ETDC Indonesian Journal of Research and Educational Review
Volume 5, No. 4, 2026, pp 2332 - 2346
e–ISSN 2809-3682
p–ISSN 2809-7505
https://doi.org/10.51574/ijrer.v5i4.5085

Developing an Interactive E-Booklet Based on Multimedia Learning Theory to Improve Learning Outcomes on Biodiversity

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Article Info

Article history:

Received May 16, 2026
Accepted July 01, 2026
Published July 10, 2026

Keywords:

Biodiversity;
Cognitive Learning Outcomes;
Interactive E-Booklet;
Islamic High School;
Multimedia Learning Theory.

ABSTRACT

Students frequently struggle with biodiversity concepts due to abstract materials and conventional, static text-based learning. This study aimed to develop, assess the feasibility and practicality, and evaluate the effectiveness of an interactive e-booklet based on multimedia learning theory to enhance student learning outcomes. Utilizing a 4D Research and Development (R&D) model, a sample of 50 tenth-grade students was selected via cluster sampling and divided equally into experimental and control classes at SMA Islam Al Ulum Terpadu Medan. Data gathered through validation sheets, practicality questionnaires, and pretest-posttest cognitive instruments were analyzed using Normalized Gain (N-Gain) and Mann–Whitney U tests. Material experts validated the product as Very Feasible with a 100% consistency score. Practicality metrics increased significantly from Feasible (67.50%) to Very Feasible (86.25%) for teachers, and consistently remained Very Feasible for students in small-group (78.13%) and large-group (88.30%) trials. Crucially, the experimental group achieved a higher posttest average of 93.00 and a medium N-Gain of 0.42, significantly outperforming the control group's posttest average of 80.00 and low N-Gain of 0.25 (Z-count > Z-table). This research contributes an innovative digital solution that actively mitigates cognitive overload, facilitates autonomous learning, and provides teachers with a proven pedagogical tool to optimize students' conceptual mastery in biology education.

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1. INTRODUCTION

Biology instruction at the senior high school level plays a crucial role in equipping students with the ability to understand various complex life phenomena (Honra, 2025). One key topic highly relevant to everyday life is biodiversity. A thorough understanding of this concept is essential for students to recognize the variety of living things and understand the network of relationships between organisms within an ecosystem (Bermudez & Lindemann-Matthies, 2020; Yli-Panula, 2018). However, this material is complex and abstract, encompassing various interconnected levels, from genetics to

species to ecosystems (Kautsaranny & Isnawati, 2024). Therefore, students are required to possess strong cognitive abilities to accurately differentiate these levels of diversity in order to gain a comprehensive understanding of the interrelationships within biological systems (Sari et al., 2023).

Despite this strategic value, the reality on the ground shows that many students still face significant difficulties in grasping the concept of biodiversity (Pedrera et al., 2023). These cognitive barriers directly impact poor learning outcomes in the material. Analysis of daily test scores confirms that the average student achievement falls short of meeting the Learning Objectives Achievement Criteria, which has a minimum score of 75. Specifically, students often experience disorientation when it comes to correctly identifying and differentiating levels of biodiversity. This phenomenon of low academic performance is not simply a class-specific problem but a widespread issue across various regions in Indonesia (Meliyani et al., 2022).

Upon closer examination, this low conceptual understanding is rooted in national learning patterns that tend to focus on linear memorization strategies without meaningful understanding (Fardian et al., 2025). As a result, students struggle to connect theoretical material to real-world conditions in their surroundings. This situation is exacerbated by limited access to a variety of learning media and the minimal integration of cutting-edge technology in the classroom. Current biology teaching still relies heavily on limited and static learning resources, with the majority of teachers relying solely on conventional printed textbooks (Wahyuni et al., 2024). This lack of digital interactivity creates a monotonous learning environment, ultimately triggering student passivity and reducing the essence of learning to merely a one-way transfer of information (Cladis, 2020; Meliyani et al., 2022).

To bridge this gap, innovation in digital technology-based learning media is absolutely necessary, in line with the demands of 21st-century educational competencies. The use of multimedia that simultaneously integrates text, images, video, and animation has been proven to stimulate student interest in analyzing complex biological concepts (Mariati, 2024). Theoretically, the implementation of digital teaching materials, such as interactive e-booklets developed based on Multimedia Learning Theory (MLT), effectively improves biology learning outcomes because attractive visual presentations are well-received by students' cognitive modalities (Purnamasari et al., 2024; Ridianti, 2024). This concept is firmly rooted in Richard E. Mayer's assumption that the learning process will be optimal when information is presented through a combination of words and images (Mayer, 2024; Zhao et al., 2025). This approach is able to maximize information processing through the visual and auditory channels in the human brain in a balanced manner, as well as reduce cognitive overload through the application of instructional design principles such as the segmentation principle (Çeken & Taşkın, 2022).

Even though the use of technology is starting to become widespread, current literature studies show that the development of digital media in biology learning is still largely dominated by one-way presentation media or e-books, which are linear and have minimal interaction (Wang et al., 2023). The potential of interactive e-booklets, which

have the advantage of flexibility through dynamic navigation and hyperlinking features, is still very underutilized in educational practice (Morris & Lambe, 2017; Sinaga et al., 2023). In addition, learning media that are designed precisely and systematically by adopting the principles of multimedia learning theory are still very limited, especially those implemented in high school level biodiversity material (Hanifah et al., 2020; Perta et al., 2024). The uniqueness of this research lies in the development of digital teaching materials in the form of interactive e-booklets that present a concise summary of biodiversity material while integrating non-linear navigation features, active links, images, and animations that are synthesized directly based on the main principles of MLT. This non-linear design differentiates it from conventional e-books, giving students complete autonomy to explore the material at their learning pace so that the learning experience becomes more interactive.

Building upon the background, problem identification, and gap analysis that have been described, this research is directed at developing valid and applicable instructional solutions. Specifically, this research aims to: (1) determine the level of feasibility of interactive e-booklet media based on multimedia learning theory based on validation results from material experts, media experts, and learning practitioners; (2) analyze objective responses from biology teachers and students regarding the ease and usefulness of using this media in classroom learning; and (3) empirically test the effectiveness of using interactive e-booklets based on multimedia learning theory in improving high school students' conceptual understanding and cognitive learning outcomes on biodiversity material.

2. METHOD

This study employed a Research and Development (R&D) approach integrated with a quasi-experimental design. The R&D approach focused on creating and testing the feasibility of an interactive e-booklet on Biodiversity, designed based on the principles of Multimedia Learning Theory. A quasi-experimental approach with a Pretest–Posttest Control Group Design was applied to empirically measure the product's effectiveness in improving students' cognitive learning outcomes. This design employed a pretest before media implementation to determine students' initial abilities, followed by a posttest after the learning intervention was completed.

The population of this study included all tenth-grade students at SMA Islam Al Ulum Terpadu Medan in the 2025/2026 academic year. Based on school documentation, there are three tenth-grade classes, each with 25 students, for a total population of 75 students. The study sample was selected using cluster random sampling, which selects samples based on naturally occurring groups or classes within the school. From this population, two classes were selected as research samples: class X-1 and class X-3, with a total sample size of 50 students. The selection of these two classes was based on strict methodological considerations, including similar academic grade points, a balanced student population, and consistent lesson schedules to ensure internal validity and objective comparisons between groups.

The two classes selected as samples were adequately divided into an experimental and a control group. Class X-3, consisting of 25 students, was designated as the experimental class, receiving a biology learning process supported by an interactive e-booklet based on Multimedia Learning Theory. Meanwhile, class X-1, also consisting of 25 students, served as the control class, implementing the learning process using conventional methods commonly used in schools. This division aimed to isolate the independent variable, the use of interactive digital media, so that differences in learning outcomes between the two groups could be validly attributed to the effectiveness of the media developed.

In the product design phase, this study adopted the 4D development model proposed by Thiagarajan, Semmel, and Semmel (Siregar & Sriyati, 2025). This model consists of four main stages: define, design, develop, and disseminate. The define stage is implemented through a learning needs analysis, curriculum review, and identification of initial student characteristics. The design stage involves designing the structure of the teaching materials, developing the biodiversity content, and integrating multimedia elements. The develop stage encompasses the media production process, validation by experts (materials, media, and learning), small group trials, and large group trials with product revisions. Finally, the disseminate stage is realized in the form of limited implementation through a trial use with target students within the experimental scope.

The data collection technique in this study was comprehensive, involving non-test instruments in the form of observation sheets and interviews for needs analysis, a Likert-scale questionnaire for feasibility testing by experts and practitioners, and teacher and student response questionnaires to measure the practicality of the media. Meanwhile, a test instrument consisting of 15 multiple-choice questions was used to measure learning outcomes in the pretest and posttest stages. Before use, the test instrument was tested for quality through validity analysis, reliability using the Kuder-Richardson 20 (KR-20) formula, difficulty level, and discriminatory power. Feasibility and practicality data analysis were calculated using descriptive quantitative percentage techniques. Furthermore, to test the effectiveness of the product, learning outcome data were analyzed using the Normalized Gain (N-Gain) formula. The final hypothesis testing was conducted through the non-parametric Mann-Whitney U Test, as a consequence of the prerequisite test results which showed that the research data were not normally distributed.

3. RESULTS AND DISCUSSION

Results

Interactive E-Booklet Feasibility Based on Expert Validation

The Interactive E-Booklet's feasibility was assessed by two expert validators. The expert validation aimed to ensure that the product met eligibility standards through expert validation of materials, media, and learning.

Table 1. Results of Validation by Material Expert I on Interactive E-Booklets

Aspects	Subject Matter Expert 1		Subject Matter Expert 2	
	Percentage	Category	Percentage	Category
Content/Material	100%	Very Worthy	100%	Very Worthy
Presentation	66,67%	Worthy	100%	Very Worthy
Language	66,67%	Worthy	100%	Very Worthy
Learning Evaluation	100%	Very Worthy	100%	Very Worthy
Total	88,89%	Very Worthy	100%	Very Worthy

The data analysis results in Table 1 demonstrate a very high level of feasibility for each component tested by the two material validators. For the content/material and learning evaluation aspects, both experts agreed on a perfect score of 100%, categorized as Very Feasible, indicating that the scientific substance in the e-booklet was accurate, free from misconceptions, and supported by relevant evaluation instruments to measure the achievement of learning objectives. Meanwhile, for the presentation and language aspects, there was variation in the assessments, with Material Expert 1 giving a score of 66.67% (Feasible) and Material Expert 2 giving a score of 100% (Very Feasible). This gap in assessments indicates room for improvement in the text's readability, the choice of scientific terms, and the systematic sequencing of the material. These were then optimized by the researchers to be more adaptive to students' thinking characteristics.

Accumulatively, the total feasibility conclusion from Material Expert 1 reached an average percentage of 88.89%, while Material Expert 2 gave a total assessment of 100%, where both final results placed the product in the Very Feasible qualification. The integration of scores from these two validators empirically confirms that the interactive e-booklet based on Multimedia Learning Theory has a very solid, valid, and academically accountable substance quality. By fulfilling the material feasibility standards, this digital teaching material is declared ready and meets the requirements for limited implementation in testing its effectiveness on the biology learning process in the classroom.

Table 2. Results of Validation by Material Expert II on Interactive E-Booklets

Aspects	Subject Matter Expert 1		Subject Matter Expert 2	
	Percentage	Category	Presentase	Percentage
Content/Material	100%	Very Worthy	100%	Very Worthy
Presentation	100%	Very Worthy	100%	Very Worthy
Language	100%	Very Worthy	100%	Very Worthy
Learning Evaluation	100%	Very Worthy	100%	Very Worthy
Total	100%	Very Worthy	100%	Very Worthy

The quantitative data presented in Table 2, the assessment results from the two material validators show an absolute level of consistency and perfection with a percentage achievement of 100% in all aspects tested, which include the content/material components, presentation, language, and learning evaluation. The

perfect score with the Very Appropriate category from Material Expert 1 and Material Expert 2 indicates that all biodiversity materials integrated into the digital teaching materials are completely scientifically accurate, presented through a systematic navigation structure, using communicative grammar, and equipped with instructionally valid evaluation instruments. With the total accumulative average obtaining a maximum value of 100% from both validators, these results confirm that the developed interactive e-booklet product has met all theoretical and practical qualification standards, so it is declared very valid without substantive revision and is fully ready to be implemented in the effectiveness trial stage in biology learning in the field.

Feasibility of Interactive E-Booklets Based on Teacher and Student Response Questionnaires

Product feasibility was measured through teacher and student response questionnaires. Product trials, conducted through questionnaires with teachers and students, aimed to determine the feasibility of the developed interactive e-booklets. The assessment was based on four aspects: appearance, ease of use, material presentation, and usability.

Table 3. Teacher Response Results to Interactive E-Booklets

	Small Group Test		Large Group Test	
Teacher	**Percentage**	**Category**	**Percentage**	**Category**
	67,50%	Worthy	86,25%	Very Worthy

Table 4. Student Response Results to Interactive E-Booklets

	Small Group Test		Large Group Test	
Student	**Percentage**	**Category**	**Percentage**	**Category**
	78,13%	Very Worthy	88,30%	Very Worthy

The analysis results in Table 3 show that teacher responses significantly improved between product trial stages. In the Small Group Test stage, teacher ratings reached 67.50%, categorized as Appropriate. This result then increased significantly in the Large Group Test stage, where the rating jumped to 86.25%, achieving a Very Appropriate rating. This increase indicates that the product improvements or revisions made after the Small Group Test successfully accommodated teachers' instructional needs, resulting in the interactive e-booklet being deemed increasingly optimal in terms of appearance, ease of use, material presentation, and usability.

Meanwhile, the data in Table 4 records positive student responses, consistently achieving the highest ratings since the beginning of testing. In the Small Group Test stage, student ratings reached 78.13%, categorized as Very Appropriate, and this figure continued to increase to 88.30%, categorized as Very Appropriate in the Large Group Test stage. This consistent performance demonstrates that interactive e-booklets based on Multimedia Learning Theory have a strong appeal to students. The integration of these two data tables confirms that this digital teaching material is not only practical and easy to operate for teachers as learning facilitators, but also highly acceptable and

capable of providing an engaging and interactive learning experience for students in the classroom.

The Effectiveness of Interactive E-Booklets Based on Multimedia Learning Theory in Improving Student Learning Outcomes

The N-Gain analysis showed that the average N-Gain for the control group was recorded in the "moderate" category. Meanwhile, the experimental group learning using interactive e-booklets showed a higher score, reaching the "high" category. A high N-Gain score indicates effective learning improvement according to the normalized gain interpretation criteria. According to the normalized gain interpretation criteria, a high category indicates that learning is able to improve students' conceptual mastery more effectively.

Table 5. Comparison of Pretest, Posttest, and N-Gain Values between the Control and Experimental Groups

Learning Group	Pretest Average	Posttest Average	N-Gain Value
Control	48	80	0.25
Experiment	45	93	0.42

The results of the data analysis in Table 5 show that both groups have relatively balanced and homogeneous initial abilities (pretest) with an average value in the range of 45.00 to 48.00. However, after being given treatment, the experimental group using an interactive e-booklet based on Multimedia Learning Theory showed a significantly higher increase in learning outcomes (posttest), reaching an average of 93.00, compared to the control group using conventional methods with an average of 80.00. This superior academic performance is reinforced by the results of the Normalized Gain (N-Gain) value analysis, where the experimental group managed to obtain an effectiveness score of 0.42 which is included in the Medium category, while the control group only obtained an N-Gain score of 0.25 which is included in the Low category, so empirically it can be concluded that the use of interactive e-booklets is much more effective in improving students' cognitive learning outcomes on biodiversity material.

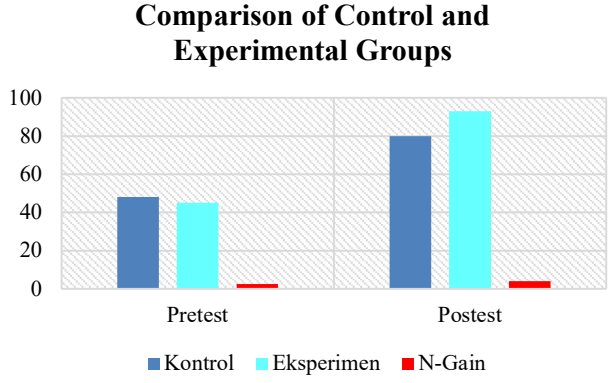

Figure 1. Comparison of N-Gain Scores of Control and Experimental Groups

Initial test results indicated that both sample groups had relatively balanced initial cognitive abilities (pretest) and were in the low category. The control group recorded an average pretest score of 48.00, while the experimental group scored 45.00. This homogenous initial condition strongly supports the internal validity of this quasi-experimental study, confirming that there were no significant differences in conceptual understanding between the two classes before the learning intervention was administered in the classroom.

However, after the intervention, the graph in Figure 1 records a contrasting spike in academic performance between the two groups in the posttest. The experimental group, which received the intervention using an interactive e-booklet based on Multimedia Learning Theory, achieved an average score of 93.00, while the control group, which learned using conventional methods, only achieved an average score of 80.00. The significance of this difference is emphasized by the achievement of the Normalized Gain (N-Gain) value represented by the red bar chart, where the experimental group recorded an N-Gain score of 0.42 (Medium category) which far outperformed the control group with an N-Gain score of only 0.25 (Low category). These results empirically prove that the use of interactive e-booklets is far more effective and significant in improving students' biology learning outcomes.

Figure 2. Features of Interactive E-Booklets Based on Multimedia Learning Theory

The visualization of the product development in Figure 2 demonstrates the readability of the curriculum structure and materials, presented systematically through the integration of engaging visual elements on the e-booklet's homepage. At the beginning of the e-booklet, there is an aesthetically pleasing cover page with a natural theme titled "Biodiversity: An Adventure to Learn About the Biodiversity of the

Indonesian Archipelago." This presentation is reinforced by the "Learning Objective Flow (ATP)" visualization in the form of an interactive roadmap containing eight phase achievement indicators in sequence, as well as a structured "Concept Map" visualization that divides the material into five main chapters, ranging from basic concepts, classification of living things, flora and fauna diversity in Indonesia, to environmental conservation efforts. This structured design aligns with the principles of information organization in Multimedia Learning Theory to facilitate students' mental construction before delving deeper into the subject matter.

In addition to the clarity of the information structure, the product developed in Figure 2 emphasizes digital interactivity with a non-linear navigation system through the provision of evaluation features and a modern discussion space. These features are realized into three interactive menus based on active linking (hyperlinking), namely the "Adventure Games" menu (Destination Adventure Mission 01) which facilitates knowledge testing through interactive games, the "Let's Test Your Knowledge!!" menu which integrates multiple-choice quizzes through direct click buttons (click here) or quick response code scanning (QR Code), and the "Question Room" menu through the "Chat with Teachers" program. The existence of all these features empirically changes the static role of printed teaching materials into dynamic digital media, providing full autonomy for students to explore independently, while reducing cognitive load through the packaging of communicative and fun learning evaluations.

Discussion

The initial evaluation by the first material expert indicated that the developed interactive e-booklet fell into the highly feasible category, while the second material expert awarded a perfect score, reinforcing its exceptional institutional viability. Despite this high overall feasibility, nuanced discrepancies between the two validators highlighted areas requiring fine-tuning, specifically within the presentation and linguistic dimensions. The first material expert assigned a "feasible" rating due to the necessity of refining the distribution of material sub-chapters, alongside suggesting detailed textual additions regarding endemic species concepts. Conversely, both validators consistently designated the learning evaluation aspect as "highly feasible," affirming that the integrated evaluation instruments were highly effective in measuring students' competency. Aligning instructional content and learning evaluations with core competencies is a pivotal determinant of educational resource quality, as precise assessment mechanisms directly reflect how effectively the curriculum supports student mastery (Polikoff & Porter, 2014; Sholikhah et al., 2022).

The media expert evaluation demonstrated that the interactive e-booklet successfully fulfilled the eligibility criteria required for seamless integration into the learning process. Within research and development (R&D) frameworks, validation by media specialists is an indispensable phase to guarantee that the developed tool complies with technical and visual design standards before field testing among learners (Lestari et al., 2024). The developed digital booklet satisfied these standard criteria by showcasing an aesthetically engaging interface backed by a stable technical architecture. Conceptually,

a viable instructional product must present information using visually stimulating graphics while maintaining high user accessibility to successfully optimize learning outcomes (Kautsaranny & Isnawati, 2024). Delivering biology concepts through structured, visually explicit designs accelerates cognitive information processing and deepens conceptual retention, emphasizing that media design quality dictates instructional efficacy (Mayer et al., 2018).

The interactive e-booklet secured a "highly feasible" rating from both the first and second learning experts, confirming that the digital media adheres strictly to pedagogical and instructional design standards. Both evaluators granted maximum scores to the product's alignment with learning objectives and its systematic adherence to the cognitive theory of multimedia learning. This maximum rating underscores that the instructional content is synchronized with target learning outcomes while effectively utilizing multimedia principles—such as integrating text, images, and animations—to reinforce students' cognitive processing (Mayer, 2024). Maintaining a tight alignment between instructional content and educational objectives is critical in product development, as structured content ensures a goal-oriented and coherent learning experience (Hanifah et al., 2020). Furthermore, the experts rated the dimensions of interactivity, learning motivation, and practicality as "highly feasible," corroborating that interactive tools stimulate student attention and engagement by offering dynamic learning experiences (Kautsaranny & Isnawati, 2024). Practical digital tools that offer seamless operation noticeably enhance student motivation by enabling flexible, autonomous access to learning materials based on individual needs (Pertiwi et al., 2019).

During the small-scale trials, feedback from teachers classified the interactive e-booklet as "feasible," indicating that while it met general operational standards, it required technical and navigational refinements. The sub-optimal percentages during this initial phase highlight that systematic formative evaluation and revision are mandatory steps in the engineering of digital learning tools. Following targeted modifications based on this initial feedback, the large-scale teacher response metrics showed a significant upward shift into the "highly feasible" category. This positive trajectory demonstrates that the revisions successfully upgraded the media's accessibility, instructional clarity, and classroom usability. Multimedia-driven platforms are proven to elevate teacher practicality when executing student-centered learning designs, thereby fostering digital education transformation within schools (Aspandi & Muttaqin, 2025; Ridianti et al., 2024). This pedagogical utility explains the substantial percentage increase from "feasible" to "highly feasible" following the product's iterative refinement.

Mirroring the teachers' feedback, the students' evaluation during the small-scale trial initially fell into the "feasible" category, showing positive acceptance alongside a demand for refined visual layouts and material presentation. Post-revision data from large-scale testing yielded a distinct shift to the "highly feasible" category, demonstrating that the upgraded e-booklet resonated with the cognitive styles of modern learners who are highly responsive to visual assets, dynamic animations, and immediate feedback systems. Interactive digital media explicitly boosts student feasibility

perceptions and engagement in biology education by presenting abstract topics both visually and contextually (Sinaga et al., 2023). Moreover, utilizing multimedia digital media correlates positively with heightened student motivation due to the interactive combination of animations, contextual images, and embedded interactive quizzes (Meliyani et al., 2022). This mutual positive reception from teachers and students aligns with the Cognitive Theory of Multimedia Learning, which posits that learning is optimized when information is presented through well-organized text and visual channels, thereby reducing extraneous cognitive load in the working memory. Specifically, the strategic implementation of coherence, segmentation, and modality principles within this e-booklet allowed students to process biological data in a highly structured, meaningful manner (Mayer, 2024).

The empirical impact of the e-booklet was verified through a comparative analysis of learning gains, where the experimental group achieved a high-category Normalized Gain (N-Gain) score of 0.88, remarkably outperforming the control group's moderate score of 0.60, yielding a significant gain margin of 0.28. This pronounced cognitive acceleration in the experimental group is heavily anchored in Richard E. Mayer's Cognitive Theory of Multimedia Learning, which establishes that blending interactive components—such as educational videos, comic strips, games, and digital quizzes—triggers active cognitive processing. Consequently, students transform from passive content recipients into active knowledge constructors capable of organizing and integrating new information into existing mental schemata (Mayer et al., 2018). This outcome corroborates previous research indicating that interactive multimedia learning tools generate superior academic performance in biology compared to conventional teaching methods (Hanifah et al., 2020). The deliberate synthesis of visuals, animations, and user interaction consistently drives student cognitive engagement (Hanif et al., 2025). Ultimately, the N-Gain discrepancies prove that the interactive e-booklet yields more optimal learning outcomes than conventional printed textbooks, though comprehensive data interpretation must always account for confounding environmental learning variables.

To validate the experimental findings, an inferential statistical analysis was conducted using the Mann-Whitney U test, which revealed that the computed Z-value exceeded the critical Z-table value (Z-count > Z-table), thereby rejecting the null hypothesis (H0) and accepting the alternative hypothesis (H1). This statistical breakthrough confirms that the interactive e-booklet exerts a profoundly significant positive influence on student learning outcomes compared to conventional instructional methods. This empirical success is driven by several underlying instructional factors: first, the interactive e-booklet inherently captivates student attention and increases learning motivation through an immersive visual layout and structured content presentation that helps students focus heavily on core concepts (Mayer et al., 2018; Sinaga et al., 2023). Second, the digital booklet provides students with excellent opportunities for flexible, self-paced, autonomous learning (Hanifah et al., 2020; Susantini et al., 2021), allowing them to review complex materials as needed to reinforce conceptual mastery. Third, this interactive media successfully mitigates

classroom boredom in comparison to conventional, one-way lectures, thereby amplifying active student participation and directly translating into higher cognitive outcomes (Kautsaranny & Isnawati, 2024). From a strict statistical standpoint, because the calculated Z-value strictly surpasses the tabular threshold, the variance in learning growth between the two groups is officially declared statistically significant.

4. CONCLUSION

The interactive e-booklet on Biodiversity based on Multimedia Learning Theory meets the quality standards of superior digital teaching materials in terms of feasibility, practicality, and instructional effectiveness. From the feasibility aspect, the accumulative assessment by material experts provides a qualification of "Very Feasible" with a consistent feasibility value of up to 100%, which confirms that the scientific substance in the media is accurate, systematic, and free from misconceptions. From the practical aspect, educator responses experienced a significant increase from the category of "Feasible" (67.50%) to "Very Feasible" (86.25%) after product optimization. These results are in line with the responses of students who consistently rated this media as "Very Feasible", both in small group tests (78.13%) and large group tests (88.30%), which proves that the integration of interactive features such as adventure games, QR code quizzes, and non-linear discussion rooms has a very high appeal and readability for users. Furthermore, the implementation of this interactive e-booklet has been proven to have a significant positive impact on improving students' cognitive learning outcomes. Although both groups had homogeneous and balanced pretest scores ranging from 45.00 to 48.00, the experimental group using the interactive e-booklet achieved a significantly higher posttest score, with an average of 93.00, compared to the control group using the conventional method, with an average of 80.00. This superior effectiveness was reinforced by the experimental group's Normalized Gain (N-Gain) score of 0.42, which falls into the "Medium" category, surpassing the control group, which only achieved an N-Gain score of 0.25, which falls into the "Low" category. Overall, this interactive e-booklet was found to be highly valid and effective as an innovative solution to facilitate independent learning, reduce cognitive overload, and optimize high school students' mastery of biodiversity concepts.

As a recommendation, biology teachers are encouraged to integrate this Multimedia Learning Theory-based interactive e-booklet as one of the primary learning media in the classroom to shift from static textual methods to dynamic, student-centered digital learning. Schools and instructional policymakers are advised to facilitate and support the development of similar non-linear teaching materials for other abstract biology topics to reduce students' cognitive load sustainably. Finally, future researchers are advised to expand the effectiveness of this product to a broader population scale and measure its impact on other 21st-century skills, such as students' critical thinking skills or digital literacy.

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