



Innovative Flipchart-Based Learning Media for Biology Education: A Developmental Research Study

Farhanah¹, Ayu², Budi³, Vivin Yuliza⁴

¹State Junior High School 33 Bandar Lampung, Lampung, Indonesia

²Nusantara Junior High School Bandar Lampung, Lampung, Indonesia

³Tirtayasa Junior High School Bandar Lampung, Lampung, Indonesia

⁴Department of Biology Education, Raden Intan State Islamic University, Lampung, Indonesia

Article Info

Article history:

Received May 15, 2026

Revised Jun 2, 2026

Accepted Jun 29, 2026

Online First Jun 30, 2026

Keywords:

Biology Learning Media
Ecosystem Education
Educational Media Development
Flipchart
Student Responses

ABSTRACT

Purpose of the study: This study aimed to develop a flipchart-based learning media for biology education on ecosystem topics for seventh-grade students and to evaluate its feasibility and user responses for classroom implementation.

Methodology: This study employed a Research and Development approach adapted from the Borg and Gall model. Data were collected through observations, interviews, documentation, and structured questionnaires. The instruments included content expert, language expert, media expert, teacher response, and student response questionnaires based on the Walker and Hess evaluation framework. Data were analyzed using descriptive quantitative techniques with percentage-based feasibility assessments.

Main Findings: The developed flipchart-based learning media was successfully produced and evaluated. Media expert validation yielded a feasibility score of 84%, language expert validation reached 91%, and content expert validation achieved 58%. Teacher responses showed an average score of 71%, while student responses reached 63%. Overall, the developed learning media was categorized as feasible and received positive responses from both teachers and students, indicating its suitability for supporting biology learning activities.

Novelty/Originality of this study: This study introduces a flipchart-based biology learning medium specifically designed for ecosystem learning at the junior secondary level. Unlike previous studies that predominantly focus on digital learning technologies, this research emphasizes a practical, low-cost, and visually structured instructional medium. The study contributes empirical evidence regarding the development process, expert validation, and user responses, thereby expanding knowledge on alternative learning media for biology education in resource-limited educational settings.

This is an open access article under the [CC BY](https://creativecommons.org/licenses/by/4.0/) license

© 2026 by the author(s)



Corresponding Author:

Farhanah

State Junior High School 33 Bandar Lampung, Drs. Hi. Nurdin Muhayat Street No. 26, Enggal, Enggal District, Bandar Lampung City, Lampung, Indonesia.

Email: hnhanafrhanaa@gmail.com

1. INTRODUCTION

Biology education plays an important role in developing students' scientific literacy, critical thinking skills, and understanding of living systems [1], [2]. At the junior secondary school level, biology concepts often involve abstract processes and structures that are difficult for students to visualize. Effective learning therefore requires instructional media that can help transform abstract concepts into more concrete and meaningful learning

Journal homepage: <http://cahaya-ic.com/index.php/JOUABE>

experiences [3], [4]. Learning media not only facilitate knowledge acquisition but also increase students' motivation and engagement during classroom activities [5], [6]. Consequently, the development of appropriate and innovative learning media remains an important concern in biology education.

The implementation of biology learning in many schools still faces various challenges related to student engagement and conceptual understanding [7], [8]. Teachers frequently rely on conventional teaching methods, such as lectures and textbook-centered instruction, which may limit students' active participation in the learning process [9], [10]. As a result, students often experience difficulties in understanding biological concepts and retaining information effectively. Limited access to technology-based resources in some educational settings further constrains the use of interactive learning media [11], [12]. These conditions indicate the need for alternative instructional media that are practical, accessible, and capable of supporting meaningful learning experiences.

Learning media have been recognized as important tools for improving the quality of science education. Previous studies have demonstrated that well-designed instructional media can enhance students' learning motivation, comprehension, and academic achievement. Visual learning resources are particularly beneficial in biology because many biological phenomena involve complex structures, relationships, and processes [13], [14]. Through the integration of visual elements, students can more easily connect theoretical concepts with real-world observations. Therefore, the selection and development of appropriate visual learning media are essential for effective biology instruction.

One instructional medium that has considerable potential for supporting biology learning is the flipchart [15], [16]. A flipchart presents information through a sequence of visual pages that combine images, diagrams, and concise explanations in an organized format. Its simple design, ease of use, and low-cost implementation make it suitable for schools with limited technological facilities. Moreover, flipcharts can facilitate interactive classroom discussions and encourage students to focus on key learning concepts [17], [18]. These characteristics suggest that flipchart-based learning media may serve as an effective alternative for improving biology instruction at the junior secondary level.

Despite the growing body of research on educational media, most previous studies have focused on digital applications, multimedia platforms, e-learning systems, and technology-enhanced learning environments [19], [20]. Comparatively fewer studies have explored the development of flipchart-based learning media, particularly in biology education for junior secondary school students [21], [22]. Existing research has generally emphasized the effectiveness of media use without providing comprehensive evidence regarding product development, feasibility evaluation, and student responses [23], [24]. This situation indicates a research gap concerning the systematic development and assessment of flipchart-based instructional media in biology learning contexts. Addressing this gap is important to provide empirical evidence regarding the educational value of flipchart-based learning resources.

The novelty of this study lies in the development of a biology learning medium specifically designed in a flipchart format for seventh-grade students and evaluated through feasibility and response assessments. Unlike many previous studies that emphasize digital learning technologies, this research focuses on an innovative visual medium that remains practical, economical, and adaptable to various classroom conditions. The developed flipchart integrates biological content, visual illustrations, and structured learning materials to facilitate student understanding. In addition, the study examines both expert validation and student responses to ensure the quality and usability of the product. This approach provides a comprehensive perspective on the development and implementation of flipchart-based learning media in biology education.

The urgency of this research is related to the continuing need for accessible, effective, and engaging instructional media that can support biology learning in diverse educational contexts. Schools require learning resources that are not only pedagogically meaningful but also feasible to implement regardless of technological limitations. The development of innovative flipchart-based learning media may contribute to improving learning quality and expanding the availability of alternative instructional resources for biology teachers. Furthermore, evidence regarding the feasibility and student acceptance of such media is necessary to support its wider application in educational practice. Therefore, this study aims to develop flipchart-based learning media for biology education and to evaluate its feasibility and students' responses toward the use of flipchart media in biology learning.

2. RESEARCH METHOD

2.1. Research Design

This study employed a research and development approach to produce and evaluate a learning medium intended to support biology instruction. Research and development is a systematic process used to create, validate, and improve educational products to ensure their effectiveness, relevance, and suitability for learning activities [25], [26]. The development procedure was adapted from the educational product development model proposed by Borg and Gall. This model was selected because it provides a comprehensive and systematic framework for developing educational products through a series of stages, beginning with identifying learning needs and ending

with product testing and refinement. The use of this development model was intended to ensure that the resulting learning medium met educational standards and could be effectively utilized in classroom learning.

2.2. Research Procedures

This study adopted a research and development procedure adapted from the model proposed by Borg and Gall [27], [28]. Although the original model consists of ten stages, this study implemented seven stages due to limitations in time and resources. The adapted stages included information gathering and needs assessment, planning, development of the initial product, preliminary field testing, product revision, main field testing, and final product revision. The first stage involved identifying learning needs through observations, interviews, and questionnaires administered to teachers and students. The collected information was used to determine existing challenges in biology learning and to establish the specifications of the flipchart-based learning media [21], [29]. The second stage was planning, which included reviewing relevant literature and designing the content, visual layout, and instructional components of the learning media.

The third stage involved developing the initial product by preparing biology learning materials, illustrations, and visual elements and organizing them into a flipchart format. The fourth stage consisted of preliminary field testing through expert validation. The product was evaluated by biology content experts, language experts, and educational media experts to assess its content accuracy, language appropriateness, and design quality [30], [31]. Based on the experts' recommendations, revisions were made to improve the product. The revised learning media was then implemented in the main field testing stage involving seventh-grade students. Student responses were collected to evaluate the practicality, attractiveness, and usability of the developed media. Finally, a final revision was conducted based on the results of the field testing, resulting in the final version of the flipchart-based biology learning media.



Figure 1. Research and Development Procedure for the Flipchart-based Biology Learning Media

2.3. Research Instruments

Data were collected using structured questionnaires designed to evaluate the feasibility and user responses toward the developed flipchart-based learning media. Prior to data collection, all instruments were reviewed and validated by academic experts to ensure content relevance, clarity, and appropriateness for the study objectives [32], [33]. The validated instruments were then employed during the expert validation and field-testing stages. The assessment criteria were adapted from the instructional media evaluation framework proposed by Walker and Hess, encompassing three dimensions: content and objectives quality, instructional quality, and technical quality. These dimensions were used to evaluate the overall quality and feasibility of the developed learning media. Five types of instruments were used in this study: a content expert validation questionnaire, a language expert validation questionnaire, a media expert validation questionnaire, a teacher response questionnaire, and a student response questionnaire. The expert validation questionnaires were used to assess the appropriateness of the learning content, language, and media design, while the response questionnaires were administered to collect perceptions regarding the practicality, attractiveness, and usability of the flipchart-based biology learning media.

Table 1. Assessment Criteria for the Flipchart-Based Learning Media

Dimension	Indicators
Content and Objectives Quality	Accuracy of content, relevance to learning objectives, completeness of material, balance of information, and attractiveness of content presentation.
Instructional Quality	Learning support, learning opportunities, motivational value, instructional flexibility, integration with learning activities, interaction quality, assessment support, and educational impact.
Technical Quality	Readability, ease of use, visual appearance, layout organization, typography, color selection, and overall design quality.

2.4. Data Collection

Data were collected through observations, interviews, questionnaires, and documentation. Observations were conducted during the preliminary stage to identify existing learning conditions, instructional challenges, and the availability of learning media used in biology classes. The information obtained from the observations was used to support the needs assessment and product development process. Semi-structured interviews were conducted with biology teachers to obtain in-depth information regarding classroom practices, learning difficulties, students' needs, and expectations for instructional media [34], [35]. The interview data provided valuable insights for designing the flipchart-based learning media and ensuring its relevance to the learning context.

Questionnaires were administered during the validation and field-testing stages. Expert validation questionnaires were distributed to content, language, and educational media experts to assess the quality and feasibility of the developed product. Teacher and student response questionnaires were used to collect feedback regarding the practicality, attractiveness, and usability of the flipchart-based learning media. Documentation was used to support and verify the research process [36], [37]. Documentation included photographs and records of learning activities, product validation, field testing, and questionnaire administration. These materials served as supporting evidence for the implementation of the study and the development of the learning media.

2.5. Data Analysis

The data obtained from expert validation questionnaires and user response questionnaires were analyzed using descriptive quantitative techniques [38], [39]. The analysis aimed to determine the feasibility, practicality, and attractiveness of the developed flipchart-based learning media. A four-point rating scale was employed, ranging from 1 (Poor) to 4 (Excellent). The percentage score for each assessment aspect was calculated using the following formula:

$$P = \frac{\sum X}{\sum X_{max}} \times 100\% \quad \dots (1)$$

The resulting percentage scores were then interpreted according to the feasibility criteria presented in Table 3. Learning media categorized as Feasible or Highly Feasible were considered suitable for classroom implementation. In addition, teacher and student response data were analyzed descriptively to evaluate the practicality and usability of the developed learning media.

Table 2. Rating Scale Used in the Questionnaires

Score	Interpretation
4	Excellent
3	Good
2	Fair
1	Poor

Table 3. Feasibility Criteria of the Developed Learning Media

Percentage (%)	Interpretation
81–100	Highly Feasible
61–80	Feasible
41–60	Moderately Feasible
21–40	Less Feasible
0–20	Not Feasible

3. RESULTS AND DISCUSSION

3.1. Media Expert Validation

Media expert validation was conducted to evaluate the quality and feasibility of the developed flipchart-based learning media. The evaluation was performed by an expert in educational technology using a structured

validation questionnaire consisting of 20 assessment items. The instrument assessed three dimensions, namely flipchart design, media components, and media suitability. The validation results showed that the developed learning media achieved an overall score of 57 out of a maximum score of 68, corresponding to a feasibility percentage of 84%. Based on the predetermined feasibility criteria, the product was categorized as Highly Feasible. The flipchart design dimension obtained a score of 36 out of 44 (82%), while the media components dimension achieved 11 out of 12 (93%). The media suitability dimension received a score of 10 out of 12 (83%). These findings indicate that all evaluated dimensions met the criteria of highly feasible, suggesting that the developed flipchart-based learning media possesses strong visual quality, appropriate design characteristics, and suitability for biology learning activities.

Table 4. Results of Media Expert Validation

Dimension	Obtained Score	Maximum Score	Percentage (%)	Interpretation
Flipchart Design	36	44	82	Highly Feasible
Media Components	11	12	93	Highly Feasible
Media Suitability	10	12	83	Highly Feasible
Total	57	68	84	Highly Feasible

3.2. Language Expert Validation

Language expert validation was conducted to evaluate the clarity, readability, grammatical accuracy, and appropriateness of the language used in the developed flipchart-based learning media. The evaluation was performed by a language expert using a structured validation questionnaire. In addition to providing quantitative ratings, the validator also offered recommendations for improvement, particularly regarding spelling conventions, language accuracy, and word choice. These suggestions were incorporated into the revision process to improve the overall quality of the learning media.

The initial validation results indicated that the developed product obtained a total score of 64 out of a maximum score of 80, corresponding to a feasibility percentage of 80%, which was categorized as Feasible. The content feasibility dimension achieved 82%, the language dimension achieved 75%, and the media suitability dimension achieved 83%. These findings suggested that the learning media was generally appropriate but required several revisions to enhance linguistic quality and consistency.

Following the revision process, the overall feasibility score increased to 91% (73 out of 80), resulting in a Highly Feasible classification. The content feasibility dimension improved from 82% to 95%, while the language dimension increased from 75% to 92%. These improvements demonstrate that the revisions successfully enhanced the quality of the language and content presentation. Overall, the validation results confirmed that the revised flipchart-based learning media met the required linguistic standards and was suitable for implementation in biology learning activities.

Table 5. Initial Language Expert Validation Results

Dimension	Obtained Score	Maximum Score	Percentage (%)	Interpretation
Content Feasibility	36	44	82	Feasible
Language Quality	18	24	75	Feasible
Media Suitability	10	12	83	Feasible
Total	64	80	80	Feasible

Table 6. Revised Language Expert Validation Results

Dimension	Obtained Score	Maximum Score	Percentage (%)	Interpretation
Content Feasibility	42	44	95	Highly Feasible
Language Quality	22	24	92	Highly Feasible
Media Suitability	9	12	75	Feasible
Total	73	80	91	Highly Feasible

3.3. Content Expert Validation

Content expert validation was conducted to assess the accuracy, completeness, relevance, and appropriateness of the ecosystem materials presented in the flipchart-based learning media. The evaluation was carried out by a biology education expert using a structured validation questionnaire. In addition to assigning scores, the validator provided suggestions for improving the content organization, language clarity, and alignment between the learning materials and instructional objectives. These recommendations were used as the basis for revising the product. The initial validation results indicated that the developed learning media obtained a total score of 40 out of a maximum score of 84, corresponding to a feasibility percentage of 48%, which was categorized as Moderately Feasible. The content feasibility dimension achieved 50%, the language dimension achieved 43%,

and the media suitability dimension achieved 50%. These findings suggested that several aspects of the learning media required revision before classroom implementation.

Following the revision process, the overall feasibility score increased to 58% (49 out of 84). Improvements were observed across all assessment dimensions. The content feasibility dimension increased from 50% to 61%, the language dimension increased from 43% to 50%, and the media suitability dimension increased from 50% to 67%. Although the revised product demonstrated better performance than the initial version, the results indicate that further refinement may still be beneficial. Nevertheless, the increase in scores across all dimensions confirms that the revision process contributed positively to improving the quality and suitability of the developed flipchart-based learning media.

Table 7. Initial Content Expert Validation Results

Dimension	Obtained Score	Maximum Score	Percentage (%)	Interpretation
Content Feasibility	22	44	50	Moderately Feasible
Language Quality	12	28	43	Moderately Feasible
Media Suitability	6	12	50	Moderately Feasible
Total	40	84	48	Moderately Feasible

Table 8. Revised Content Expert Validation Results

Dimension	Obtained Score	Maximum Score	Percentage (%)	Interpretation
Content Feasibility	27	44	61	Feasible
Language Quality	14	28	50	Moderately Feasible
Media Suitability	8	12	67	Feasible
Total	49	84	58	Moderately Feasible

3.4. Biology Teacher Responses

Following the expert validation process, the revised flipchart-based learning media was evaluated by three biology teachers from three different junior secondary schools. The evaluation aimed to determine teachers' perceptions regarding the feasibility, practicality, and usefulness of the developed learning media in classroom instruction. The results indicated that the developed learning media received positive responses from all participating teachers. The teacher from School A assigned a feasibility score of 64%, while the teachers from School B and School C assigned scores of 73% and 75%, respectively. The overall average feasibility score was 71%, indicating that the developed flipchart-based learning media was categorized as Feasible for classroom implementation. These findings suggest that teachers perceived the media as appropriate and potentially useful for supporting biology learning activities.

Table 9. Biology Teacher Responses Toward the Developed Learning Media

School	Obtained Score	Maximum Score	Percentage (%)	Interpretation
School A	72	112	64	Feasible
School B	82	112	73	Feasible
School C	84	112	75	Feasible
Average	238	336	71	Feasible

3.5. Student Responses

The practicality of the developed flipchart-based learning media was further evaluated through field testing involving students from three junior secondary schools. Prior to large-scale implementation, a small-scale trial was conducted with 15 students to identify potential weaknesses and gather initial feedback. The small-scale trial produced a feasibility score of 65%, indicating that the learning media was appropriate for further testing. Subsequently, a broader field test was conducted in three schools. The results showed that students responded positively to the developed learning media, with feasibility percentages of 61%, 65%, and 62% across the participating schools. The overall average score was 63%, which falls within the Feasible category. These findings indicate that students considered the flipchart-based learning media useful, understandable, and appropriate for supporting biology learning activities.

Table 10. Student Responses During Field Testing

School	Percentage (%)	Interpretation
School A	61	Feasible
School B	65	Feasible
School C	62	Feasible
Average	63	Feasible

Based on feedback obtained from expert validators, biology teachers, and students, several improvements were made to the developed learning media. The revisions focused on enhancing content organization, language clarity, visual presentation, and overall usability. The final product was designed as a flipchart-based biology learning medium covering ecosystem topics for seventh-grade students. The completed product had undergone expert validation and field testing and demonstrated acceptable levels of feasibility and practicality. Therefore, the developed flipchart-based learning media can be used as an alternative instructional resource to support biology learning in junior secondary schools.

The findings indicate that the developed flipchart-based learning media demonstrated an acceptable level of feasibility based on evaluations from media experts, language experts, content experts, teachers, and students. Rather than merely reflecting the quality of the product, these findings suggest that flipcharts remain a relevant instructional medium despite the increasing emphasis on digital learning technologies. The positive evaluations imply that effective learning media are determined not only by technological sophistication but also by their ability to present learning materials in an organized, visually meaningful, and pedagogically appropriate manner [40], [41]. In biology education, where many concepts are abstract and interconnected, sequential visual representations help learners construct conceptual understanding more systematically. Consequently, the developed flipchart can be viewed as an instructional tool that supports cognitive processing by reducing unnecessary cognitive load while emphasizing essential biological concepts.

The relatively high evaluation from media and language experts indicates that visual presentation and linguistic clarity are essential components influencing the overall quality of instructional media. A well-organized layout, readable typography, appropriate illustrations, and concise explanations facilitate students' attention and improve the accessibility of learning materials. This finding aligns with multimedia learning principles, which emphasize that students understand concepts more effectively when verbal explanations are integrated with meaningful visual representations. Although the developed product is not technology-based, its visual sequencing and structured content organization allow students to process information gradually, making complex ecosystem concepts easier to comprehend [42], [43].

An interesting finding of this study is the difference in evaluation scores among expert validators. While media and language experts categorized the product as highly feasible, the content expert provided a considerably lower assessment even after revision. This discrepancy suggests that educational media development should not focus solely on technical design and readability but also ensure strong alignment between scientific content, curriculum objectives, and conceptual accuracy. The content expert's recommendations indicate that scientific precision remains a critical aspect of biology instructional materials. Therefore, iterative revisions involving subject-matter specialists are indispensable during the development process to improve both pedagogical quality and scientific validity before broader classroom implementation [44], [45].

The positive responses from biology teachers further demonstrate the practical value of the developed flipchart in supporting classroom instruction. Teachers perceived the media as sufficiently flexible and easy to integrate into existing teaching practices, particularly in schools with limited technological resources [46], [47]. This finding reinforces the notion that instructional innovation should consider contextual realities rather than assuming that digital technologies are always the most appropriate solution. In many educational settings, especially those with limited infrastructure, affordable and portable instructional media may provide more sustainable learning support than technology-dependent alternatives [48], [49].

Similarly, student responses indicate that the developed media successfully attracted learners' interest and facilitated classroom learning. Although the response scores were moderate rather than exceptionally high, they suggest that students generally accepted the flipchart as a useful learning resource. The sequential presentation of ecosystem concepts, accompanied by visual illustrations, likely contributed to improved engagement during learning activities. Student acceptance is particularly important because motivation and engagement often influence the effectiveness of instructional media [50], [51]. When students perceive learning materials as understandable and visually appealing, they are more likely to participate actively and retain conceptual knowledge.

The present findings are consistent with previous studies investigating flipchart-based instructional media. Okereke and Okoro [15] reported that flipchart-supported instruction significantly increased students' interest in biology learning compared with conventional teaching approaches. Likewise, Mawaddah and Rasyidah [16] found that flipchart media effectively enhanced students' scientific literacy by presenting biological concepts through organized visual materials. Similar results were also reported by Tantu et al. [21], who demonstrated that flipchart-based learning media developed for the human digestive system achieved satisfactory feasibility and supported students' conceptual understanding. Furthermore, Dongoran et al. [22] concluded that integrating flipchart media into science instruction contributed positively to students' learning outcomes. Collectively, these previous studies strengthen the present findings by providing empirical evidence that flipcharts remain an effective instructional medium across different biology topics and educational contexts.

Compared with previous research, this study contributes additional evidence by employing a comprehensive development framework that combines expert validation, teacher evaluation, and student responses

within a single research process. Many previous studies primarily focused on measuring learning outcomes after implementation, whereas the present study emphasizes the systematic development and quality assurance process before classroom application. This comprehensive evaluation provides stronger evidence regarding the feasibility and practical applicability of flipchart-based instructional media for junior secondary biology education.

This study provides several practical implications for biology education. First, the developed flipchart offers teachers an alternative instructional medium that is inexpensive, portable, and independent of internet connectivity or electronic devices, making it particularly suitable for schools with limited technological infrastructure. Second, the systematic development procedure adopted in this study may serve as a practical reference for teachers and educational practitioners who intend to develop similar instructional materials for other biology topics or science subjects. Third, the findings encourage educational institutions to recognize that innovation in learning media does not necessarily require sophisticated technology; rather, instructional effectiveness depends on pedagogical appropriateness, visual organization, and alignment with curriculum objectives. Therefore, flipchart-based media may become a practical solution for improving classroom engagement while maintaining accessibility across diverse educational environments.

Several limitations should be acknowledged when interpreting the findings of this study. First, the product evaluation primarily focused on feasibility and user responses rather than measuring its effectiveness in improving students' academic achievement, conceptual understanding, or long-term knowledge retention. Second, the study involved participants from only three junior secondary schools, limiting the generalizability of the findings to broader educational settings. Third, the relatively moderate assessment provided by the content expert indicates that additional refinement of scientific content may further improve the instructional quality of the developed media. Finally, the study evaluated only ecosystem topics for seventh-grade students; therefore, future research should investigate the applicability of flipchart-based learning media across different biology topics, grade levels, and instructional contexts while incorporating experimental designs to examine learning effectiveness more comprehensively.

4. CONCLUSION

This study successfully developed a flipchart-based learning media for biology education on ecosystem topics for seventh-grade students. The developed product was designed using attractive visual elements, sequential illustrations, clear content organization, and language appropriate to students' learning characteristics. The development process followed a systematic research and development procedure involving expert validation, revision, and field testing. The feasibility evaluation indicated that the learning media achieved a score of 84% from the media expert, 91% from the language expert, and 58% from the content expert. Teacher responses yielded an average score of 71%, while student responses reached 63%, indicating that the developed media was considered feasible and positively received by users. Overall, the findings suggest that the flipchart-based learning media can serve as an alternative instructional resource to support biology learning and enhance students' engagement in the classroom.

ACKNOWLEDGEMENTS

The authors would like to thank all parties who contributed to the successful completion of this research, including the experts, teachers, students, and school administrators who participated in the study. Their support, cooperation, and valuable feedback were greatly appreciated.

AUTHOR CONTRIBUTIONS

Conceptualization, F. and V.Y.; Methodology, F. and V.Y.; Software, F.; Validation, F., A., B., and V.Y.; Formal Analysis, F.; Investigation, F., A., and B.; Resources, A. and B.; Data Curation, F.; Writing – Original Draft Preparation, F.; Writing – Review & Editing, V.Y., A., and B.; Visualization, F.; Supervision, V.Y.; Project Administration, F.; Funding Acquisition, V.Y.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY

Not applicable.

REFERENCES

- [1] H. Semilariski and A. Laisu, "Exploring biological literacy: A systematic literature review of biological literacy," *Eur. J. Educ. Res.*, vol. 10, no. 4, pp. 1907–1918, 2021, doi: 10.12973/eu-jer.10.3.1181.
- [2] H. Suwono, N. L. Rofi'Ah, M. Saefi, and R. Fachrunnisa, "Interactive socio-scientific inquiry for promoting scientific literacy, enhancing biological knowledge, and developing critical thinking," *J. Biol. Educ.*, vol. 57, no. 5, pp. 944–959,

- Oct. 2023, doi: 10.1080/00219266.2021.2006270.
- [3] H. M. Hsbollah and H. Hassan, "Creating meaningful learning experiences with active, fun, and technology elements in the problem-based learning approach and its implications," *Malaysian J. Learn. Instr.*, vol. 19, no. 1, pp. 147–181, 2022, doi: 10.32890/mjli2022.19.1.6.
 - [4] R. Koskinen and H. Pitkaniemi, "Meaningful learning in mathematics: A research synthesis of teaching approaches," *Int. Electron. J. Math. Educ.*, vol. 17, no. 2, pp. 1–16, Feb. 2022, doi: 10.29333/iejme/11715.
 - [5] Y. D. Puspitarini and M. Hanif, "Using learning media to increase kearning motivation in elementary school," *Anatol. J. Educ.*, vol. 4, no. 2, pp. 53–60, 2019, doi: 10.29333/aje.2019.426a.
 - [6] A. Alfiyani and D. Darmawan, "The influence of classroommmManagement and the use of learning media on increasing student learning motivation," *Hikmah*, vol. 20, no. 2, pp. 372–382, 2023, doi: 10.53802/hikmah.v20i2.336.
 - [7] R. M. J. Lagura and M. L. Bulay, "Enhancing students' engagement and conceptual understanding on select biological concepts in an interactive learning management system," in *2025 14th International Conference on Educational and Information Technology (ICEIT)*, IEEE, Mar. 2025, pp. 273–280. doi: 10.1109/ICEIT64364.2025.10975885.
 - [8] M. Z. Afnan and R. P. Puspitawati, "Exploration of biological concept understanding through augmented reality: A constructivism theory approach," *JPBI (Jurnal Pendidik. Biol. Indones.)*, vol. 10, no. 3, pp. 1139–1147, 2024, doi: 10.22219/jpbi.v10i3.36896.
 - [9] M. Zheng, "Psychology curriculum and teaching based on the student-centered approach," *Adv. Educ. Technol. Psychol.*, vol. 8, no. 3, pp. 30–37, 2024, doi: 10.23977/aetp.2024.080305.
 - [10] A. Ahmed and B. C. Ekong, "Do we need special preparation for teaching the special children?," *Edutama J. Ilm. Penelit. Tindakan Kelas*, vol. 2, no. 2, pp. 140–146, 2026, doi: 10.69533.
 - [11] L. S. Sitorus *et al.*, "Literature review on the use of technology-based learning media in the context of distance learning," *J. Med. Med.*, vol. 4, no. 3, pp. 283–289, 2025.
 - [12] H. Apriani, "Utilization of 'learning house' as a technology-based media for technology-based Indonesian learning," *Edunesia J. Ilm. Pendidik.*, vol. 4, no. 2, pp. 695–710, 2023, doi: 10.51276/edu.v4i2.294.
 - [13] V. Mutale, A. Chikonde, and P. Mwewa, "An appraisal of diagrams and models in biology education : Examining the extent of their pedagogical integration, pedagogical value, and influence on learner performance in Kitwe, Zambia," *J. Res. Innov. Implic. Educ.*, vol. 10, no. 1, pp. 561–573, 2026, doi: 10.59765/n2tw8.
 - [14] L. Aja *et al.*, "Impacts of instructional materials in enhancing biology concepts retention among secondary school students in Izzi, Ebonyi State, Nigeria," *J. Res. Environ. Sci. Educ.*, vol. 3, no. 1, pp. 46–57, 2026, doi: 10.70232/jrese.v3i1.43.
 - [15] E. I. Okereke and N. G. Okoro, "Improving students' interest in biology using powerpoint presentation and flipchart teaching strategies," *African J. Sci. Technol. Math. Educ.*, vol. 0141, no. 6, pp. 413–421, 2023.
 - [16] H. Mawaddah and R. Rasyidah, "Enhancing students' scientific literacy on competence aspect through flipchart media : A development study on human respiratory system learning," *J. Pembelajaran dan Biol. Nukl.*, vol. 11, no. 3, pp. 1160–1173, 2025, doi: 10.36987/jpbn.v11i3.8100.
 - [17] J. M. V. Campoverde, I. S. L. Quishpe, and G. S. V. Álvarez, "The flip chart to enhance efl learners' vocabulary," *Rev. Científica Innovación Educ. y Soc. Actual "ALCON"*, vol. 5, no. 1, pp. 144–165, 2025, doi: 10.62305/alcon.v5i1.388.
 - [18] I. Y. Y. Awalia, M. N. Z. Makmun, and L. Fadilah, "The implementation of course review horay learning model with flip chart media to improve thematic learning outcomes of elementary school students," *J. Child. Dev.*, vol. 4, no. 1, pp. 72–86, 2024, doi: 10.25217/jcd.v4i1.4476.
 - [19] M. Lubis, M. Nurkanti, and R. Hartono, "The role of technology-enhanced learning media in supporting innovative teaching methods in higher education," *Int. J. Technol. Educ. Sci.*, vol. 10, no. 3, pp. 676–692, 2026, doi: 10.46328/ijtes.8123.
 - [20] M. Yu, "Technology-Enhanced Education," in *The Wiley Handbook of Sustainability in Higher Education Learning and Teaching*, Wiley, 2022, pp. 133–151. doi: 10.1002/9781119852858.ch7.
 - [21] Y. A. Tantu, M. H. Sumampouw, and M. M. F. Rampengan, "Development of flipcharts as a learning media with material on the human digestive system for students at smp negeri 4 bitung," *Dharma Acariya Nusant. J. Pendidikan, Bhs. dan Budaya*, vol. 1, no. 2, pp. 103–115, 2023, doi: 10.47861/jdan.v1i2.487.
 - [22] J. Dongoran *et al.*, "The effect of circuit learning model assisted by flip chart media on science learning outcomes," *J. Darma Agung*, vol. 32, no. 1, pp. 311–322, 2024, doi: 10.46930/ojsuda.v32i1.4025.
 - [23] Masrizal, R. Sukmana, and B. Trianto, "The effect of islamic financial literacy on business performance with emphasis on the role of islamic financial inclusion: Case study in Indonesia," *J. Islam. Mark.*, vol. 16, no. 1, pp. 166–192, Jan. 2025, doi: 10.1108/JIMA-07-2022-0197.
 - [24] J. Kim, S. Yu, R. Detrick, and N. Li, "Exploring students' perspectives on Generative AI-assisted academic writing," *Educ. Inf. Technol.*, vol. 30, no. 1, pp. 1265–1300, Jan. 2025, doi: 10.1007/s10639-024-12878-7.
 - [25] R. K. Dewi *et al.*, "Development research in science education: A systematic literature review of trends in development models and instruments used," *J. Penelit. Pendidik. IPA*, vol. 10, no. 5, pp. 250–261, 2024, doi: 10.29303/jppipa.v10i5.6876.
 - [26] A. Syahrul, K. Mustami, and S. Ondeng, "Research and development (r&d) and evaluation research: A comparative analysis of methodologies and applications in educational and technological innovation," *Agency J. Manag. Bus.*, vol. 5, no. 1, pp. 105–111, 2025, doi: 10.54065/agency.5.1.2025.469.
 - [27] R. A. Assirri, I. P. Artayasa, N. Hidayatullah, R. D. Sapitri, R. S. Irawan, and S. Rahayu, "Exploring the application of the borg&gall development model in science education: A review of literature," *Indones. J. Innov. Educ. Res.*, vol. 2, no. 2, pp. 59–64, 2025, doi: 10.63980/ijier.v2i2.112.
 - [28] A. Purba, "Indonesian teaching materials in competency-based universities text orientation; Research and development at the University of Jambi through the borg & gall model," *Pakistan J. Life Soc. Sci.*, vol. 22, no. 2, pp. 24355–24369, 2024, doi: 10.57239/pjlss-2024-22.2.001739.

- [29] A. B. Haryanti, "Needs analysis for the development of flipchart-based learning media with the jigsaw method to improve students' concept understanding of vector material in class x sma Bengkulu City," *Indones. J. Pedagog. Teach. Educ.*, vol. 1, no. 1, pp. 27–32, 2023, doi: 10.58723/ijopate.v1i1.70.
- [30] M. Nurrahman, S. Marmoah, and K. C. Suryandari, "Assessing srpb-based instructional materials: An expert judgment approach," in *Social, Humanities, and Educational Studies*, 2025, pp. 92–104.
- [31] S. B. P. Utami, N. Riska, R. Rusilanti, and A. Gumelar, "Evaluation of content validity for an educational media instrument to enhance early childhood education (paud) teachers' nutrition knowledge," *J. Pendidik. dan Pembelajaran Indones.*, vol. 5, no. 4, pp. 1801–1808, 2025, doi: 10.53299/jppi.v5i4.2531.
- [32] H. R. Ganesha and P. S. Aithal, "Choosing an appropriate data collection instrument and checking for the calibration, validity, and reliability of data collection instrument before collecting the data during Ph.D. program in India," *Int. J. Manag. Technol. Soc. Sci.*, vol. 7, no. 2, pp. 497–513, 2022, doi: 10.47992/ijmts.2581.6012.0235.
- [33] L. M. C. Benavides, J. A. T. Arias, D. Burgos, and A. Martens, "Measuring digital transformation in higher education institutions – content validity instrument," *Appl. Comput. Informatics*, vol. 22, no. 1, pp. 129–144, 2022, doi: 10.1108/ACI-03-2022-0069.
- [34] Z. Farhana, A. S. Khan, and S. A. Chowdhury, "ICT in biology education: Teachers' readiness and implementation challenges in the context of Bangladesh," *Discov. Educ.*, vol. 3, no. 1, pp. 1–17, 2024, doi: 10.1007/s44217-024-00273-w.
- [35] H. K. Manggopa, D. R. H. Kumampung, and J. R. Batmetan, "Teachers' perspectives on integrating information technology into biology education management in senior high schools," vol. 4, no. 2, pp. 157–171, 2025.
- [36] T. Ebbers *et al.*, "The impact of structured and standardized documentation on documentation quality; a multicenter, retrospective study," *J. Med. Syst.*, vol. 46, no. 7, pp. 1–7, 2022, doi: 10.1007/s10916-022-01837-9.
- [37] B. W. Furidha, "Comprehension of the descriptive qualitative research method: A critical assessment of the literature," *ACITYA WISESA J. Multidiscip. Res.*, vol. 2, no. 4, pp. 1–8, 2023, doi: 10.56943/jmr.v2i4.443.
- [38] J. A. Nenohai, D. A. Rokhim, N. I. Agustina, and M. Munzil, "Development of gamification-based wordwall game platform on reaction rate materials," *Orbital*, vol. 14, no. 2, pp. 116–122, 2022, doi: 10.17807/orbital.v14i2.16206.
- [39] B. Dursun, "A qualitative research technique: Interview," *J. Interdiscip. Educ. Res.*, vol. 7, no. 14, pp. 100–113, 2023, doi: 10.57135/jier.
- [40] N. N. Yusupova, "Intensive learning of english in the pedagogical educational environment on the basis of media technologies," *J. Posit. Sch. Psychol.*, vol. 6, no. 4, pp. 5666–5674, 2022.
- [41] B. A. Ambe *et al.*, "Electronic media learning technologies and environmental education pedagogy in tertiary institutions in Nigeria," *Soc. Sci. Humanit. Open*, vol. 9, no. November 2023, pp. 1–7, 2024, doi: 10.1016/j.ssaho.2023.100760.
- [42] R. Febrianasari, E. Susantini, and S. Suryanti, "Needs analysis for the development of contextual card media to enhance understanding of ecosystem harmony in fifth-grade elementary students," *J. Innov. Res. Prim. Educ.*, vol. 4, no. 4, pp. 3610–3620, 2025, doi: 10.56916/jirpe.v4i4.2387.
- [43] M. Jamshidi, A. Dehghaniyan Serej, A. Jamshidi, and O. Moztaizadeh, "The meta-metaverse: Ideation and future directions," *Futur. Internet*, vol. 15, no. 8, pp. 1–31, 2023, doi: 10.3390/fi15080252.
- [44] E. C. Iderima, "The development phase in instructional design: Putting instructional elements together," *Int. J. Innov. Educ. Res.*, vol. 4, no. 13, pp. 267–278, 2025, doi: 10.5281/zenodo.17581384.
- [45] L. R. Marzalius and I. R. Jasril, "Interactive multimedia learning for vocational electronics education : development, validation, and classroom implementation," *J. Hypermedia Technol. Learn.*, vol. 4, no. 1, pp. 16–29, 2026, doi: 10.58536/j-hytel.210.
- [46] H. Akram, A. H. Abdelrady, A. S. Al-Adwan, and M. Ramzan, "Teachers' perceptions of technology integration in teaching-learning practices: A systematic review," *Front. Psychol.*, vol. 13, pp. 1–9, 2022, doi: 10.3389/fpsyg.2022.920317.
- [47] A. I. Ngao, G. Sang, and J. E. Kihwele, "Understanding teacher educators' perceptions and practices about ict integration in teacher education program," *Educ. Sci.*, vol. 12, no. 8, pp. 1–18, 2022, doi: 10.3390/educsci12080549.
- [48] C. Mbaleki, F. A. Elegbeleye, O. A. Esan, and T. Rabotapi, "Power supply rationing in an era of e-learning: Evidence from the rural university," *EUREKA Soc. Humanit.*, no. 6, pp. 3–12, 2023, doi: 10.21303/2504-5571.2023.003184.
- [49] S. M. Simiyu and E. Masibo, "Amplifying Student Voice in a Divided Digital Landscape," in *Addressing Digital Divides in International Higher Education*, IGI Global Scientific Publishing, 2026, pp. 167–198. doi: 10.4018/979-8-3373-6911-2.ch006.
- [50] F. An, L. Xi, and J. Yu, "The relationship between technology acceptance and self-regulated learning: The mediation roles of intrinsic motivation and learning engagement," *Educ. Inf. Technol.*, vol. 29, no. 3, pp. 2605–2623, 2024, doi: 10.1007/s10639-023-11959-3.
- [51] J. I. Chisunum and C. N. Nwadiokwu, "Enhancing student engagement through practical production and utilization of instructional materials in an educational technology class: A multifaceted approach," *NIU J. Educ. Res.*, vol. 10, no. 2, pp. 81–89, 2024, doi: 10.58709/niuved.v10i2.2002.