BIO-INOVED
Jurnal Biologi-Inovasi Pendidikan
Volume 7, Issue 3, October 2025 page. 359-371

P-ISSN : 2684-9062 | E-ISSN : 2714-9803
https://ppjp.ulm.ac.id/journal/index.php/bino
DOI: 10.20527/bino.v7i3.22668

Revealing the impact of scientific culture understanding on students' biological literacy: The role of digital mindfulness and local wisdom literacy

Asham Bin Jamaluddin [1] *, Muhiddin Palennari [1], Adnan [1], Evrialiani Rosba [2]

[1] Department of Biology Education, Faculty of Mathematics and Natural Sciences, Universitas Negeri Makassar, Makassar, South Sulawesi, Indonesia
[2] Department of Biology Education, Faculty of Science and Technology, Universitas PGRI Sumatera Barat, Padang, West Sumatra, Indonesia

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

Article Information

Keyword:
Scientific culture understanding;
Biological literacy;
Digital mindfulness;
Local wisdom literacy;
Students

Kata Kunci:
Pemahaman budaya ilmiah;
Literasi biologi;
Kesadaran digital;
Literasi kearifan lokal;
Mahasiswa

History:
Received : 31/05/2025
Revised : 13/09/2025
Accepted : 20/09/2025
Published : 25/09/2025

Abstract

The low level of biological literacy among students shows the importance of exploring and integrating the dimensions of scientific, cultural and digital understanding in learning. This study aims to analyze the influence of scientific culture understanding on students' biological literacy, by exploring the mediating role of digital mindfulness and local wisdom literacy. The study used a quantitative approach with an explanatory design and Partial Least Squares Structural Equation Modeling (PLS-SEM) analysis. The sample consisted of 495 biology education students from three universities in Makassar, selected using a purposive sampling technique. The research instrument was a four-point Likert scale closed questionnaire to measure four main constructs. The results of the analysis showed that scientific culture understanding had a significant effect on biological literacy directly and indirectly through digital mindfulness and local wisdom literacy. The strongest relationship was found between scientific culture understanding and local wisdom literacy, while the contribution of digital mindfulness was weak but significant. The R^2 value for biological literacy of 0.440 indicated a moderate model contribution. The conclusion of this study emphasizes the importance of integrating cultural, technological, and scientific approaches in biology learning in higher education. This study provides theoretical contributions to the development of local context based scientific literacy as well as practical recommendations for educators and policy makers in designing quality and effective curricula.

Abstrak. *Rendahnya tingkat literasi biologi di kalangan mahasiswa menunjukkan pentingnya untuk mengeksplorasi dan mengintegrasikan dimensi pemahaman sains, budaya dan digital dalam pembelajaran. Penelitian ini bertujuan untuk menganalisis pengaruh scientific culture understanding terhadap literasi biologi mahasiswa, dengan mengeksplorasi peran mediasi dari digital mindfulness dan literasi kearifan lokal. Penelitian menggunakan pendekatan kuantitatif dengan desain eksplanatori dan analisis Partial Least Squares Structural Equation Modeling (PLS-SEM). Sampel terdiri dari 495 mahasiswa pendidikan biologi dari tiga universitas di Makassar, yang dipilih menggunakan teknik purposive sampling. Instrumen penelitian berupa angket tertutup skala Likert empat poin untuk mengukur empat konstruk utama. Hasil analisis menunjukkan bahwa scientific culture Understanding berpengaruh signifikan terhadap literasi biologi secara langsung, maupun tidak langsung melalui digital mindfulness dan literasi kearifan lokal. Hubungan paling kuat ditemukan antara scientific culture Understanding dan literasi kearifan lokal, sedangkan kontribusi digital mindfulness tergolong lemah namun signifikan. Nilai R^2 untuk literasi biologi sebesar 0.440 mengindikasikan kontribusi model yang moderat. Kesimpulan penelitian ini menegaskan pentingnya integrasi pendekatan budaya, teknologi, dan ilmiah dalam pembelajaran biologi di pendidikan tinggi. Penelitian ini memberikan kontribusi teoritis terhadap pengembangan literasi sains berbasis konteks lokal serta rekomendasi praktis bagi pendidik dan pengambil kebijakan dalam merancang kurikulum yang berkualitas dan efektif.*

A. Introduction

Science education currently faces major challenges in fostering scientific literacy that is not only cognitive, but also contextual, critical, and reflective. Biological literacy, as a form of scientific literacy, requires students to understand biological concepts comprehensively and be able to apply them in real life (Önel & Durdukoca, 2019; Prayitno et al., 2022). However, the current fact is that biological literacy in Indonesia is in a worrying condition (Ristanto & Darmawan, 2020; Subiantoro et al., 2021). In addition, scientific culture understanding plays an important role in fostering a scientific way of thinking that prioritizes evidence, openness, and a critical attitude towards information (Sun et al., 2024). Scientific culture understanding not only refers to mastery of scientific concepts, but also includes scientific mindsets, values, and practices such as critical thinking, being skeptical of information, and appreciating evidence (Sobach et al., 2023). In the context of biology learning, scientific culture understanding plays a role in helping students relate biological concepts to real life, especially in dealing with global issues such as climate change, biodiversity, and biotechnology. Without a strong foundation of scientific culture understanding, students tend to understand biology superficially and are less able to apply it contextually (Kamila et al., 2024; Zukswert et al., 2019).

Important aspects that help shape biological literacy more contextually are local wisdom literacy and digital mindfulness. Local wisdom literacy allows students to understand science through the lens of their own culture, making biology learning more relevant and meaningful (Jamaluddin, Palennari, et al., 2023). As in the concept of ecosystem and conservation can be better understood if associated with local practices or local wisdom (Wajdi et al., 2022). Meanwhile, digital awareness is key in the era of information digitalization, where students must be able to sort, understand, and evaluate biological information that is widely distributed online (Sumatokhin et al., 2020). Without digital awareness, students are prone to distraction and get caught up in incorrect or irrelevant information (Ellis et al., 2017). However, empirical studies that examine the relationship between scientific cultural understanding and biological literacy by considering the role of local wisdom literacy and digital awareness are still very limited, especially in Indonesia. Most previous studies still examine these variables separately or not in one comprehensive model (Bahri et al., 2023; Jamaluddin et al., 2021; Listia et al., 2025; Najmah et al., 2024; Yosep et al., 2024). This causes a gap in the development of an integrative biology education model that is adaptive to local culture, and responsive to digital challenges.

This study aims to analyze the influence of scientific cultural understanding on students' biological literacy, by exploring the mediating role of local wisdom literacy and digital awareness. The novelty of the study lies in the integration of the four variables into a comprehensive conceptual model that has not been widely studied in Indonesian higher education. The justification of the hypothesis is based on sociocultural and constructivist theories, which emphasize the importance of the interaction between cognition, culture, and the digital environment in shaping scientific understanding. Theoretically, this study enriches the science education literature by showing that biological literacy is not only formed from cognitive aspects, but is also influenced by cultural context and the ability to manage digital information wisely. Practically, the results of this study are useful for educators in designing culture and technology-based learning, as well as for educational institutions and policy makers as a basis for developing a more holistic science literacy curriculum that is rooted in local values and the needs of the digital era.

Conceptual framework and hypothesis development

Scientific culture not only shapes the way of thinking about science, but also influences the way individuals respond to and use digital information consciously and purposefully (Lu & Wan, 2018; Schultz, 2024). Students who are accustomed to thinking scientifically will tend to use technology more reflectively, critically, and in a controlled manner the main characteristics of digital mindfulness (Yablokov, 2022). They are able to sort out valid information, question information sources, and avoid the information overload trap that is common in the digital world. In other words, scientific culture provides a framework of thinking that underlies students' digital awareness in interacting with scientific content spread across various digital platforms.

H1: Scientific culture understanding has a significant effect on digital mindfulness

Scientific culture understanding reflects an individual's ability to think logically, analytically, and evidence based in understanding natural phenomena (Arjaya et al., 2024). This scientific cultural framework can shape students' perspectives in interpreting local wisdom values scientifically and rationally (Jamaluddin et al., 2022). Students who have a good understanding of scientific culture tend to be more open to integrating scientific knowledge with local practices that are hereditary. In this context, scientific culture understanding encourages students to see local wisdom not as a passive tradition, but as a source of knowledge that can be studied and developed through a scientific approach, thereby increasing literacy towards local culture in a more reflective and scientific way (Verawati & Wahyudi, 2024; Sudjarwo et al., 2018).

H2: Scientific culture understanding has a significant effect on local wisdom literacy

Biological literacy does not only depend on conceptual knowledge, but also on scientific ways of thinking that are part of scientific culture. Students who understand scientific culture tend to be able to critically examine biological concepts, understand scientific processes in biology, and apply scientific principles in solving biological problems in real life (Chen & Ping, 2024). Scientific culture encourages deeper and more applicable biology learning because students not only receive knowledge, but also question, test, and evaluate the concepts learned (Kaaronen et al., 2023). Therefore, scientific culture is an important foundation in forming biological literacy that is not only cognitive, but also reflective and contextual.

H3: Scientific culture understanding has a significant effect on biological literacy

Digital mindfulness refers to an individual's ability to use technology consciously, critically, and reflectively not just to access information, but also to sort, understand, and manage digital content wisely. When students have a high level of digital mindfulness, they tend to be more selective and responsible in seeking and disseminating information about local wisdom in the digital era (Munisa et al., 2024; Widana et al., 2023). Local wisdom literacy itself requires a deep understanding of local values, which are now widely documented in digital forms such as articles, videos, forums, and social media (Pradana et al., 2024). Therefore, digital awareness is an important means of bridging modern knowledge and traditional values, as well as strengthening local wisdom literacy among the younger generation (Baharun et al., 2022).

H4: Digital mindfulness has a significant effect on Local Wisdom Literacy

Digital mindfulness, or digital awareness, plays an important role in the process of learning biology in the digital era (Nanda & Budimansyah, 2020). Students who are digitally aware have the ability to focus, sort scientific information critically, and avoid distractions during online learning (Akman et al., 2023). In the context of biological literacy, digital mindfulness helps students to be more selective in accessing valid sources of information, evaluating the validity of biological data, and developing a deep understanding of biological material (Ridzal & Haswan, 2023). Thus, digital mindfulness supports the formation of biological literacy that is not only based on knowledge, but also relies on critical thinking skills and scientific information literacy skills.

H5: Digital mindfulness has a significant effect on biological literacy

Local wisdom literacy allows students to understand science, especially biology, through the lens of local culture and practices that have been proven to be ecologically sustainable (Arsih et al., 2021). The connection between local traditions and biological concepts such as biodiversity, conservation, and ecological systems provides a more concrete and meaningful context for students (Jamaluddin, Zubaidah, et al., 2023). Thus, students who have a high level of local wisdom literacy will find it easier to link local values to scientific principles in biology (Iskandar et al., 2022). This strengthens their ability to understand, analyze, and apply biological concepts in a relevant and contextual way in everyday life.

H6: Local wisdom literacy has a significant effect on biological literacy

Digital mindfulness can also be a mediating variable in the relationship between scientific culture understanding and biological literacy. Students who think scientifically will be more likely to develop awareness in using digital technology productively and purposefully (Adigwe, 2021; Kocoglu et al., 2023). This awareness, in turn, increases the effectiveness in accessing, evaluating, and using biological information digitally (Jamaluddin et al., 2025). Through this pathway, scientific culture not only contributes directly to biological literacy but also strengthens it indirectly through increasing students' digital awareness. Thus, digital mindfulness strengthens the impact of scientific culture understanding on students' biological abilities in a digital context.

H7a: Scientific culture understanding has a significant effect on students' biological literacy through digital mindfulness

Local wisdom literacy can function as a mediator between scientific culture understanding and biological literacy. Students who have a strong understanding of scientific culture tend to appreciate and evaluate local practices scientifically (Suhirman & Khotimah, 2020). When local values are understood through a scientific framework, students are better able to relate them to modern biological concepts (Zulirfan et al., 2023). This process strengthens biological literacy because students not only understand the material from a scientific perspective, but also through cultural narratives that are close to their lives (Bahri et al., 2021; Syamsiah et al., 2024). Therefore, local wisdom literacy bridges the understanding of scientific culture with contextual and relevant biological applications.

H7b: Scientific culture understanding has a significant effect on students' biological literacy through local wisdom literacy.

B. Material and method

This type of research is quantitative research with an explanatory approach. This approach allows hypothesis testing through standardized instrument-based data collection and inferential statistical analysis. This study uses a cross-sectional design, namely data collection is carried out at a certain point in time. This design was chosen because it is suitable for evaluating the relationship and influence between variables simultaneously in a short time. Data analysis was carried out using Partial Least Squares Structural Equation Modeling (PLS-SEM) (Mahande, Fakhri, et al., 2025), which is suitable for testing complex conceptual models with many latent variables and indicators. The relationship between the proposed variables is visualized in the Analysis path diagram in Figure 1.

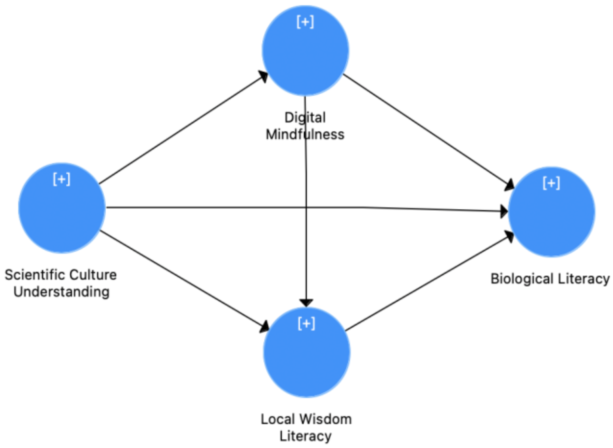

Figure 1 SEM model diagram (Source: Authors' own elaboration)

The research subjects were students of the biology education study program at Universitas Negeri Makassar, Universitas Muhammadiyah Makassar, and Universitas Islam Negeri Makassar. Research subjects must be students who have completed at least one year of study (Table 1). The sampling technique was carried out using purposive sampling, with the following criteria: 1) active students, 2) have taken basic science and basic biology courses, 3) have experience in using digital media for learning, and 4) are of Bugis/ Makassar/Toraja/Mandar ethnicity. These four ethnic groups were chosen because the research focus is on local wisdom literacy, which is related to the culture and traditions of the people of South Sulawesi, where these four ethnic groups are the dominant ethnic groups. The minimum number of samples was determined based on the minimum criteria in the PLS-SEM analysis, which is 10 times the largest number of indicators in one latent construct.

Table 1 Demographics of research subjects

Variable	Total (n)	Percentage (%)
Gender		
Male	227	45.86
Female	268	54.14
Admission year		
2022	138	27.88
2023	194	39.19
2024	163	32.93

The instrument used in this study was a closed questionnaire based on a 4-point Likert scale (4=Strongly Agree, 3=Agree, 2=Disagree, and 1=Strongly Disagree), which was designed to measure four main constructs: scientific culture understanding, local wisdom literacy, digital awareness, and biological literacy. Each construct was measured using several indicators that had been developed based on the latest literature review (Table 2). The validity of the instrument was consulted with experts in the fields of biology education, learning technology, and cultural practitioners. The validation results showed that the instrument was suitable for use with a score in the range of 3.44 (Valid). Range (4.00-3.51 = very valid, 3.50-3.01 = valid, 3.00-2.50 = invalid, and below 2.50 = very invalid).

Table 2 Research instrument

Indicators/ Constructs	Variable items	Survey item statement	Modification from source
Scientific culture understanding	SCU1	I understand that science develops through observation and experimentation.	(Bybee & Mccrae, 2011; Estrada et al., 2011; Hess et al., 2022; Martín et al., 2021)
	SCU2	I recognize the importance of being objective and impartial in scientific activities.	
	SCU3	I value scientific evidence more than personal opinion in making decisions.	
	SCU4	I am accustomed to asking critical questions about the information I receive.	
	SCU5	I believe that scientific knowledge can change as new evidence is discovered.	
	SCU6	I am accustomed to working together and discussing to solve problems scientifically.	
	SCU7	I feel that scientific activities reflect an honest, thorough, and responsible attitude.	
Digital mindfulness	DMS1	I am aware of the impact of gadget use on my mental and physical health.	(Islamiyanti et al., 2023; Jamaluddin, Jufri, et al., 2023; Suhadi et al., 2023)
	DMS2	I am able to control my use of social media so that it does not interfere with productivity.	
	DMS3	I take time to be offline to maintain a balance between digital and real life.	
	DMS4	I use digital devices with a clear purpose such as learning, not just a habit.	
	DMS5	I am able to recognize when I am digitally distracted and try to overcome it.	
	DMS6	I set time limits on my use of digital technology every day.	
	DMS7	I feel calmer and more focused when using technology consciously and purposefully.	

Indicators/ Constructs	Variable items	Survey item statement	Modification from source
Local wisdom literacy	LWL1	I understand the cultural values and local wisdom that apply in my area.	(Jamaluddin et al., 2022; Uge et al., 2019; Yuliana et al., 2023)
	LWL2	I always appreciate the diversity of traditions and customs, both in and outside the educational environment.	
	LWL3	I can explain the role of local wisdom in preserving the environment and socio-culture.	
	LWL4	I believe that local wisdom is still relevant in today's modern life.	
	LWL5	I actively seek information about culture and local wisdom through media or social interactions.	
	LWL6	I use local wisdom values as guidelines for my attitudes and behavior.	
	LWL7	I feel it is important to preserve and pass on local wisdom to the next generation.	
Biological literacy	BGL1	I understand basic biological concepts such as cells, tissues, organs, organ systems, and individuals.	(Sari et al., 2023; Schultchen et al., 2020; Yosep et al., 2024)
	BGL2	I can explain how biology is applied in everyday life.	
	BGL3	I am able to interpret graphs, tables, or data related to biology.	
	BGL4	I am aware of the impact of biology on health, the environment, and public policy.	
	BGL5	I can make decisions based on an understanding of biological principles.	
	BGL6	I have an interest in continuing to learn and explore biology in depth.	
	BGL7	I am aware of contemporary biological issues such as biotechnology and climate change.	

Data collection used an electronic questionnaire (e-questionnaire) based on a 4-point Likert scale. This method was chosen because it is efficient in reaching a large number of respondents spread across various universities, and is in accordance with the cross-sectional approach which only requires one data collection. The survey was conducted online using a platform such as Google Form which is easily accessible to students and can be done anywhere and anytime.

The data analysis technique in this study used the Partial Least Squares Structural Equation Modeling (PLS-SEM) approach (Hair et al., 2011), which is very suitable for analyzing complex structural models with many latent constructs and indicators, especially in the context of exploring causal and mediating relationships between variables. PLS-SEM was chosen because it has advantages in overcoming relatively small sample sizes, non-normal data distributions, and predictive and theoretical models (Al-Maroof & Al-Emran, 2018). The analysis was carried out using SmartPLS software version 3.2.2.

Testing the measurement model of convergent validity is tested through the loading factor value (ideal > 0.7) and the Average Variance Extracted (AVE) value (must > 0.5) (Hair et al., 2021; Mahande, Abdal, et al., 2025). AVE measures the proportion of indicator variance that is successfully explained by the latent construct. Construct Reliability is tested with two main measures, namely Composite Reliability (CR) and Cronbach's Alpha, with an ideal value above 0.7 (Syamsiah et al., 2024). This ensures that the indicators in one construct measure the same thing consistently. Discriminant validity is tested using the Fornell-Larcker Criterion method (Fornell & Larcker, 1981). Discriminant validity shows that different constructs in the model do not overlap.

Significance testing is carried out through bootstrapping with 5,000 replications to obtain t-statistic and p-value values (Henseler, 2012). The path value is considered significant if the t value> 1.96 for a significance level of 5% (p = 0.05). Analysis for the R^2 Value (R-Square) indicates how much the independent variable is able to explain the dependent variable. An R^2 value ≥ 0.25 is considered weak, ≥ 0.5 moderate, and ≥ 0.75 strong (Hair et al., 2021).

C. Results and discussion

Table 3 shows that all constructs show very good internal reliability, with Cronbach's Alpha and Composite Reliability (CR) values above 0.87, indicating high consistency between items. Convergent validity is also met, indicated by the AVE value ≥ 0.5 for all constructs, meaning that more than 50% of the indicator variance can be explained by the construct. Several indicators such as DMS5, LWL1, LWL2, and BGL6 have loadings <0.7, so they are removed (labeled "Out") to improve construct validity. This finding is supported by previous empirical studies that suggest removing weak indicators as a strategy to improve the fit of the measurement model in PLS-SEM. Several studies have also suggested that indicators with low loadings are questionable in their contribution to measuring the constructs they measure. This decision is based on the principle that indicators with low loadings can obscure relationships between constructs and create noise in the model (Benitez et al., 2020; Hair et al., 2019; Mahande, Abdal, et al., 2025). Thus, the measurement model in this study can be said to meet the criteria for strong validity and reliability to proceed to the structural analysis stage.

Table 4 presents the results of the discriminant validity test between constructs using the Fornell-Larcker criterion, where the diagonal value represents the square root of the Average Variance Extracted (AVE) of each construct. Discriminant validity has been met because the diagonal (the root of AVE) is greater than the correlation value between constructs located in the related rows and columns. It can be seen that all diagonal values (e.g., SCU = 0.756, DMS = 0.818, LWL = 0.762, and BGL = 0.780) are higher than the correlation between the corresponding constructs. For example, SCU (0.756) is more related to LWL (0.734) than to DMS (0.434), which indicates that students' scientific culture understanding is more closely related to their ability to appreciate local wisdom literacy, while their digital mindfulness has a weaker relationship with these constructs. According to Fornell & Larcker (1981), discriminant validity is crucial in a structural model because it ensures that each construct actually measures a different concept and there is no conceptual overlap. In addition, previous studies have also emphasized that without adequate discriminant validity, the results of structural model testing are at risk of misinterpretation. Therefore, the fulfillment of the Fornell-Larcker criteria is a strong basis for continuing to a deeper analysis of the relationship between constructs.

Table 3 Evaluation of the measurement model

Indicators	Outer loadings	Alpha	Rho_A	CR	AVE
SCU1	0.762				
SCU2	0.731				
SCU3	0.776				
SCU4	0.750	0.875	0.876	0.903	0.571
SCU5	0.736				
SCU6	0.795				
SCU7	0.737				
DMS1	0.806				
DMS2	0.729				
DMS3	0.845				
DMS4	0.879	0.901	0.907	0.924	0.670
DMS5	0.637 (Out)				
DMS6	0.824				
DMS7	0.819				
LWL1	0.665 (Out)				
LWL2	0.667 (Out)				
LWL3	0.726				
LWL4	0.749	0.819	0.828	0.873	0.581
LWL5	0.704				
LWL6	0.818				
LWL7	0.806				
BGL1	0.750				
BGL2	0.787				
BGL3	0.803				
BGL4	0.810	0.871	0.871	0.903	0.608
BGL5	0.770				
BGL6	0.675 (Out)				
BGL7	0.756				

Table 4 Results of discriminant validity between constructs with Fornell-Larcker criteria

	SCU	DMS	LWL	BGL
SCU	0.756			
DMS	0.434	0.818		
LWL	0.734	0.482	0.762	
BGL	0.630	0.424	0.573	0.780

Table 5 shows that discriminant validity is met because each indicator has the highest loading on its original construct compared to other constructs. For example, the SCU1 indicator has the highest loading of 0.762 on the SCU construct, higher than its loading on DMS, LWL, and BGL. Similar patterns appear consistent in almost all indicators, such as DMS4 (0.879 on DMS), LWL6 (0.818 on LWL), and BGL4 (0.810 on BGL), indicating that each indicator measures the right construct and does not overlap significantly. For example, the clear separation between BGL and other indicators indicates that BGL is influenced by SCU and LWL, but is not affected by other dimensions that have lower correlations with this construct.

Discriminant validity through cross loadings is an important part of assessing conceptual clarity between latent constructs, that high indicator loading on the intended construct and low on other constructs reflects empirical separation of constructs. The clarity of differentiation between constructs such as SCU, DMS, LWL, and BGL has direct implications for inferential strength in testing the relationship between constructs in the proposed hypothesis, and ensures that the results of the analysis are not influenced by conceptual bias due to overlapping measurements between constructs (Hair et al., 2019; Yolida, 2023).

Table 5 Cross loadings between indicators on constructs in the measurement model

Variable items	SCU	DMS	LWL	BGL
SCU1	0.762	0.335	0.580	0.396
SCU2	0.731	0.178	0.519	0.378
SCU3	0.776	0.334	0.614	0.477
SCU4	0.750	0.364	0.605	0.489
SCU5	0.736	0.349	0.487	0.530
SCU6	0.795	0.322	0.550	0.478
SCU7	0.737	0.383	0.517	0.560
DMS1	0.297	0.806	0.289	0.288
DMS2	0.358	0.729	0.322	0.408
DMS3	0.341	0.845	0.417	0.294
DMS4	0.417	0.879	0.498	0.321
DMS6	0.369	0.824	0.421	0.435
DMS7	0.330	0.819	0.384	0.320
LWL3	0.503	0.380	0.726	0.344
LWL4	0.508	0.373	0.749	0.466
LWL5	0.512	0.326	0.704	0.360
LWL6	0.641	0.406	0.818	0.417
LWL7	0.616	0.356	0.806	0.564
BGL1	0.506	0.298	0.381	0.750
BGL2	0.537	0.252	0.374	0.787
BGL3	0.444	0.337	0.493	0.803
BGL4	0.495	0.368	0.478	0.810
BGL5	0.484	0.366	0.510	0.770
BGL7	0.482	0.359	0.437	0.756

Table 6 Results of hypothesis testing of influence paths in the structural model

H	Path	Original sample (O)	T statistics (|O/STDEV|)	P values
H1	Scientific culture understanding on digital mindfulness	0.434	10.477	0.000
H2	Scientific culture understanding on local wisdom literacy	0.647	22.857	0.000
H3	Scientific culture understanding on biological literacy	0.429	6.472	0.000
H4	Digital mindfulness on local wisdom literacy	0.201	6.212	0.000
H5	Digital mindfulness on biological literacy	0.148	3.705	0.000
H6	Local wisdom literacy on biological literacy	0.186	2.512	0.012
H7a	Scientific culture understanding on digital mindfulness on biological literacy	0.064	3.281	0.001
H7b	Scientific culture understanding on local wisdom literacy on biological literacy	0.120	2.460	0.014

Table 6 shows that all relationship paths have a p value <0.05, that all influences in the model are statistically significant. The strongest relationship is in the scientific culture understanding on local wisdom literacy (H2) path with an original sample value of 0.647 and a T-statistic of 22.857. Theoretically, these results indicate a synergy between scientific knowledge and local values, which is in line with the ecopedagogy and transdisciplinary approaches. Scientific culture understanding influences local wisdom literacy because scientific culture forms a logical, critical, and evidence-based way of thinking that allows students to evaluate local wisdom scientifically and reflectively (Listia et al., 2025; Verawati & Wahyudi, 2024). When students understand the values and principles in scientific culture, they do not see local wisdom as a static traditional heritage, but as a source of knowledge that can be studied and developed through a scientific approach. The values of conservation, sustainability, and balance contained in local practices can be recognized and interpreted scientifically by students who have a strong scientific culture understanding (McPherson et al., 2016). Furthermore, the strong relationship between scientific cultural understanding and local wisdom literacy in South Sulawesi is due to the close interaction between scientific concepts and cultural values deeply ingrained in the community. As a region rich in local wisdom and cultural traditions, it possesses local practices and knowledge that can be integrated with scientific understanding. This approach is in line with the contextual and transdisciplinary learning paradigm that encourages the integration of science with cultural values.

Therefore, scientific culture not only strengthens scientific literacy, but also opens up space for strengthening local wisdom literacy in relevant and meaningful biology education.

Meanwhile, the weakest but still significant relationship was found in the mediation path H7a and H7b, which showed an indirect effect of scientific culture understanding on biological literacy through digital mindfulness and local wisdom literacy. The significant but weak effect is because the two mediators act as conceptual channels that gradually strengthen the effect of SCU. Students with scientific culture understanding tend to have a tendency to think reflectively, critically, and rationally, which then encourages them to be more aware of using technology wisely (digital mindfulness) (Wahyudiati & Qurniati, 2023), and more open in appreciating and evaluating local values scientifically (local wisdom literacy) (Setyorini et al., 2022). Although the effect of DM and LWL on BGL is not as strong as the direct effect of SCU, both still contribute to shaping the way students' access, understand, and apply biological concepts in digital and cultural contexts (Jamaluddin, Palennari, et al., 2023). The weakness of this effect could be caused by the large individual variation in digital experience and understanding of local culture, as well as the complexity of other factors such as learning motivation and self-regulatory capacity that were not measured in the study.

Path H6 (local wisdom literacy on biological literacy) is also significant at the 5% level ($p = 0.012$), confirming that local wisdom literacy contributes to increasing biological literacy. A significant relationship occurs because local wisdom literacy provides a strong and relevant cultural context for students in understanding and applying biological concepts (Larassati et al., 2025). Local wisdom often contains ecological and biological principles that have been proven to be sustainable for generations, such as nature conservation practices, biodiversity preservation, and wise management of natural resources (Damopolii et al., 2024). When students understand and internalize these values, they find it easier to relate them to theories and concepts in modern biology, making biology learning more meaningful, contextual, and applicable (McLeod, 2019; Palennari et al., 2023). In addition, a learning approach that integrates local values encourages students' emotional and social involvement in environmental and biological issues around them.

In addition, the influence of scientific culture understanding (SCU) on digital mindfulness (DM), biological literacy (BGL), and the influence of DM on local wisdom literacy (LWL) and BGL can be explained through the fundamental role of scientific culture understanding in forming reflective, critical, and evidence-based mindsets that underlie digital behavior and how to understand biology. Students who are accustomed to thinking scientifically tend to be more aware of using technology, are able to sort out credible information, and avoid distractions, which are the core of digital mindfulness (Naamati-Schneider & Alt, 2023; Tangkish et al., 2024). In addition, scientific culture also directs students not to simply memorize biological concepts, but to understand and apply them critically in real contexts, thereby strengthening biological literacy (Mahdi, 2024). Meanwhile, digital mindfulness helps students become more selective in absorbing information, including that related to local culture, thereby strengthening literacy towards local wisdom (Liu & Liu, 2025; Sagala et al., 2024). In the context of biology learning, digital mindfulness also allows students to focus, evaluate scientific information better, and form a deeper understanding, thereby improving biological literacy.

Based on Figure 2, the R^2 value for the Digital Mindfulness variable is 0.189, which is below the threshold of 0.25, so it is categorized as a weak contribution. Scientific culture understanding focuses more on developing evidence-based and critical scientific thinking, while digital awareness involves practical skills in managing interactions with digital media, such as avoiding distractions and filtering relevant information. Meanwhile, local wisdom literacy has an R^2 value of 0.572, which is included in the moderate category because it is between 0.5 and 0.75. Meanwhile, biological literacy has an R^2 value of 0.440, which is also included in the moderate category. These results indicate that scientific culture understanding, digital mindfulness, and local wisdom literacy collectively have moderate explanatory power for biological literacy and local wisdom literacy, but relatively low for digital mindfulness.

Scientific culture understanding and local wisdom provides a strong context in building meaningful biological literacy, that meaningful learning occurs through the interaction between scientific knowledge and cultural context (Cavagnetto, 2010; Norambuena-Meléndez et al., 2023). An empirical also supports this finding, where the integration of scientific and social contextual literacy resulted in a significant increase in biological understanding (Mahanal et al., 2016). The low R^2 value for the digital mindfulness variable may reflect that other factors such as intrinsic motivation, digital experience, or self-regulation have a major contribution to digital mindfulness (Buchanan et al., 2017). This finding reinforces the importance of a holistic approach in developing scientific and biological literacy by considering the combination of science, technology, culture, and local values.

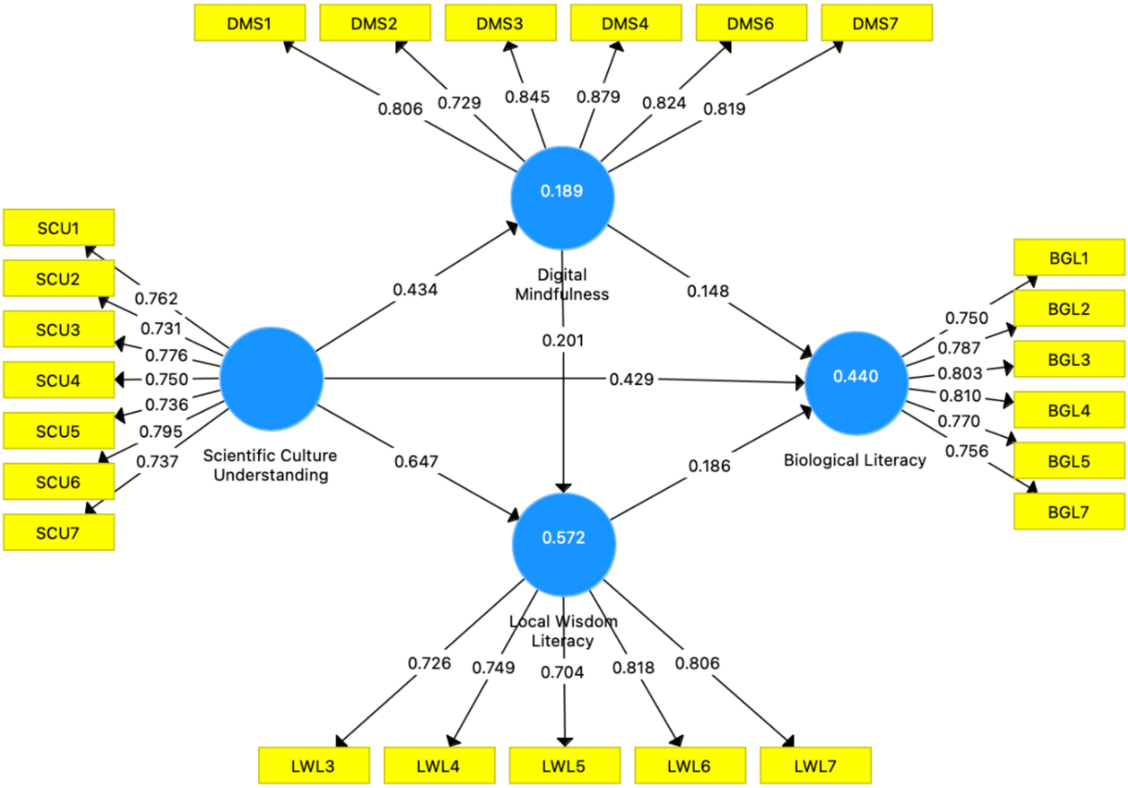

Figure 2 Structural model with R^2 value and path coefficients (Source: Authors' own elaboration, using SmartPLS 3.3.2)

D. Conclusion

Based on the research findings, it can be concluded that scientific culture understanding plays an important role in shaping students' biological literacy directly and indirectly through the mediation of digital mindfulness and local wisdom literacy. These four variables are interrelated in a complete conceptual model, where scientific culture is the main foundation that fosters critical, reflective thinking, and openness to local values and digital challenges. These findings indicate that in depth and contextual biological literacy is not only influenced by cognitive aspects, but also by students' ability to manage digital information and integrate local cultural values into their scientific understanding. This study makes a significant contribution to the development of scientific literacy theory in higher education, especially with the ecopedagogy approach and integration of science in the cultural context. The practical implications of this study include recommendations for developing a curriculum that integrates culture-based education and technology, training educators in utilizing local values in science learning, and strategies for increasing digital awareness among students. However, this study has several limitations, including a cross-sectional approach that is unable to capture the dynamics of literacy development longitudinally, and the focus of research subjects which is limited to students from certain areas in South Sulawesi. Therefore, further research is recommended to use a longitudinal approach and involve more geographically and demographically diverse samples. Exploration of additional variables such as learning motivation, previous digital experience, and self-regulation are also important to gain a deeper understanding of the factors that influence biological literacy in the evolving digital era. Furthermore, this study recommends using a more specific approach, such as qualitative research, to explore how students integrate local wisdom into their understanding of biology through in-depth interviews or focus group discussions. Experimental research can also be conducted to test the effectiveness of learning models that combine scientific cultural understanding, digital awareness, and local wisdom literacy in biology learning. This research can provide empirical evidence regarding the impact of integrating these three aspects on students' high-quality biological literacy.

E. References

Adigwe, I. (2021). Identifying the moderating and mediating variables in parental mediation practices in Nigerian families in the digital age. *Social Media + Society*, *7*(3), 1-12. DOI: https://doi.org/10.1177/20563051211033817

Akman, E., İdil, Ö., & Çakır, R. (2023). An investigation into the levels of digital parenting, digital literacy, and digital data security awareness among parents and teachers in early childhood education. *Participatory Educational Research*, *10*(5), 248-263. DOI: https://doi.org/10.17275/per.23.85.10.5

Al-Maroof, R. A. S., & Al-Emran, M. (2018). Students' acceptance of google classroom: An exploratory study using PLS-SEM approach. *International Journal of Emerging Technologies in Learning*, *13*(6), 112–123. DOI: https://doi.org/10.3991/ijet.v13i06.8275

Arjaya, I. B. A., Suastra, I. W., Redhana, I. W., & Istri Sudiatmika, A. A. (2024). Global trends in local wisdom integration in education: A comprehensive bibliometric mapping analysis from 2020 to 2024. *International Journal of Learning Teaching and Educational Research*, *23*(7), 120-140. DOI: https://doi.org/10.26803/ijlter.23.7.7

Arsih, F., Zubaidah, S., Suwono, H., & Gofur, A. (2021, March). The implementation of RANDAI to improve pre-service biology teachers' communication skills. In *AIP Conference Proceedings* (Vol. 2330, No. 1, p. 030033). AIP Publishing LLC. DOI: https://doi.org/10.1063/5.0043166

Baharun, H., Wahid, A. H., Qodriyah, K., Wahyuni, S., & Fatmawati, F. (2022). Building a literacy culture based on local wisdom through women's leadership. *Jurnal Obsesi Jurnal Pendidikan Anak Usia Dini*, *6*(4), 2533-2543. DOI: https://doi.org/10.31004/obsesi.v6i4.2044

Bahri, A., Jamaluddin, A. B., Muharni, A., Fikri, M. J. N., & Arifuddin, M. (2021, May). The need of science learning to empower high order thinking skills in 21st century. In *Journal of Physics: Conference Series* (Vol. 1899, No. 1, p. 012144). IOP Publishing. DOI: https://doi.org/10.1088/1742-6596/1899/1/012144

Bahri, A., Muharni, A., Jamaluddin, A. B., Hidayat, W., & Arifin, A. N. (2023). Smart teaching based on lesson study promoting stundent's digital literacy in the rural area. *European Journal of Educational Research*, *12*(2), 901–911. DOI: https://doi.org/10.12973/eu-jer.12.2.901

Benitez, J., Henseler, J., Castillo, A., & Schuberth, F. (2020). How to perform and report an impactful analysis using partial least squares: Guidelines for confirmatory and explanatory IS research. *Information and Management*, *57*(2), 103168. DOI: https://doi.org/10.1016/j.im.2019.05.003

Buchanan, R., Southgate, E., Smith, S. P., Murray, T., & Noble, B. C. (2017). Post no photos, leave no trace: Children's digital footprint management strategies. *E-Learning and Digital Media, 14*(5), 275–290. DOI: https://doi.org/10.1177/2042753017751711

Bybee, R. W., & Mccrae, B. (2011). Scientific literacy and student attitudes: Perspectives from PISA 2006 Science, *International Journal of Science Education*, *33*(1), 7-26. DOI: https://doi.org/10.1080/09500693.2010.518644

Cavagnetto, A. R. (2010). Argument to foster scientific literacy: A review of argument interventions in K–12 science contexts. *Review of educational research*, *80*(3), 336-371. DOI: https://doi.org/10.3102/0034654310376953

Chen, Y., & Ping, W. S. (2024). The impact of family cultural capital, school environment, and peer relationships on scientific literacy among primary school students. *Journal of Digitainability Realism & Mastery (Dream)*, *3*(10), 21-31. DOI: https://doi.org/10.56982/dream.v3i10.266

Damopolii, I., Nunaki, J. H., Jeni, J., Rampheri, M. B., & Ambusaidi, A. (2024). An integration of local wisdom into a problem-based student book to empower students' conservation attitudes. *Participatory Educational Research*, *11*(1), 158-177. DOI: https://doi.org/10.17275/per.24.10.11.1

Ellis, K., Kent, M., & Peaty, G. (2017). Captioned recorded lectures as a mainstream learning tool. *M/C Journal*, *20*(3), DOI: https://doi.org/10.5204/mcj.1262

Estrada, M., Woodcock, A., Hernandez, P. R., & Schultz, P. W. (2011). Toward a model of social influence that explains minority student integration into the scientific community. *Journal of Educational Psychology*, *103*(1), 206-222. DOI: https://doi.org/10.1037/a0020743

Fornell, C., & Larcker, D. F. (1981). Evaluating structural equation models with unobservable variables and measurement error. *Journal of marketing research*, *18*(1), 39-50. DOI: https://doi.org/10.1177/002224378101800104

Hair, J. F., Ringle, C. M., Hult, G. T. M., & Sarstedt, M. (2021). Partial Least Squares Structural Equation Modeling (PLS-SEM) Using R. In *Handbook of market research* (pp. 587-632). Cham: Springer International Publishing. DOI: https://doi.org/10.1007/978-3-319-57413-4_15

Hair, J. F., Ringle, C. M., & Sarstedt, M. (2011). PLS-SEM: Indeed a silver bullet. *Journal of Marketing Theory and Practice*, *19*(2), 139–152. DOI: https://doi.org/10.2753/MTP1069-6679190202

Hair, J. F., Risher, J. J., Sarstedt, M., & Ringle, C. M. (2019). When to use and how to report the results of PLS-SEM. *European Business Review*, *31*(1), 2–24. DOI: https://doi.org/10.1108/EBR-11-2018-0203

Henseler, J. (2012, January). PLS-MGA: A non-parametric approach to partial least squares-based multi-group analysis. In *Challenges at the Interface of Data Analysis, Computer Science, and Optimization: Proceedings of the 34th Annual Conference of the Gesellschaft für Klassifikation e. V., Karlsruhe, July 21-23, 2010* (pp. 495-501). Berlin, Heidelberg: Springer Berlin Heidelberg. DOI: https://doi.org/10.1007/978-3-642-24466-7_50

Hess, R. A., Erickson, O. A., Cole, R. B., Isaacs, J. M., Alvarez-Clare, S., Arnold, J., ... & Dolan, E. L. (2023). Virtually the same? Evaluating the effectiveness of remote undergraduate research experiences. *CBE—Life Sciences Education*, *22*(2), ar25. DOI: https://doi.org/10.1101/2022.01.03.474815

Iskandar, B. S., Iskandar, J., Suroso, S., Alfian, R. L., & Mulyanto, D. (2022). Non-edible plants traded in traditional markets of Beringharjo, Yogyakarta and

Pasar Baru, East Kalimantan, Indonesia: The role of biocultural system. *Biodiversitas Journal of Biological Diversity*, *23*(9), 4657-4669. DOI: https://doi.org/10.13057/biodiv/d230932

Islamiyanti, D. F., Lisdiana, L., & Yuniastuti, A. (2023). Development of CTL-based teaching material supplements in biological literacy training. *Journal of Innovative Science Education*, *12*(2), 262-268. DOI: https://doi.org/10.15294/jise.v12i2.71935

Jamaluddin, A. B., Bahri, A., Citra Pratiwi, A., & Merici Lembang, A. (2025). ChatGPT as a pedagogical tool: measuring its influence on cognitive engagement and academic achievement of biology students. *Jurnal Pendidikan MIPA*, *26*(1), 36-50. DOI: https://doi.org/10.23960/jpmipa/v26i1.pp36-50

Jamaluddin, A. B., Palennari, M., Fatmawati, A., & Rosba, E. (2023). SIRI learning model in empowering biology students' critical thinking. *Jurnal Penelitian Pendidikan IPA*, *9*(SpecialIssue), 22–29. DOI: https://doi.org/10.29303/jppipa.v9ispecialissue.5511

Jamaluddin, A. B., Zubaidah, S., Mahanal, S., & Bahri, A. (2023, January). SIRI (stimulation, investigation, review, and inference) learning model to promote creative thinking. In *AIP Conference Proceedings* (Vol. 2569, No. 1, p. 020020). AIP Publishing LLC. DOI: https://doi.org/10.1063/5.0112382

Jamaluddin, A. B., Zubaidah, S., Mahanal, S., & Gofur, A. (2021). The effect of integrated flipped classroom with local cultural values on character building in higher education. *Elementary Education Online*, *20*(2), 54–66. DOI: https://doi.org/10.17051/ilkonline.2021.02.11

Jamaluddin, A. B., Zubaidah, S., Mahanal, S., & Gofur, A. (2022). Exploration of the Indonesian Makassar-Buginese Siri' educational values: The foundation of character education. *International Journal of Evaluation and Research in Education*, *11*(1), 10–19. DOI: https://doi.org/10.11591/ijere.v11i1.21670

Jamaluddin, J., Jufri, A. W., & Ramdani, A. (2023). Effect of e-readiness skills, metacognitive awareness, and biological literacy on the high school students' misconceptions. *Jurnal Pendidikan IPA Indonesia*, *12*(2), 252-264. DOI: https://doi.org/10.15294/jpii.v12i2.37536

Kaaronen, R. O., Waring, T. M., & Mulder, M. B. (2023). *Applying cultural evolution to address climate and environmental challenges*. In *The Oxford Handbook of Cultural Evolution*. Oxford University Press. DOI: https://doi.org/10.1093/oxfordhb/9780198869252.013.73

Kamila, K., Wilujeng, İ., Jumadi, J., & Ungirwalu, S. Y. (2024). Analysis of integrating local potential in science learning and its effect on 21st century skills and student cultural awareness: Literature review, *Jurnal Penelitian Pendidikan IPA, 10*(5), 223-233. DOI: https://doi.org/10.29303/jppipa.v10i5.6485

Kocoglu, E., Oğuz-Haçat, S., & Gocer, V. (2023). The relationship between digital literacy and digital citizenship levels of STEM teacher candidates: The mediating role of digital teaching material development self-efficacy. *Journal of Education in Science Environment and Health*, *9*(3), 194-205. DOI: https://doi.org/10.55549/jeseh.1331283

Larassati, A. A. S., Suciati, S., Sari, M. W., Silvita, S., Prasetyo, O., & Rachman, H. T. (2025). Identification of scientific knowledge of the Patehan Tradition of Yogyakarta Palace as a source of natural science learning. *Jurnal Pendidikan Sains Indonesia*, *13*(1), 213-232. DOI: https://doi.org/10.24815/jpsi.v13i1.42319

Listia, A. P., Wijayanti, A., Ernawati, T., & Septiani, D. (2025). Integration of local culture in the search, solve, create and share (SSCS) learning model to improve scientific literacy: A literature review. *Formatif Jurnal Ilmiah Pendidikan Mipa*, *15*(1), 357-374. DOI: https://doi.org/10.30998/formatif.v15i1.27945

Liu, Y., & Liu, Y. P. (2025). Hoarding knowledge or hoarding stress? Investigating the link between digital hoarding and cognitive failures among chinese college students. *Frontiers in Psychology*, *15*, 1518860. DOI: https://doi.org/10.3389/fpsyg.2024.1518860

Lu, C., & Wan, C. (2018). Cultural self-awareness as awareness of culture's influence on the self: implications for cultural identification and well-being. *Personality and Social Psychology Bulletin*, *44*(6), 823-837. DOI: https://doi.org/10.1177/0146167217752117

Mahanal, S., Zubaidah, S., Bahri, A., & Maratusy, D. S. (2016). Empowering students' critical thinking skills through Remap NHT in biology classroom. In *Asia-Pacific Forum on Science Learning and Teaching* (Vol. 17, No. 2, pp. 1-13). Hong Kong Institute of Education. Retrieved from https://www.eduhk.hk/apfslt/v17_issue2/zubaidah/index.htm#con

Mahande, R. D., Abdal, N. M., Nasir, N., & Rahmi, U. (2025). Design and effectiveness of the HyFlex-VR learning model for emancipated learning in higher education. *Journal of Applied Research in Higher Education*. DOI: https://doi.org/10.1108/JARHE-12-2024-0713

Mahande, R. D., Fakhri, M. M., Suwahyu, I., & Sulaiman, D. R. A. (2025). Unveiling the impact of ChatGPT: investigating self-efficacy, anxiety and motivation on student performance in blended learning environments. *Journal of Applied Research in Higher Education*. DOI: https://doi.org/10.1108/JARHE-07-2024-0372

Mahdi, K. (2024). Class XI students' science literacy ability profile on biology material in MAN 1 KOLAKA. *Journal of Digital Learning and Distance Education*, *3*(2), 975-980. DOI: https://doi.org/10.56778/jdlde.v3i2.277

Martín, C., Segarra, I. M., Toro Ibáñez, M. Á., Mira, S., Fajardo, C., & González-Benito, M. E. (2021). Effectiveness of a hybrid project-based learning (H-

Pbl) approach for students' knowledge gain and satisfaction in a plant tissue culture course, *Education Sciences, 11*(7), 335. DOI: https://doi.org/10.3390/educsci11070335

McLeod, J. J. (2019). The effects on student retention by implementing contextualised, program-specific learning modules in an online student success course. A practice report. *Student Success*, *10*(1), 141–146. DOI: https://doi.org/10.5204/ssj.v10i1.1095

McPherson, J., Sammy, J., Sheppard, D. J., Mason, J. J., Brichieri-Colombi, T. A., & Moehrenschlager, A. (2016). Integrating traditional knowledge when it appears to conflict with conservation: Lessons from the discovery and protection of Sitatunga in Ghana. *Ecology and Society*, *21*(1), 24. DOI: https://doi.org/10.5751/es-08089-210124

Munisa, M., Putri, U. N., Sari, W. V., & Fitri, N. A. (2024). Digital literacy based on local wisdom in inclusive education, *Pionir Jurnal Pendidikan, 13*(1), 120-124. DOI: https://doi.org/10.22373/pjp.v13i1.22058

Naamati-Schneider, L., & Alt, D. (2023). Enhancing collaborative learning in health management education: An investigation of padlet-mediated interventions and the influence of flexible thinking. *BMC Medical Education, 23*(1), 846. DOI: https://doi.org/10.1186/s12909-023-04796-y

Najmah, N., Rusdi, R., & Ristanto, Rizhal H. (2024). Correlational between: Biological literacy and metacognitive abilities with critical thinking in junior high school students. *Jurnal Pendidikan Biologi Indonesia, 10*(3), 1161-1170. DOI: https://doi.org/10.22219/jpbi.v10i3.35137

Nanda, V. S., & Budimansyah, D. (2020). Strengthening of digital media literacy-based character education on hoax news spreading to students (Case study on citizenship education learning in SMP Negeri 2 Bandung). In *Journal of International Conference Proceedings* (Vol. 3, No. 1, pp. 283-290). Association of International Business and Professional Management. DOI: https://doi.org/10.32535/jicp.v2i4.804

Norambuena-Meléndez, M., Guerrero, G., & González-Weil, C. (2023). What is meant by scientific literacy in the curriculum? A comparative analysis between Bolivia and Chile. *Cultural Studies of Science Education*, *18*(3), 937-958. DOI: https://doi.org/10.1007/s11422-023-10190-3

Önel, A., & Durdukoca, Ş. F. (2019). Identifying the predictive power of biological literacy and attitudes toward biology in academic achievement in high school students. *International Online Journal of Educational Sciences*, *11*(2), 214-228. DOI: https://doi.org/10.15345/iojes.2019.02.014

Palennari, M., Jamaluddin, A. B., Syam, S., Nurdiyanti, Rosba, E., Machmud, M. T., & Fatmawati, A. (2023). The power of educational values for shaping the character of university students in the disruption era: Exploring local culture. *Journal of Educational and Social Research*, *13*(6), 224-238. DOI: https://doi.org/10.36941/jesr-2023-0160

Pradana, P. H., Agustini, K., Dantes, G. R., & Wawan Sudatha, I. G. (2024). The urgency of digital literacy learning in educational units: Systematic literature review. *Child Education Journal*, *6*(1), 25-33. DOI: https://doi.org/10.33086/cej.v6i1.6100

Prayitno, B. A., Sugiharto, B., & Titikusumawati, E. (2022). Effectiveness of collaborative constructivist strategies to minimize gaps in students' understanding of biological concepts. *International Journal of Emerging Technologies in Learning, 17*(11), 114-127. DOI: https://doi.org/10.3991/ijet.v17i11.29891

Ridzal, D. A., & Haswan, H. (2023). Analysis of the correlation between science literacy and critical thinking of grade eight students in the circulatory system. *Jurnal Pijar Mipa*, *18*(1), 1-5. DOI: https://doi.org/10.29303/jpm.v18i1.4469

Ristanto, R. H., & Darmawan, E. (2020). Biology reading literacy: Measurement and empowerment through CIRC learning model. *Journal for the Education of Gifted Young Scientists*, *8*(4), 1305-1318. DOI: https://doi.org/10.17478/jegys.679378

Sagala, R. E., Adisaputera, A., & Dalimunthe, S. F. (2024). Analyzing discourse in the digital literacy contains Pakpak local wisdom in procedure text in class. *Journal of Pragmatics and Discourse Research*, *4*(1), 111-118. DOI: https://doi.org/10.51817/jpdr.v4i1.856

Sari, N., Liskinasih, A., & Jansz, M. (2023). Students' engagement in digital mind mapping-supported collaborative learning during the post-pandemic era. *Jurnal Inspirasi Pendidikan*, *13*(1), 59-68. DOI: https://doi.org/10.21067/jip.v13i1.8207

Schultchen, D., Terhorst, Y., Holderied, T., Stach, M., Meßner, E.-M., Baumeister, H., & Sander, L. (2020). Stay present with your phone: a systematic review and standardized rating of mindfulness apps in European App Stores. *International Journal of Behavioral Medicine*, *28*(5), 552-560. DOI: https://doi.org/10.1007/s12529-020-09944-y

Schultz, A. (2024). Messages in the medium: Modernism and self-awareness in the digital age. *Educational Theory*, *74*(6), 803-821. DOI: https://doi.org/10.1111/edth.12672

Setyorini, L., Haryani, S., & Susilaningsih, E. (2022). Development of e-module based on local wisdom to improve science literacy and reading literacy. *Jurnal Pendidikan Kimia*, *14*(1), 28-38. DOI: https://doi.org/10.24114/jpkim.v14i1.32948

Sobach, N. V., T. Marpaung, R. R., Maulina, D., & Yolida, B. (2023). The effect of project-based learning model assisted by interactive digital modules on scientific literacy in biotechnology topic in in 9th grade of junior high school. *Assimilation Indonesian Journal of Biology Education*, *6*(2), 133-140. DOI: https://doi.org/10.17509/aijbe.v6i2.61482

Subiantoro, A. W., Treagust, D. F., & Tang, K. (2021). Indonesian biology teachers' perceptions about socio-scientific issue-based biology instruction. *Asia-Pacific Science Education*, *7*(2), 452-476. DOI: https://doi.org/10.1163/23641177-bja10032

Sudjarwo, S., Sunyono, S., & Herpratiwi, H. (2018). Multicultural approach based education model contribution towards appreciation of the values of local wisdom of elementary school students in Bandar Lampung Indonesia. *The Turkish Online Journal of Design, Art and Communication-TOJDAC*, *8*, 24-30. DOI: https://doi.org/10.7456/1080mse/003

Suhadi, A. P., Ristanto, Rizhal H., Sigit, D. V., & Supriyatin, S. (2023). Assessment of biological literacy for high school students. *Biosfer Jurnal Pendidikan Biologi*, *16*(1), 25-36. DOI: https://doi.org/10.21009/biosferjpb.24765

Suhirman, S., & Khotimah, H. (2020). The effects of problem-based learning on critical thinking skills and student science literacy. *Lensa Jurnal Kependidikan Fisika*, *8*(1), 31-38. DOI: https://doi.org/10.33394/j-lkf.v8i1.2794

Sumatokhin, S., Petrova, O., Serovayskaya, D., & Chistiakov, F. (2020). Digitalization of school biological education: Problems and solutions. In *SHS Web of Conferences* (Vol. 79, p. 01016). EDP Sciences. DOI: https://doi.org/10.1051/shsconf/20207901016

Sun, N., Wang, Y., Ye, C., & Yuehui, L. (2024). Integrating nature of science (NOS) into pedagogical content knowledge (PCK): Enhancing science teaching and learning. *Advances in Education, Humanities and Social Science Research*, *10*(1), 180-180. DOI: https://doi.org/10.56028/aehssr.10.1.180.2024

Syamsiah, S., Jamaluddin, A. B., & Pratiwi, A. C. (2024). Exploring the impact of educational background, spiritual beliefs, and media exposure on environmental knowledge and attitudes. *Eurasia Journal of Mathematics, Science and Technology Education*, *20*(11), em2537. DOI: https://doi.org/10.29333/ejmste/15644

Tangkish, N. P., Tumashbay, T., Shaldarbekova, A., Rakhimshikova, M., Aripzhan, G., & Yerbota, A. (2024). Digital mind and human consciousness: Integration of digital technology in shaping learning experiences. *Perspectives of Science and Education*, *16*(3), 56-75. DOI: https://doi.org/10.32744/pse.2024.3.4

Uge, S., Neolaka, A., & Yasin, M. (2019). Development of social studies learning model based on local wisdom in improving students' knowledge and social attitude. *International Journal of Instruction*, *12*(3), 375-388. DOI: https://doi.org/10.29333/iji.2019.12323a

Verawati, N. N. S., & Wahyudi, W. (2024). Raising the Issue of Local Wisdom in Science Learning and Its Impact on Increasing Students' Scientific Literacy. *IJETE*, *1*(1), 42-54. DOI: https://doi.org/10.33394/ijete.v1i1.10881

Wahyudiati, D., & Qurniati, D. (2023). Ethnochemistry: Exploring the potential of sasak and javanese local wisdom as a source of chemistry learning to improve the learning outcomes of pre-service teachers. *Jurnal Pendidikan Sains Indonesia*, *11*(1), 12-24. DOI: https://doi.org/10.24815/jpsi.v11i1.26790

Wajdi, M., Jamaluddin, A. B., Nurdiyanti, N., & Magfirah, N. (2022). The effectiveness of problem-based learning with environmental-based comic in enhancing students environmental literacy. *International Journal of Evaluation and Research in Education*, *11*(3), 1049–1057. DOI: https://doi.org/10.11591/ijere.v11i3.22140

Widana, I. W., Sumandya, I. W., & Restu Asih, N. P. (2023). Evaluative study: Literacy outreach program based on local wisdom at SDN 1 Apuan Bangli. *Jisae Journal of Indonesian Student Assesment and Evaluation*, *9*(1), 26-36. DOI: https://doi.org/10.21009/jisae.v9i1.32533

Yablokov, B. (2022). The use of digital technologies in education: Academic university experience. *Law & Digital Technologies*, *2*(2), 36. DOI: https://doi.org/10.18254/s278229070024165-7

Yolida, B. (2023). The effect of Indonesian local culture integrated students' environmental awareness on Sdgs: PLS-Sem approach. *Biosfer Jurnal Pendidikan Biologi*, *16*(2), 427-438. DOI: https://doi.org/10.21009/biosferjpb.35493

Yosep, I., Suryani, S., Mediani, Henny S., Mardhiyah, A., & Ibrahim, K. (2024). Types of digital mindfulness: improving mental health among college students – a scoping review. *Journal of Multidisciplinary Healthcare,* 43-53. DOI: https://doi.org/10.2147/jmdh.s443781

Yuliana, Y., Fathurohman, A., & Siahaan, S. M. (2023). Analysis of needs for the development of local wisdom-based junior high school science e-modules related to ethnoscience in South Sumatera. *Jurnal Penelitian Pendidikan IPA*, *9*(10), 7865-7870. DOI: https://doi.org/10.29303/jppipa.v9i10.5292

Zukswert, J. M., Barker, M., & McDonnell, L. (2019). Identifying troublesome jargon in biology: Discrepancies between student performance and perceived understanding. *Cbe—Life Sciences Education*, *18*(1), ar6. DOI: https://doi.org/10.1187/cbe.17-07-0118

Zulirfan, Z., Yennita, Y., Ma'aruf, Z., & Sahal, M. (2023). Ethnoscientific literacy in Pacu Jalur Tradition: Can students connect science with their local culture? *Eurasia Journal of Mathematics Science and Technology Education*, *19*(1), em2210. DOI: https://doi.org/10.29333/ejmste/12773