



Development of a Maluku Local Wisdom-Based Science E-Module to Enhance Elementary School Students' Conceptual Mastery

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ARTICLE INFO

Article History:

Received: 14 March 2026

Accepted: 31 May 2026

Published: 20 June 2026

Keywords:

ADDIE;

Concept mastery;

E-module;

Maluku local wisdom;

Plant blindness.

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ABSTRACT

Science learning, particularly botany in elementary school, is often constrained by low mastery of concepts due to plant blindness. This research aims to develop, test its feasibility, and measure the effectiveness of the Rambuku E-Module (Maluku's Cultural Diversity), based on local wisdom, to overcome these obstacles. This research and development (R&D) study applied the ADDIE framework and integrates a pre-experimental one-group pretest-posttest design. The research participants comprised 3 expert validators, 2 science teachers, and 30 Grade IV students from Private Islamic Elementary School (MIS) Al-Madinah Ambon, who were selected through purposive sampling. Data collection used a Likert-scale questionnaire (1–4) to assess eligibility parameters and 20 multiple-choice objective test items to measure students' cognitive learning outcomes (C1–C4). The expert board's assessment recorded a very high validity score of 98% (Very Valid). The practicality parameter was also deemed very practical, with positive responses from teachers (92%) and students (92.42%). Inferential analysis using paired t-tests confirmed a highly significant increase in learning outcomes, with a group-average N-gain score of 0.77 (High). The integration of local content on cloves and nutmeg has proven effective as a cognitive bridge for contextualizing science material. The Rambuku E-Module has been validated as feasible and effective in improving children's understanding of science. This study recommends applying this model of digital culture-responsive development on a broader regional scale.

To cite this article:

Buton et al. (2026). Development of a Maluku Local Wisdom-Based Science E-Module to Enhance Elementary School Students' Conceptual Mastery. *Pedagogy Review*, 5(1), 124-135. doi: <https://doi.org/10.61436/pedrev/v5i1.pp124-135>

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■ INTRODUCTION

Learning about plant organs and structures at the elementary school level is a fundamental pillar in science education that requires deep attention. This urgency is affirmed by Liunokas and Billik (2022) and Susilawati and Muhfahroyin (2021), who state that mastery of the material is crucial for building basic scientific reasoning and stimulating students' curiosity about the environment. However, the reality on the ground reveals a significant gap: Lestari et al. (2024) confirm that, at the national level, students' average scores in biology mastery have consistently fallen below the minimum competency threshold for several consecutive years. The root of this low learning achievement is not only local, but is triggered by a global psychological challenge known as plant blindness. This phenomenon reflects

students' cognitive biases, as they prioritize the animal world (*fauna*) over the plant world (*flora*). As a result, this neglect of flora creates chronic obstacles that systematically reduce the quality and effectiveness of botanical learning at the basic education level.

The problem in science education is clearly reflected in the learning activities at Private Islamic Elementary School (MIS) Al-Madinah Ambon. Based on direct observation, three main obstacles were identified that align with the national and global trends of the crisis. These obstacles include conventional teaching approaches, a lack of diversification in mathematics or science teaching aids, and a reluctance to integrate digital devices into classrooms (Komaini et al., 2023; Telussa, 2023). This passive instructional climate has adverse implications for students' emotional engagement at school. When teachers neglect

modern technology and remain stuck in rigid lecture methods, students' attention is diverted, preventing knowledge transfer from occurring optimally. The accumulation of these determinant factors ultimately erodes children's motivation to learn and is the main mastermind behind their low mastery of academic concepts.

To disrupt the stagnation of conventional methods, the adoption of interactive electronic modules (e-modules) emerges as a visionary pedagogical instrument amid the flow of global educational digitalization (Alyusfitri et al., 2024; Tarigan & Sinaga, 2023). This digital media integration offers comprehensive advantages that physical textbooks lack. Gorham et al. (2023) demonstrate that multimedia stimulation, in the form of animation and interactive simulation, can accelerate concept understanding through cognitive processing dualism and trigger students' intrinsic motivation through flexible access to materials. In addition, e-modules enable teachers to implement differentiated learning to embrace the diversity of students' learning styles in the classroom (Latif et al., 2022). This real effectiveness is reinforced by a series of empirical studies documenting significant increases in science learning outcomes and high student acceptance of the digital ecosystem (Fauziah et al., 2023; Komaini et al., 2023; Setianingrum et al., 2023). In fact, a large-scale meta-analysis confirms that digital interactive media are much more effective at boosting academic achievement than traditional teaching models (Noesgaard & Ørngreen, 2015). This multi-layered advantage arises because the e-module shifts the student's role from a passive listener to an active participant in control of their own learning pace. When science content is presented visually and in context, students' cognitive load is reduced, making abstract concepts in plant biology easier to internalize. Therefore, the implementation of e-module-based innovations is a strategic imperative that not only addresses learning boredom at the local level but also drives the transformation of instructional quality towards modern educational standards.

Although the literature on e-modules continues to grow, a fundamental research gap remains: the majority of digital science media remain alienated from students' local cultural roots. In fact, local wisdom that encapsulates the value order, indigenous knowledge, and traditions of the community has great potential to contextualize abstract science concepts into a reality that is familiar to students (Banawi et al., 2026; Lee et al., 2012; Nurasiah et al., 2022; Zidny & Eilks, 2020). Zidny et al. (2020)

emphasize that the integration of local wisdom should not stagnate at the surface level or be merely cosmetic, but rather engage the epistemological dimension, involving the community's original perspective in interpreting natural phenomena. In this realm, Traditional Ecological Knowledge (TEK), which encompasses the adaptive accumulation of relationships between living things and their environment across generations, serves as a valid and pedagogically rich scientific system that complements the limitations of Western biological science. This synergy is strengthened by Kimmerer's (2012) argument that the fusion of traditional ecological knowledge with modern science is not additive (mutually additive) but synergistic, producing more holistic learning outcomes when students are guided to reflect, compare, and synthesize the two perspectives. Through this approach, the rigid separation between formal school knowledge and cultural wisdom at home can be bridged. When students recognize that the environmental traditions around them have scientific explanations on par with modern biological theories, the psychological and cognitive burden of understanding botanical materials will be reduced, thereby fostering a sense of pride in their own cultural identity (Ramdiah et al., 2020). Thus, the need to design digital learning media that authentically integrates TEK is a pressing step toward creating inclusive, relevant, and meaningful science learning at the basic level. It can be applied at the local level to schools where students live, work, and learn, both theoretically and empirically, as well as in other areas (Setiawan et al., 2017).

The real implementation of this integration of local wisdom is manifested in the exploration of endemic commodities of the Maluku Islands, especially clove plants (*Syzygium aromaticum*) and nutmeg (*Myristica fragrans*), as essential materials in botanical learning. The Maluku people's traditional knowledge of these two plants is not limited to the introduction of their physical structure or morphology. More than that, it contains a mature local agroecological system, the heritage of herbal medicine methods, and a very rich track record of world trade history, where all aspects can be a solid epistemological entrance to construct students' understanding of biology (Lestari et al., 2024; Zidny & Eilks, 2020). This urgency is reinforced by recent research showing that the use of culturally responsive digital media can significantly boost enthusiasm, a sense of belonging, and academic achievement among students from diverse cultural backgrounds (Bulkani et al., 2022;

Zidny & Eilks, 2020). By lifting cloves and nutmeg into an interactive digital format, students of MIS Al-Madinah Ambon no longer study science as mere memorization of unfamiliar theories. They were invited to see that the plants they encountered every day in the surrounding environment have high scientific, historical, and ecological value, making the process of internalizing biological concepts much more intuitive and meaningful. Although its pedagogical potential is very abundant, until now there has not been a single study that specifically develops or tests the effectiveness of digital science modules based on local wisdom for the Islamic Elementary School level in Maluku; a major research gap that is directly to be answered and resolved through this research.

As a concrete step to bridge the literary gap, this study initiated the development of a comprehensive evaluation of the Rambuku E-Module (Maluku's Cultural Diversity), a digital science instructional tool based on local wisdom, specifically designed for grade IV students at Islamic Elementary School, with a focus on plant structure and function. In detail, this scientific investigation is designed to test the three pillars of product accountability by formulating specific problems. First, this study assesses the validity of the Rambuku E-Module through a comprehensive evaluation by a board of experts comprising media, linguistics, and content experts. Second, this study maps the level of practicality of implementing this digital gadget in the classroom ecosystem, reviewed directly from the perspectives of the science teacher and students. Third, the analysis aims to assess the extent of the Rambuku E-Module's effectiveness in boosting students' conceptual mastery of plant parts. This tripartite investigation is essential because holistic testing, from theoretical feasibility to clinical effectiveness in the field, will ensure that the modules developed are not just an engaging visual medium but truly adaptive to students' cognitive needs.

■ METHODS

Research Design and Procedures

This research adopted a Research and Development (R&D) design, applying the ADDIE procedural framework: Analysis, Design, Development, Implementation, and Evaluation, as systematized by Branch (2009). The selection of ADDIE was based on the characteristics of its structured and cyclical workflow, which allows for iterative testing of the educational validity as well as practical feasibility of the product, where this model has proven to be reliable in various spectrums of

instructional research (Jais et al., 2022; Spatioti et al., 2022). To evaluate the parameters of product effectiveness in the Implementation phase, this study employed a pre-experimental design using a one-group pretest-posttest scheme (Sugiyono, 2013, p. 415). Although this model has limitations in definitively isolating causal interpretation (Richey & Klein, 2007), its application is considered particularly relevant for feasibility studies in the early stages of digital media development. The operational implementation of the entire series of field experiment procedures took place at MIS Al-Madinah Ambon, Maluku Province, Indonesia, from January to June 2023.

The material and visual architectural construction of the Rambuku E-Module is produced collaboratively, combining the *Canva* platform as a graphic design engine and *Flip Builder* (online.flipbuilder.com) as the interactive digital book publication engine. The synergy of these two software was chosen to combine the aesthetic aesthetics of static infographics with the flexibility of dynamic digital layouts, so that botanical (basic biology) content can be presented in an attractive way for the psychology of elementary school-age children. The cycle of its realization is chronologically through the five stages of the ADDIE model (Molenda, 2015). The initial step begins with the analysis phase, which diagnoses the real needs of the class through instructional observation and in-depth interviews with teachers, the study of the competency map of the science curriculum Class IV MI, and the preparation of a database of local flora diversity in Maluku, with the main focus on the commodities of cloves (*Syzygium aromaticum*) and nutmeg (*Myristica fragrans*). The flow then moves into the design phase, where the module's blueprints, including navigation maps, interface layouts, and content structures, begin to mature on the *Canva* platform by integrating Moluccan cultural ornaments and documentation of endemic plants into the design of the learning targets. Furthermore, during the development phase, all draft sheets from Canva were compiled in Flip Builder and equipped with interactive features such as automated evaluation quizzes, digital concept maps, motivational stimuli, and enrichment sheets, followed by validation assessments by a board of experts and iterative product improvements. During the implementation phase, the final revised prototype of the e-module was used with 30 students in Class IV at MIS Al-Madinah Ambon over six face-to-face sessions. Data on practicality were gathered through response questionnaires, while effectiveness was

assessed using pre- and post-test instruments. This series of procedures ended with an evaluation phase that processes all quantitative data accumulation from field instruments as an empirical basis for making final improvements to media products. Through this comprehensive ADDIE stage, a mature e-module product is produced that is content-precise and has high pedagogical accountability for use in the archipelago-based primary education ecosystem.

Participants

This study's participant clusters were structured in three parts to gather data on product validity, practicality, and effectiveness. The first group comprised three expert validators with doctoral qualifications (each an expert in language, science content, and learning media) evaluating the e-module's content validity. The second group comprised two Grade IV science teachers at MIS Al-Madinah Ambon, who evaluated the practicality of instruction from their perspective. The third group comprised 30 Grade IV students (16 girls and 14 boys, with an average age of 10 years) who were selected through purposive sampling for the implementation trial. The determination of a sample size of ($N = 30$) students was considered adequate and representative for the formative trial scale in a small-scale instructional design research scenario (Richey & Klein, 2007). Using data from the three participant clusters, the internal and external validity of the development of digital learning media can be empirically assessed.

Instruments

The collection of data on theoretical feasibility and practical practicality of the e-module relies on a non-test instrument in the form of a structured questionnaire. The first instrument was the Electronic Module Validation Questionnaire, which used a 1–4 Likert scale (1 = poor, 4 = very good). This summary covers 30 statements evenly divided into three main categories: media aspects (10 items) evaluating visual layout, navigation, aesthetics, interactivity, and technical performance; linguistic aspects (10 items) assessing text clarity, age relevance, grammatical correctness, and consistency of scientific terminology; and material substance (10 items) measuring curriculum coherence, scientific validity, depth of local Maluku knowledge integration, and pedagogical significance. Meanwhile, the acceptability of digital devices in the classroom was measured using the Teacher and Student Response

Questionnaire, both of which used a 1–4 Likert scale. The assessment sheet for teachers contained 20 indicators, focusing on the dimension of operational ease (10 items) and the usefulness and efficiency of learning (10 items). In contrast, the evaluation sheet for students includes 20 items of instruments that record aspects of ease of access to media (10 items) as well as their level of interest and emotional involvement throughout science learning at school. The specification of the distribution of statement items in this non-test instrument is designed to ensure that all research subjects' perception data are recorded comprehensively and objectively. In the existing questionnaire, each item (statement) is given a score, the total is calculated, and then the percentage is determined.

Students' conceptual mastery was evaluated objectively through pre- and post-tests. This evaluation tool uses an objective test instrument consisting of 20 multiple-choice questions with four answer options (A, B, C, D). The questions were arranged in alignment with the basic competency indicator (KD 3.1) on the structure and function of plant organs in the science curriculum for Grade IV Islamic Elementary School. The construction of the instrument maps four dimensions of cognitive taxonomy proportionally, which include the aspect of remembering or C1 (6 items), the aspect of understanding or C2 (8 items), the aspect of applying or C3 (4 items), and the aspect of analyzing or C4 (2 items). To ensure the empirical feasibility of this evaluation instrument before it is implemented in class IV, an internal consistency test is conducted using the Kuder–Richardson 20 (KR-20) reliability formula. The statistical test yielded a reliability coefficient of 0.76. Referring to established psychometric standards, the index's acquisition is above the minimum threshold ($\text{Alpha} > 0.60$) (Nunnally, 1967), so this instrument is categorized as having a high level of acceptable reliability for consistently measuring student academic performance.

Data Analysis

The processing of raw data from the research results was divided into two main pillars of analysis: evaluating the technical feasibility parameters and the instructional effectiveness of the e-module. In the first pillar, the interpretation of the average percentage score from expert validators and user response questionnaires used percentage-scale standardization, as described by Isnaini et al. (2022). Mathematically, a score in the range of 81%–100% is interpreted as a "Very Valid" category, which reflects that the digital module

has met quality standards without requiring significant improvements or only minor revisions. Furthermore, the interval of 61%–80% falls under the qualification of "Valid" (worthy of use with slight refinement), the index of 41%–60% is positioned as "Moderately Valid", the range of 21%–40% is considered "Less Valid", and calculations below 20% are categorized as "Invalid". The division of identical percentage interval clusters was also implemented to measure the practicality parameters, with the adjustment of the predicate nomenclature successively to "Very Practical", "Practical", "Quite Practical", "Less Practical", and "Not Practical" for the accumulation of feedback data from teachers and Grade IV students.

In the second pillar, the significance of e-module carrying capacity for students' cognitive strengthening was evaluated by calculating Normalized Gain (N-gain) scores using a formulation developed by Hake (1998). The *N-gain* index output ≥ 0.70 was set as the "High" category, indicating a substantial leap in concept mastery from the pre-test phase to the post-test. Scores between 0.30 and 0.69 (inclusive of 0.30 but exclusive of 0.70) were grouped into the "Medium" category to reflect moderate growth in understanding. In contrast, scores below 0.30 were identified as "Low," indicating a lack of intervention effects. This statistical classification framework is applied systematically to dissect fluctuations in learning achievement scores, both at the level of individual student competency and at the aggregate level.

A more in-depth study of the distribution of students' perceptions for each instrument item was conducted by standardizing and aligning response values. To map the distribution of students' answers at the item level, the Likert-scale raw scores of 1–4 for each individual are converted to a maximum-achievement-based percentage.

The results of the mathematical conversion were then classified into five levels of predicates hierarchically, including: "Very High" (81%–100%), "High" (61%–80%), "Medium" (41%–60%), "Low" (21%–40%), and "Very Low" (0%–20%). This scaling approach is crucial for sensitively detecting which statements receive the highest appreciation, as well as identifying media practicality indicators that still need technical refinement from the child's psychological perspective. This grade stratification is further integrated into Figure 1 to provide a comprehensive visual illustration of the distribution of student responses across the 20 items of the Rambuku E-Module practicality

questionnaire.

■ RESULTS AND DISCUSSION

E-Module Development

The development of the Rambuku e-Module (Maluku's Cultural Diversity) is based on empirical field needs and aligned with the national curriculum. In the analysis phase, the results of the initial diagnosis at MIS Al-Madinah Ambon identified three root causes of instructional problems, namely the lack of culturally responsive science teaching materials, the dominance of monotonous lecture methods, and the low utilization of digital infrastructure. Through the lens of curriculum alignment, the material focuses on Basic Competencies (KD 3.1) on plant organs and their functions for class IV MI. The construction of the local content of Maluku is then formulated into three thematic clusters that are integrated: Part I (*Getting to Know Rambuku*) which presents an introduction to Maluku cultural values and the community's attachment to the existence of flora; Part II (*Plants from the Moluccas*) which dissects the morphological characteristics, ethnopharmacological properties, and historical track record of cloves and nutmeg in the constellation of the world spice trade; and Part III (*Parts of Plants and Their Functions*) which makes clove and nutmeg plants as the main reference specimens to illustrate the biological function of plant organs contextually. This thematic tripartite approach is deliberately designed to break down the familiar dividing line between formal Western science and Traditional Ecological Knowledge (TEK), so that botanical material is no longer seen as an abstract, unfamiliar concept. This holistic content arrangement provides the runway for the research team to formulate the media's physical architecture in the next stage.

The transformation of conceptual drafts into interactive digital products is mutually matured through rigorous technical design and quality testing phases. During the design phase, the Rambuku E-Module is produced with a maximum thickness of 50 pages, leveraging the dynamic navigation system on the *Flip Builder* platform. The visual blueprint of this module brings together concept map features, enrichment activities, automatic evaluation quizzes, and motivational stimuli, distributed proportionally across each learning unit, with decorative illustrations of Maluku cultural motifs that dominate the aesthetic aspects. Next, in the development phase, the worksheets originally designed in *Canva* are compiled into an interactive flip book in *Flip Builder*, complete with supporting audio narration and

interactive quiz features. Before the product is clinically tested in the classroom, a series of formative assessments by the expert board are conducted periodically, culminating in 14 specific revisions that address grammatical improvements, the accuracy of the material content, and the functionality of media elements. The execution of these 14 product improvements reflects a high level of accountability in product development, where technical weaknesses and material biases have been eliminated early on to ensure children's cognitive safety during independent learning. The successful completion of the validated final draft marks the Rambuku E-Module's readiness to enter the field effectiveness testing stage.

Validity of the E-Module

Evaluations from three expert validators indicate an exceptionally high level of theoretical feasibility. Media experts' assessments of 10 aesthetic and technical parameters yielded an average score of 97%. Meanwhile, the linguistic aspect received the highest score, 99%, among the ten communicative criteria. The assessment of subject-matter experts on 10 curriculum and content indicators yielded a score of 98%. Cumulatively, the combined validity index of this e-module reached 98% (very valid). Nevertheless, some constructive input is still accepted for product improvement. The suggestions include improving language structure in two learning units. The research

team was also asked to improve the visual resolution sharpness on three pages of text. A final note is the tightening of citation attribution for Traditional Ecological Knowledge (TEK) sources. All of the formative revision points have been completed before the field trial begins.

The high score of 98% demonstrates absolute agreement among the expert board. The 14 minor revision items from the validator are proven to be linear, with a high product feasibility percentage. These positive findings are consistent with a developmental study by Rofi'i et al. (2022). Their Lombok ethnobotany-based e-module research achieved a validity index of 92.18%, accompanied by substantive suggestions. The results were also aligned with those of the ethnoscience study conducted by Fauziah et al. (2023). Their Riau local wisdom digital module posted a high level of validity through repeated revision cycles. The consistency of this data confirms that expert input strengthens the instructional quality of digital media. This solid validation confirms the Rambuku E-Module's readiness to measure its effectiveness on students' cognitive performance.

Practicality of the E-Module

Evaluations from educators confirm that this digital media is very practical for classroom learning. Two Class IV science teachers at MIS Al-Madinah Ambon completed a questionnaire with 20 indicators. The assessment instruments are divided equally into

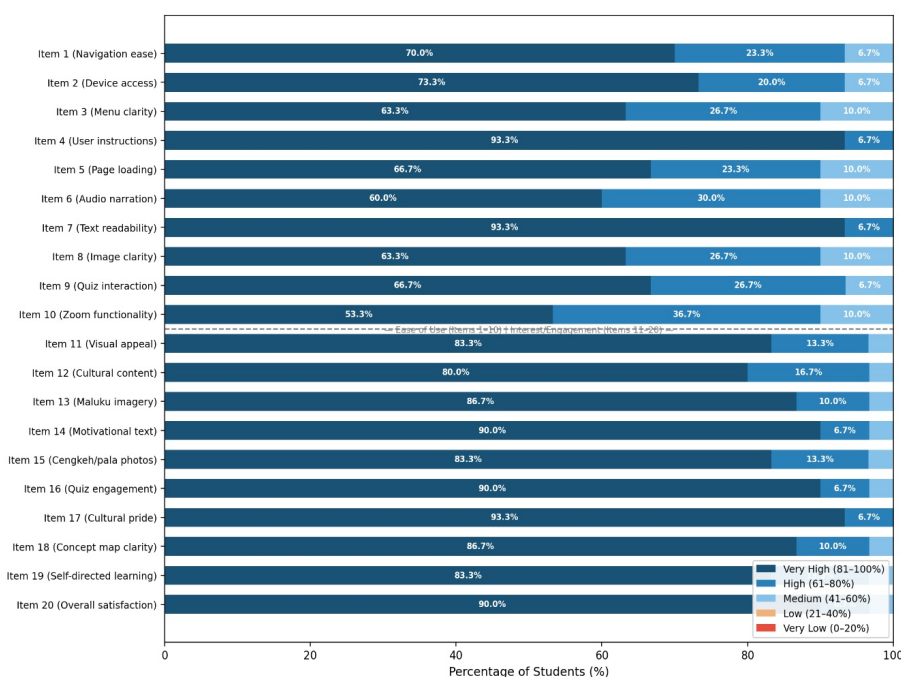


Figure 1. Distribution of Student Responses for each Practicality Item

two main dimensions. The first dimension is operational ease that measures navigation, interface, and technical accessibility. The classroom management aspect was also assessed and obtained an average score of 91% (Very Practical). The second dimension concerns usefulness and teaching efficiency. This point tests the relevance of the curriculum, instructional flexibility, and clarity of the study guide. The evaluation of this aspect of dayaguna yielded an average score of 93% (Very Practical). Cumulatively, the practicality index from the teacher's perspective reached 92%. The teacher's qualitative notes indicate that the Flip Builder system requires minimal onboarding. This e-module can be instantly integrated seamlessly from the first meeting in class. In addition, visualizing cloves and nutmeg has proven effective at capturing students' attention during the instructional session.

The 100% stacked bar graph in Figure 1 presents details on the perceptions of 30 students. Each horizontal bar represents the distribution of student responses across the 20 items of the practicality questionnaire. The color-coded chart divides the rating into five hierarchical categories from "Very High" to "Very Low". In the operational convenience dimension (Items 1–10), the "Very High" predicate dominates most indicators. The lowest percentage is at 53.3% for the screen zoom function (Point 10). Meanwhile, the highest score reached 93.3% for the indicators of instructions for use and text readability (Points 4 and 7). The predicate "High" became the second largest cluster throughout the evaluation. The combined categories of "Medium" to "Very Low" were recorded below 15% for eight instruments. Interestingly, Items 4 and 7 had no negative response under the "High" category at all. These findings indicate an almost universal level of satisfaction with

the media's technical design. Evaluations on the dimensions of interest and emotional engagement (Items 11–20) also show a very positive trend. The data graph is strongly skewed towards the "Very High" category across the indicator. Item 17 regarding pride in the local culture of Maluku received 93.3% "Very High" responses and 6.7% "High" responses. Not a single student gave a low rating on this aspect of cultural pride. Furthermore, Items 11, 15, and 19 consistently pocketed 83.3% of the votes in the "Very High" category. The dominance of positive values in these 20 instruments is strong empirical evidence. This micro data supports a cumulative practicality score of 92.42% among students.

These empirical findings strengthen the theoretical justification for the reliability of digitally based instructional media. The results of this study are consistent with those of Latif et al. (2022). Their study demonstrates that digital modules supporting independent learning consistently achieve high practicality scores. In addition, data alignment was also found in the research of Lee et al. (2012). They confirmed that integrating local knowledge into science modules effectively boosted primary school students' interest. This contextual approach has also been shown to foster a sense of pride in their own local cultural identity. The consistency of high practical values of the two stakeholder groups (teachers and students) is a crucial indicator. This accumulation of positive data confirms the Rambuku E-Module's full readiness for implementation en masse across a wider class scale.

Effectiveness of the E-Module

The data visualization in Figure 2 compares students' pre-test and post-test average scores. The learning outcomes were mapped separately according to Bloom's four

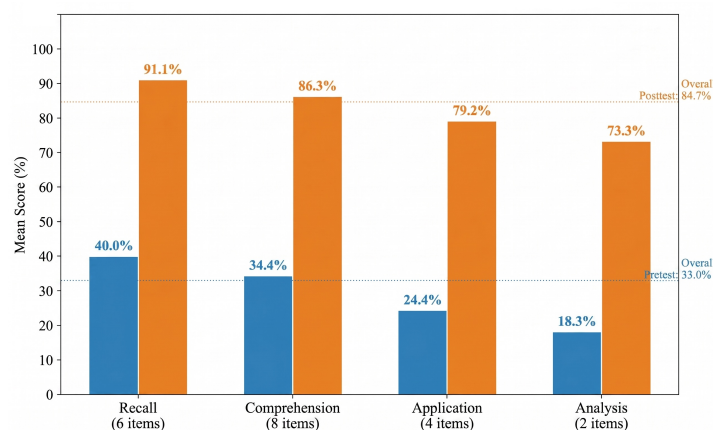


Figure 2. Comparison of average pretest and posttest scores of student learning outcomes

cognitive levels. The measurement parameters rely on 20 objective test instruments in KD 3.1 material. The pattern of value growth is consistent across the four levels of thinking. This positive trend demonstrates that the instructional impact of e-modules does not stagnate at low-level memorization. The pedagogical effect of this digital media extends to higher-order thinking skills (HOTS), including application and analysis. The largest absolute score spike was observed on the recall dimension (C1). These findings are linear with the dense visual coverage of the content directly inside the electronic module. On the other hand, the growth of absolute values was detected at the slowest in the domain of analysis (C4). This lack of spikes reflects the high-level cognitive demands that remain inherently challenging for Grade IV students' developmental psychology.

Figure 3 maps the fluctuations in scores before and after the in-person intervention. The diagonal reference line is drawn as the boundary of equivalence between the initial and final values. Visually, all 30 students' data points positioned themselves far above the reference line. This graphical trend confirms a positive increase in learning competence for each individual in grade IV. The coloration of the point indicator is determined by the obtained cluster of N-gain coefficients. A total of 25 students (83.3%) fall into the "High" category (≥ 0.70), which is marked in dark blue. Meanwhile, the remaining 5 students (16.7%) fell into the "Medium" category (0.30–0.69), as shown in the orange visualization. No student was found to fall into the "Low" category. Micro-wise, the range of individual *N-gain* scores moved steadily from 0.65 to 0.91. This grade distribution shows that the Rambuku E-Module effectively supports

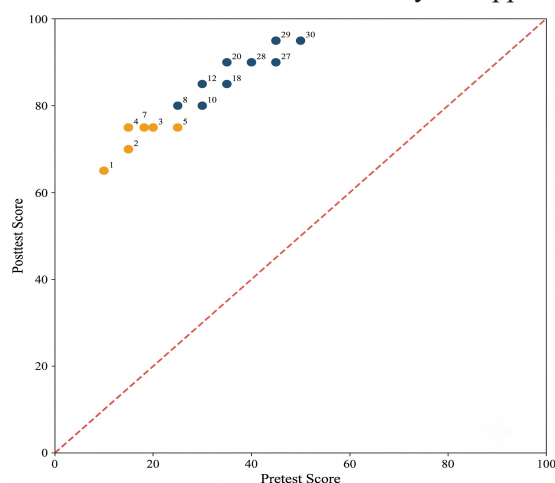


Figure 3. Pretest-posttest scores presented in scatter plot

students of all ability levels. The improvement in botanical skills (basic biology) reflects genuine collective growth, not just a data anomaly caused by a few high-achieving students.

A comparison of the distributions of pretest and posttest scores for students is presented in Figure 4 using a box-and-whisker diagram. The initial data profile showed very low achievement, with an average score of 33.00 (SD = 9.21; Median = 35; IQR = 25-40; range = 15-50). These statistical parameters shift to extremes during the final measurement phase. Posttest scores showed a spike in the average to 84.67 (SD=7.53; Median=85; IQR=80-90; range=70-95). Visually, the shape of the posttest box has a much tighter structure while being fully lifted upwards. The decrease in the standard deviation (SD) indicates that the variability of competency among students becomes more homogeneous after the intervention. This graphical phenomenon demonstrates a massive, accelerating, and consistent instructional impact on the mastery of the science botany concept across all Grade IV samples.

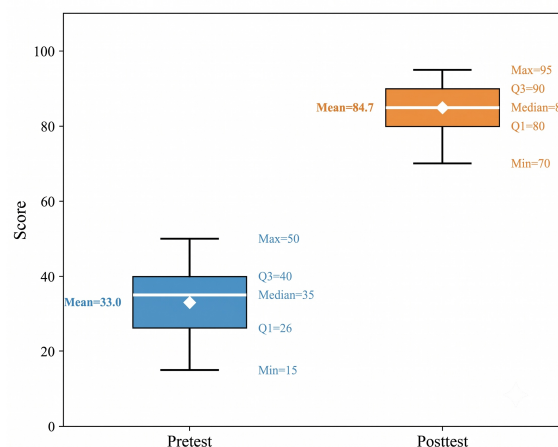


Figure 4. Student score distribution

The statistical significance of the improved learning outcomes was tested using a paired t-test. As an absolute requirement, the difference score distribution was assessed for normality using the Shapiro-Wilk test ($W=0.94$; $p=0.09$). Inferential results confirmed a very significant increase in average scores from the pretest phase ($M=33.00$; $SD=9.21$) to posttest ($M=84.67$; $SD=7.53$). The accumulated value growth difference was recorded at 51.67 points ($SD = 7.53$; $t(29) = 93.32$; $p = 0.001$; $d = 17.04$). The calculation of the effect size using Cohen's d , with a value of 17.04, indicates a very strong practical magnitude in the field. In addition, the group's average *N-gain* score was 0.77 (high).

The low initial achievement on the pretest (33.00) clearly reflects students' limited prior knowledge. This condition does not indicate any latent learning obstacles or difficulties in children. The post-intervention posttest score aligned with the Rambuku E-module instructional design map. However, drawing causal conclusions must still be done with caution due to the limitations of a one-group design. The observed gradients could be influenced by the test instrument's familiarity bias, the child's natural maturation, or the cumulative effects of other daily learning experiences at school. These aspects of external variables should be considered when assessing the research's internal validity.

The effectiveness of the Rambuku E-module is strengthened by a series of empirical findings in several regions in Indonesia. For comparison, Komaini et al. (2023) reported an increase in equivalent learning outcomes through electronic modules based on Mentawai local wisdom, with an N-gain score of 0.72 (high category). Furthermore, Telussa (2023) also demonstrated that ethnoscience-based science e-modules are effective in triggering significant conceptual reinforcement among elementary school students, with an N-gain of 0.69 (medium-high category). This success factor is explored in depth by Sari et al. (2024). Their study confirms that interactive flipbook packaging is reliable in boosting children's emotional engagement and cognitive understanding. The carrying capacity is sourced from adaptive navigation systems and dynamic multimedia integration (Ormancı & Çepni, 2020). The common thread of these cross-cultural studies presents irrefutable convergent evidence. Integrating local wisdom into digital learning media has been proven to be the most promising instructional strategy for optimizing the mastery of science concepts at the elementary level. Thus, science learning in elementary schools is influenced by the design of teaching methods that connect diversity, technology, and emotions (Soriano-Sánchez, 2025).

This study provides theoretical contributions by offering empirical support for two main propositions in culturally responsive science education. The first proposition aligns these findings with Ausubel's theory of meaningful learning (Zidny & Eilks, 2020). This theory states that the assimilation of new knowledge will proceed optimally when it is associated with students' existing cognitive structures. The tripartite thematic structure in the Rambuku E-Module clearly applies the principle of progressive differentiation. Children's new knowledge grows meaningfully

through the gradual refinement of botanical science concepts rooted in local culture.

The second proposition reinforces the culturally responsive teaching framework initiated by Gay (2018). This research demonstrates that digital media can be an effective pedagogical tool in Islamic elementary schools. The high student interest engagement score (94%) is consistent with the classic literature on culturally responsive teaching. Lee et al. (2012) emphasized that children's motivation to learn increases sharply when the learning content reflects their cultural identity. Through the exploration of Maluku culture in the Islamic Elementary School environment, this research succeeded in filling an empirical gap that had not been touched before.

In practice, the Rambuku E-Module offers a cost-effective, easily replicable model for science media development. This advantage stems from the use of open-access platforms such as *Canva* and *Flip Builder* within ADDIE's work corridor. This instructional model is highly promising for independent application across various regions of the Indonesian archipelago, which is highly culturally diverse (Erni et al., 2023; Salmia & Bancong, 2024; Usmeldi & Amini, 2020). Nevertheless, some fundamental limitations in this study must still be openly acknowledged. The first limitation stems from the use of a single-group pre-experimental design without a companion control class. This condition limits the drawing of absolute conclusions of cause-and-effect relationships. Second, product trials are still limited to a micro scale with a sample of 30 students at MIS Ambon City. The limitations of this sample mean that the generalizability of the results to the wider population still needs to be tested further. Third, the implementation duration in the classroom is very short: only 6 sessions totaling 210 minutes. The short duration of the intervention limits in-depth analysis of long-term memory retention and the consistency of students' motivation to learn.

■ CONCLUSION

This research has successfully produced the Rambuku E-Module as a valid, practical, and effective digital science medium. This teaching tool, based on Maluku local wisdom, is designed for Grade IV MI students on the plant structure material. Using the ADDIE framework, *Canva*, and *Flip Builder*, this product achieved an expert validity score of 98%. The practicality parameters were also rated very strongly by both teachers (92%) and students (92.42%). Furthermore, the clinical

trial recorded a high N-gain coefficient of 0.77 in mastering the concept of child science botany. However, the conclusion regarding absolute causality in this research remains limited by the use of a single-group design.

The assimilation of Maluku culture through nutmeg and clove specimens has been tested to be a solid instructional strategy. This 50-page interactive digital book successfully contextualizes science (basic biology) material into the reality of students' lives. These positive findings enrich the empirical body of knowledge regarding the urgency of culturally responsive digital learning media in Indonesia. In addition, this research offers a very systematic blueprint for tripartite integration. The flow of material, from cultural introductions and exploration of local species to formal scientific content, is highly adaptable to various regional contexts.

A series of strategic recommendations were formulated to expand the impact and theoretical validity of this development model. First, future research is suggested to migrate to purely experimental or quasi-experimental designs with control classes. Sample sizes also need to be enlarged and reach a wider geographic diversity to test product causality. Second, follow-up evaluations should be designed to record long-term memory retention and the longitudinal consistency of students' motivation to learn. Diversification of bound variables and expansion of material topics are the next pillars of recommendations. Third, product testing should begin measuring other psychological variables, such as higher-order thinking skills (HOTS), scientific attitudes, and the strengthening of children's cultural identity. Fourth, the researchers are encouraged to explore adapting the structure of this Rambuku module to other science topics. The scale of its implementation can also be increased to higher levels of education throughout the Indonesian archipelago.

■ ACKNOWLEDGMENTS

The authors express sincere gratitude to the educators, staff, and Class IV students of Private Islamic Elementary School (MIS) Al-Madinah Ambon for their generous participation and invaluable feedback throughout this research. We also thank the expert validators for their thorough and constructive reviews of the e-module.

■ AUTHOR CONTRIBUTIONS

Author HB contributed to conceptualization, data collection, e-module development, and writing the original draft. Author AB contributed to manuscript writing

and methodology. Author DR contributed to manuscript writing and formal analysis. All authors have read and approved the final manuscript.

DECLARATION OF GENERATIVE AI USAGE IN THE WRITING PROCESS

The author(s) declare that DeepSeek and Claude were used as generative AI assistants to improve the structure, clarity, and logical flow of specific sections of the manuscript. In contrast, Grammarly was used to enhance grammar and spelling. No generative AI tools were used for data analysis, interpretation of results, or generation of scientific conclusions. All AI-generated suggestions were reviewed and validated by the author(s), who assume full responsibility for the manuscript's content.

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