Development”. (Chow et al., 2022; Zidny & Eilks, 2020) said that integrating ESD such local wisdom in botanical lesson, could demonstrate the potential of transformative learning in fostering plant awareness among trainee teachers. Interviewee 4's emphasis on utilizing project-based learning and social media assignments is particularly pertinent in today's digital landscape. Project-based learning (PBL) encourages students to engage in hands-on, inquiry-based activities that address authentic problems, allowing them to apply botanical concepts in practical ways (Adinugraha, 2022). By connecting botanical education with local wisdom and contemporary issues, students can explore how traditional ecological knowledge can inform sustainable practices in their communities (Al Muhdhar et al., 2019; Sriyati et al., 2021).

As highlighted by (Saputra & Siddiq, 2020) social media can serve as a tool for students to participate in sustainability campaigns, thereby enhancing their digital literacy while promoting environmental awareness. This approach not only makes learning more relevant and engaging but also prepares students to navigate the complexities of global sustainability efforts. Moreover, the integration of technology in botanical education facilitates collaborative learning experiences, where students can work together on projects that have real-world implications. This collaborative aspect of PBL fosters essential skills such as communication, critical thinking, and problem-solving, which are crucial for addressing environmental challenges (Kimani, 2024; Krajcik & Shin, 2022; Priyatni & As’ari, 2019).

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Discrepancy in the development of digital literacy and botanical literacy

An ordinary educational approach is insufficient to promote a deep understanding of sustainability. (Beasley et al., 2021, 2023; Burke et al., 2022) Botanical literacy must be actively promoted through a curriculum that integrates botanical learning with digital technology. Several student interviewees noted that many students show less interest in botany if the course is perceived as unimportant to their major or if it is not presented engagingly (Parsley, 2020b). Consequently, students may lack motivation to study botany if they do not see its direct relevance to their career or life goals (Balding & Williams, 2016; Cil, 2016). Some students may enter college with varying levels of basic digital skills, meaning not all students possess the same foundational knowledge in digital literacy, which impacts their progress in acquiring more advanced skills (Buchholz et al., 2020; Sá et al., 2021). Additionally, students may not have adequate access to technology or the necessary support to develop their digital skills comprehensively (Pangrazio et al., 2020; Perdana et al., 2019).

Students with strong digital literacy tend to be more responsive to sustainability issues; however, they require greater exposure to botanical concepts. The use of digital technology in botanical education, such as plant identification applications, ecosystem simulations, and botanical data analysis, can be effective strategies for enhancing student interest and understanding of botany (Kizi, 2024; Pettit et al., 2014a). Furthermore, the development of interdisciplinary programs that combine technology and environmental science could be a crucial step in improving botanical literacy. Project-based education that allows students to apply digital technology in botanical research can also provide a deeper and more meaningful learning experience (Adinugraha, 2022; Krajcik & Shin, 2022).

Conclusions

The results findings suggests that digital literacy among students in Malang Raya categorized enough in varies across different aspects, with certain groups demonstrating particularly weak in specific areas such information and data literacy thus digital content creation. Moreover results indicate that Group A exhibits a higher level of botanical literacy across all levels compared to the other groups. Nevertheless, the lower scores observed at the multidimensional level suggest challenges in applying botanical knowledge comprehensively, which may require further educational interventions to enhance students' abilities to utilize botanical understanding across diverse contexts.

Suggestion and Recommendation

Integrating digital literacy with botanical literacy is essential for fostering students' engagement in environmental sustainability efforts and enhancing their understanding of plant biology and future world. However, the current educational landscape reveals a disparity in the development of these literacies. To address this challenge, educators should implement project-based learning or and meaningful assignments that connect botanical concepts to real-world issues, leveraging technology and social media to facilitate collaborative learning and increase students' awareness of sustainability challenges in their communities.

Future research should focus on designing and evaluating innovative curriculum models that integrate botanical literacy with digital technology to foster student engagement and sustainability awareness. Considering the varying levels of digital skills among students, it is essential to investigate differentiated instructional strategies and support systems that can accommodate diverse digital competencies. Further studies are also recommended to explore the effectiveness of project-based learning that combines digital tools and botanical content in enhancing students' understanding and motivation. Additionally, interdisciplinary approaches that link technology, environmental science, and botanical education should be developed and assessed to promote more meaningful and applicable learning experiences. Researchers are encouraged to examine how access to technology and the perceived relevance of botany to students' personal and professional goals influence their learning outcomes and engagement.

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