

DEVELOPMENT OF RESEARCH-BASED MACROSCOPIC PATHOGENIC FUNGI TEACHING MATERIALS: AN INNOVATION TO IMPROVE BIOLOGY LEARNING IN HIGH SCHOOLS

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ABSTRACT: Biology learning in Kotapinang State Senior High School heavily relies on conventional textbooks that lack local context, creating a gap between curriculum content and the students' plantation environment. While applied mycological studies on local oil palm pathogens exist, their integration into high school biology media remains unexplored. This study aims to bridge this gap by developing an innovative pocket book on macroscopic pathogenic fungi based on authentic local research. Utilizing the Research and Development (R&D) approach with the 4D model (limited to the Develop stage), the prototype underwent rigorous validation by material, learning, and design experts. Practicality was assessed by biology teachers, followed by a small-scale trial involving 15 grade 11 students selected via random sampling. The trial procedure required students to review the pocket book's readability and layout through guided skimming, after which their user experience was evaluated using a structured practicality questionnaire. Expert validation results ranged from 85.88% to 96.36%, indicating very high validity. The practitioner assessment yielded a highly positive response (100%), while the student evaluation achieved 85.74%, placing it in the very practical category. This product has the potential to contextualize biology learning by integrating local research findings, serving as a suitable way to provide contextual supplementary learning materials in schools based in plantation areas.

Keywords: 4D Model, Local Research, Oil Palm, Pathogenic Fungi, Teaching Materials.

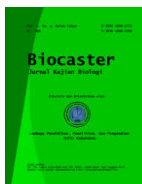
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INTRODUCTION

Biology learning is essentially a vehicle for equipping students with critical thinking and problem-solving skills through direct observation of natural phenomena. Within the context of national curricula, the topic of Fungi (Mushrooms) serves as a crucial core competency for high school students to grasp the ecological roles and economic impacts of microorganisms. However, effective delivery depends heavily on contextualized teaching materials that can bridge classroom theory with real-world phenomena (Arsyad et al., 2025; Safnowandi,



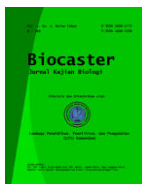
2021). When teaching materials remain generic, students fail to see the practical relevance of biological sciences, which ultimately diminishes their cognitive engagement and reading interest (Uyun et al., 2022).

This detachment from local reality is clearly visible at SMA Negeri 2 Kotapinang. Geographically, the school is situated within extensive oil palm plantation areas. These agricultural ecosystems are highly vulnerable to devastation by macroscopic pathogenic fungi, most notably *Ganoderma boninense*, which causes basal stem rot disease (Khoo & Chong, 2023). Given that the oil palm industry serves as the economic backbone of the Kotapinang region, this phytopathological issue represents a profound socioeconomic concern. Despite its immediate relevance to the community, initial observations and interviews revealed that biology instruction at SMA Negeri 2 Kotapinang remains highly conventional, relying solely on commercial national textbooks. These standard resources focus almost exclusively on ubiquitous, non-threatening examples like tempeh mold (*Rhizopus*) or straw mushrooms (*Volvariella*), completely omitting the critical pathological phenomena occurring in the students' immediate surroundings (Arsyad et al., 2025; Bonifasius et al., 2024).

The research gap in this study lies in the unaddressed disconnect between advanced agricultural research and practical school-level biology media. Previous educational innovations have attempted to address the abstraction of fungal materials by developing supplementary resources, such as general electronic modules, macromycetes encyclopedias, or web-based floras (Permatasari et al., 2023; Zendrato et al., 2025). However, these prior studies exhibit critical limitations: they focus almost exclusively on high-level taxonomic identification and general biodiversity in protected forests or conservation areas. None of these existing media bridge biology learning with applied plant pathology or localized agricultural issues that directly affect the community's economy.

Consequently, current commercial teaching materials remain heavily insufficient for several reasons. Structurally, national textbooks present a "one-size-fits-all" curriculum that relies on generic, urbanized examples (such as commercial button mushrooms or bread mold), which completely ignore the ecological realities of rural or plantation-based schools (Arsyad et al., 2025). Pedagogically, these textbooks fail to foster regional environmental literacy because they treat mycology as an abstract, static classification system rather than an active, observable phenomenon in the students' immediate environment. While advanced scientific reports and specialized journals extensively cover the devastation of oil palm pathogens like *Ganoderma boninense*, this vital knowledge remains trapped in complex academic literature that is linguistically and conceptually inaccessible to high school students (Syahrini, 2025). Therefore, a significant gap persists in the systematic transformation of raw field-research data into a portable, visually simplified instructional format that can contextualize high school biology.

To provide a solid scientific foundation for this product, the development of the pocket book directly incorporates primary data from a preliminary local mycological survey conducted in the oil palm plantations surrounding SMA Negeri 2 Kotapinang. This underlying research specifically identified and documented *Ganoderma boninense* as the primary macroscopic pathogenic fungus devastating



the local oil palm fields. The specific field findings integrated into the book include high-resolution photographic documentation of the pathogen's basidiocarp morphology, its distinct zoning growth on the host bark, and the structural degradation stages of infected oil palm trunks.

Integrating these empirical findings is educationally valuable for several reasons. From a pedagogical standpoint, it replaces generic drawings with real-world, localized specimens that students can easily observe in their daily environment, shifting the learning paradigm from passive memorization to place-based inquiry. Furthermore, by linking the physiological features of Fungi directly to the localized agricultural crisis of basal stem rot, these findings cultivate critical thinking and systemic environmental awareness. Students do not just learn taxonomy; they comprehend the ecological and economic impact of a plant pathogen that directly affects their community's livelihood. Unlike previous studies, which mainly focused on media development without incorporating specific field research data, the present study integrates local mycological findings into a pocket book validated by experts in content, pedagogy, and design. Therefore, this study aims to develop and evaluate the validity and practicality of a research-based pocket book on macroscopic pathogenic fungi for Grade 11 biology learning.

METHODS

This research is a type of development research or Research and Development (R&D). The development procedure follows the 4D framework (Define, Design, Develop, and Disseminate) formulated by Thiagarajan et al. (1974). In accordance with the localized scope of this project, the procedure is restricted to the third stage, Develop, focusing on producing a valid and practically feasible instructional tool for SMA Negeri 2 Kotapinang

Development Procedure

The implementation of the 4D framework was executed through three systematic phases:

Define Stage

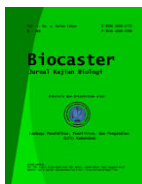
Conducted a front-end analysis to address the reliance on non-contextual textbooks, a student analysis to establish learner profiles, a task and concept analysis to map the mycological structures of local fungi, and a specification of learning objectives aligning local pathogenic data with core biology curriculum indicators (Permatasari et al., 2023)

Design Stage

Aimed at producing the initial prototype of the pocket book. This phase involved media selection (pocket book format), structural layout selection for optimal portability, and draft designing. Primary field data regarding *Ganoderma boninense* morphology and infection symptoms were converted into high-resolution, informative visual contents (Zendrato et al., 2025).

Develop Stage

Focused on iterative evaluation and refinement through a two-step process: expert validation and a subsequent field trial. The prototype was reviewed by a multidisciplinary panel consisting of a material expert (mycology), a learning expert (pedagogy), and a design expert (learning media). This stage is divided into



two main steps: 1) expert validation: The book prototype was validated by three experts, namely a material expert (mycology/biology expert), a learning expert (pedagogy expert), and a design expert (learning media expert) (Alwi et al., 2024); and 2) field trial: The assessment was carried out by one biology subject teacher and a small-scale limited trial was conducted on 15 class XI students of SMA Negeri 2 Kotapinang. To optimize manuscript space and eliminate excessive tabular detail, the structured distribution of the instrument items across all evaluator categories is consolidated in Table 1.

Table 1. Consolidated Grid for Validation and Practicality Instruments.

No.	Evaluator Category	Assesment Aspect	Number of Items
1	Subject matter expert	Content suitability, learning flow	17
2	Learning expert	Learning outcomes, student context	11
3	Design expert	Visual appearance, functionality	15
4	Biology teacher	Content suitability, program display	14
5	Student respondent	Perceived usefulness, ease of use	10

Source: Hastini & Tanjung (2022).

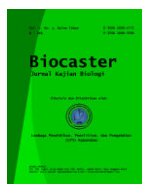
Research Subjects and Locations

The research was situated at SMA Negeri 2 Kotapinang, South Labuhanbatu Regency, an educational institution embedded within an oil palm plantation zone. Practitioner evaluation was performed by one senior biology teacher. The limited user trial involved 15 Grade 11 students. To ensure objective generalizability within the designated cohort, a simple random sampling technique was utilized, where respondents were drawn systematically using a lottery method based on the official classroom registry. This sample size conforms to the Small Group Evaluation protocol in R&D, serving to identify user interface constraints, text readability, and technical discrepancies prior to macro-scale implementation (Yuniarsih & Setiawan, 2025).

Data Collection Instruments and Techniques

Data collection utilized structured Likert-scale questionnaires. The assessment instruments were adapted from established media evaluation criteria and optimized for high school biological materials. To ensure scientific rigor, the instrument quality was evaluated through two parameters: 1) instrument validity: Established via qualitative and quantitative expert judgment. Construct and content indicators were refined based on validator consensus until the statement items achieved perfect content validity index scores (Alwi et al., 2024); and 2) reliability: Internal consistency was measured mathematically using Cronbach's Alpha coefficient (α). The evaluation instruments yielded reliable criteria with $\alpha > 0.75$, exceeding the standard empirical reliability threshold of 0.60, confirming the high internal stability of the data gathering tool (Pertiwi et al., 2024).

The data in this study were obtained through a non-test instrument in the form of a questionnaire. Data collection techniques include: 1) expert validation questionnaire: To measure the theoretical feasibility of a book based on aspects of content, presentation, and visual design (Pertiwi et al., 2024); and 2) teacher and student response questionnaire: To measure the level of practicality of the book in the field.



This study used a 1-5 Likert scale questionnaire that was analyzed using descriptive and quantitative data obtained from the validation and practicality sheets were analyzed using descriptive statistics. To test the validity and practicality of the instrument (Sugiyono, 2017). Quantitative data was used to determine the feasibility of the media, while the results of the small-scale trial served as the basis for further improvement and development.

Table 2. Likert Scale.

No. Scale	Meaning of Scale
5	Very Valid
4	Valid
3	Quite Valid
2	Less Valid
1	Very Less Valid

The quality of the teaching material content was evaluated by subject matter experts using an instrument adapted from (Hastini & Tanjung, 2022). This instrument covers two main aspects: content appropriateness (5 items) and learning aspects (12 items), which aim to assess the content's suitability to learning objectives and the completeness of the information to ensure the media's effectiveness.

Table 3. Subject Matter Expert Grid.

No.	Aspect	Number of Grains
1	Content Suitability	5
2	Learning	12

Source: Hastini & Tanjung (2022).

Evaluation of the quality of teaching materials was conducted by learning experts using an instrument adapted from Hastini & Tanjung (2022). This instrument covers three aspects: learning outcomes (2 items), student characteristics (7 items), and methods (2 items).

Table 4. Learning Expert Grid.

No.	Aspect	Number of Grains
1	Learning Outcomes	2
2	Student Characteristics	7
3	Method	2

Source: Hastini & Tanjung (2022).

The design quality of the teaching materials was evaluated by design experts using an instrument adapted from Hastini & Tanjung (2022). This instrument covers appearance (11 items) assessing visual elements and programmatic aspects (4 items) assessing technical functionality. This evaluation aims to ensure the research-based textbook is visually appealing and systemically stable, making it suitable for use in learning. The assessment also considers the consistency of the layout, readability of the text, and appropriateness of the visual components in supporting students' understanding of the learning content. The evaluation identifies areas for improvement before textbook implementation.

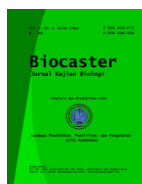


Table 5. Design Expert Grid.

No.	Aspect	Number of Grains
1	Appearance	11
2	Programming	4

Source: Hastini & Tanjung (2022).

The validated teaching materials were then assessed by biology teachers to gauge responses to the macroscopic pathogenic fungi textbook. The instrument, adapted from Hastini & Tanjung (2022), covered aspects of content suitability (8 items) and display/program (6 items).

Table 6. Biology Teacher Response Grid.

No.	Aspect	Number of Grains
1	Suitability of Material Content	8
2	Display and Programming	6

Source: Hastini & Tanjung (2022).

During the limited trial, students were asked to skim (glance at the display) the layout, quality of the mushroom images, and ease of use of the language without working on cognitive test questions. The main focus of data collection at this stage is to see whether this research-based pocket book innovation is able to increase student interest compared to conventional textbooks. Student responses as end users were measured using an instrument adapted from Hastini & Tanjung (2022). This assessment covered three main aspects: usefulness (4 items) for understanding the material, ease of use (4 items) related to accessibility, and satisfaction (2 items) regarding the convenience of use and functionality of the media. The feedback guided improvements before the pocket book's next learning stage.

Table 7. Respondent Assessment.

No.	Aspect	Number of Grains
1	Benefits	4
2	Convenience	4
3	Satisfaction	2

Source: Hastini & Tanjung (2022).

The formula used to calculate the percentage of all answers is as follows.

$$\text{Validity Percentage} = \frac{\text{Total score obtained}}{\text{Total score}} \times 100\%$$

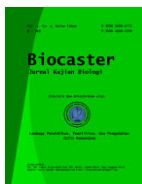
The eligibility interval can be determined as follows:

$$\text{Maximum Percentage} = \left(\frac{5}{5}\right) \times 100\% = 100\%$$

$$\text{Minimum Percentage} = \left(\frac{1}{5}\right) \times 100\% = 20\%$$

$$\text{Range} : 100\% - 20\% = 80\%$$

$$\text{Length of Classs Interval} = \frac{80\%}{5} = 16\%$$



After Based on the length of the interval class above, the quantitative feasibility scores were mapped onto standardized interpretation scales to guide the product revision process. However, the decision to refine the prototype was not determined solely by these statistical thresholds; it was heavily driven by a qualitative feedback loop.

Product Revision Procedures

The development framework enforced a strict iterative refinement phase following the expert validation stage. Qualitative suggestions, critiques, and corrections provided by the multidisciplinary panel were systematically compiled into a technical correction matrix. These insights were then directly incorporated into the pocket book prototype through three targeted engineering procedures:

Mycological and Content Adjustments:

In response to the subject matter expert's feedback regarding taxonomic precision, missing anatomical labels were explicitly mapped onto the *Ganoderma boninense* structural diagrams. Ambiguous field descriptions were revised to strictly align with standard phytopathological nomenclature, ensuring that the local research data was scientifically accurate for a high school biology context.

Pedagogical and Readability Refinements:

Criticisms from the learning expert regarding text density and cognitive load were resolved by transforming long, dense paragraphs into concise, bulleted takeaway points. The typography was optimized using an 11-point font size with enhanced line spacing to match 10th-grade readability standards, and contextual scaffolding questions were embedded within the page margins to promote place-based scientific inquiry. Additionally, visual cues and clear section headings were incorporated to improve information navigation and support students' understanding of key scientific concepts.

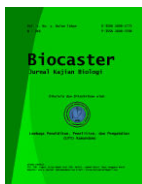
Visual Layout and Ergonomic Corrections

To address the design expert's evaluation of the user interface, the physical layout of the pocket book was standardized to a compact B6 size to ensure true portability and ease of handling for students. Furthermore, the color contrast between textual descriptions and background elements was digitally adjusted, and high-resolution bounding boxes were added around the fungal morphology photographs to highlight diagnostic structural features clearly. This systematic integration of qualitative expert suggestions ensured that all design and content discrepancies were fully resolved, establishing an empirically refined version of the pocket book prior to its deployment in the student field trials to revise the modified development product from Hastini & Tanjung (2022) can be determined, as in Table 8.

Table 8. Likert Scale Interval Scale for Validation.

Scale Range	Percentage Interval	Criteria
$84 \leq 100$	$84 \leq x \leq 100\%$	Very Worthy
$67 \leq 83$	$67 \leq x \leq 83\%$	Worthy
$50 \leq 66$	$50 \leq x \leq 66\%$	Quite Decent
$33 \leq 49$	$21 \leq x \leq 40\%$	Not Feasible
$0 \leq 32$	$0 \leq x \leq 20\%$	Totally Unworthy

Source: Hastini & Tanjung (2022).



Research data obtained from biology teachers and students were analyzed using a Likert scale. The results of the validation questionnaire data were in the form of checklist data (✓). Next, calculate the results of the responses of biology teachers and students to the research-based book teaching materials developed using the following formula:

$$\% \text{ Response} = \frac{\{\text{Score obtained}\}}{\{\text{Total score}\}} \times 100\%$$

The quantitative data obtained from the Likert-scale responses of both the biology subject teacher and the student participants were systematically tabulated and computed using Microsoft Excel 2021. This data analysis software was utilized to calculate the sum of earned scores, convert raw parameters into exact feasibility and practicality percentages, and generate descriptive statistical summaries. Additionally, standard deviations and internal consistency verifications were cross-analyzed using IBM SPSS Statistics version 26.0 to ensure zero computational error. The resulting final percentages were then interpreted directly using the standardized, non-overlapping product response criteria scale to determine whether the pocket book met the practical threshold for field implementation of responses from biology subject teachers and the students concerned were interpreted using the modified response criteria from Hastini & Tanjung (2022), as in Table 9.

Table 9. Interpretation of Respondent Criteria.

Scale Range	Criteria
$84 \leq \% \text{ Score} \leq 100$	Very Practical
$67 \leq \% \text{ Score} \leq 83$	Practical
$50 \leq \% \text{ Score} \leq 66$	Quite Practical
$33 \leq \% \text{ Score} \leq 49$	Impractical
$0 \leq \% \text{ Score} \leq 32$	Very Impractical

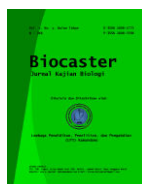
Source: Hastini & Tanjung (2022).

RESULTS AND DISCUSSION

This research and development project successfully produced a contextualized biology instructional tool in the form of a research-based pocket book titled "Macroscopic Pathogenic Fungi." The content is explicitly tailored to the agricultural ecosystem surrounding SMA Negeri 2 Kotapinang. The empirical findings obtained chronologically through the development phases are delineated below.

The Define and Design Outcomes

The front-end and student analyses executed during the Define phase revealed a significant pedagogical gap: 100% of the existing biology instructional materials at SMA Negeri 2 Kotapinang relied on standard national textbooks that omitted local environmental contexts. Although 95% of the student population permanently resides within oil palm plantation zones, baseline diagnostic evaluations indicated that their contextual literacy regarding the phytopathological crises occurring in their immediate surroundings was critically low. Furthermore, student diagnostic profiling identified a practical, physical barrier to learning:



students demonstrated a strong reluctance to carry conventional biology textbooks due to their excessive weight and density. Based on the subsequent task and concept analyses, curricular indicators were structurally modified to explicitly link standard high school fungal taxonomy with the morphological and physiological traits of localized oil palm pathogens (Aulia et al., 2025).

To address these empirical needs, the Design phase translated these parameters into a portable pocket book prototype. This specific structural format was selected to optimize portability and maximize user compliance among Grade 11 students. Primary mycological field data specifically concerning the destructive lifecycle and macroscopic structures of oil palm pathogens were transformed into highly visual, full-color pedagogical content. The layout was engineered to follow a visual-heavy architecture, integrating original high-resolution photographic documentation of fungal structures to serve as a concrete substitute for abstract textbook diagrams (Pratiwi et al., 2025).

The Develop Outcomes: Product Transformation and Refinement

The execution of the Develop phase generated a 128-page localized instructional guide. To maintain strict scientific integrity and geographic alignment with the plantation ecosystem, the book focuses exclusively on relevant tropical macro-fungi, primarily *Ganoderma boninense*, omitting unrelated non-local species to prevent cognitive overload. The pocketbook cover design is shown in Figure 1.



Figure 1. Pocketbook Front Cover.

The design of the pocketbook's back cover is shown in Figure 2.

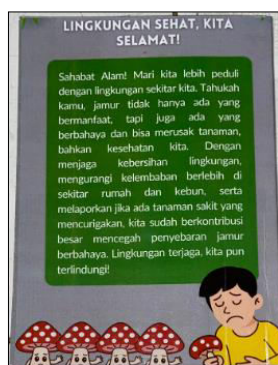
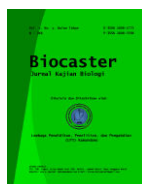


Figure 2. Back Cover of the Pocketbook.



Material Expert Validation Results

The product development phase begins with a validation process by subject matter experts to ensure the accuracy of the scientific content presented in the handbook. The assessments include the appropriateness of the content and the learning aspects integrated into high school biology materials. This validation aims to ensure that the transformation of field research data into teaching materials maintains scientific integrity and aligns with the expected learning outcomes. Based on the assessment, quantitative data were obtained indicating the level of appropriateness of the material, as summarized in Table 10 below:

Table 10. Results of the Material Expert Validation Test.

Aspect	Number of Grains	Max Score	Answer Score	Percentage
Content Suitability	5	25	21	84%
Learning	12	60	52	86%
Total	17	85	73	85,88%

Material validation evaluated content feasibility and pedagogical alignment, yielding a mean score of 85.88% (Table 10), which corresponds to the "Very Feasible" category. This quantitative outcome indicates that the integration of empirical research data regarding *Ganoderma boninense* from local oil palm plantation ecosystems aligns with high school biology curriculum requirements (Nia, 2024). Rather than relying on generalized textbook examples, the inclusion of localized phytopathological data provides specific taxonomic and ecological contexts for learners. Consequently, this score reflects a measured structural consistency between current field-based pathological phenomena and the conceptual framework required for high school mycological instruction.

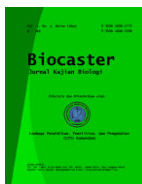
Results of the Learning Expert Validation Test

After going through the material validity testing process, the next stage is an assessment by learning experts to examine the instructional feasibility of the developed pocketbook. The assessment focus at this stage includes learning outcomes with competency indicators in the biology curriculum, student characteristics, and methods. This validation is a crucial instrument to ensure that this research-based pathogenic fungi book can function effectively as a self-learning tool that can transform technical information into conceptual understanding that is easily digested by students. The results of the comprehensive evaluation by learning experts are presented in Table 11.

Table 11. Results of the Learning Expert Validation Test.

Aspect	Number of Grains	Max Score	Answer Score	Percentage
Learning Outcomes	2	10	8	80%
Student Characteristics	7	35	35	100%
Method	2	10	10	100%
Total	11	55	53	96,36%

Learning expert validation focused on learning outcomes, student characteristics, and pedagogical methods, yielding a score of 96.36% (Table 11), which falls into the "Very Appropriate" category. This quantitative result indicates alignment between the structural framework of the pocket book and the expected



cognitive progression of secondary-level students in understanding contextual mycological concepts. The instructional architecture incorporates a systematic content progression, transitioning from general fungal taxonomy to specific localized phytopathological case studies in oil palm plantations (Kumalasari et al., 2022). This structural organization supports systematic knowledge acquisition by aligning the density of information with the cognitive characteristics of Grade 11 students, thereby satisfying the pedagogical criteria required for classroom implementation.

Design Expert Validation Test Results

Visual aspects and ease of use are crucial components in overcoming the problem of low student interest in reading conventional textbooks. Therefore, validation was conducted by design experts to evaluate the physical feasibility of the developed pocket book. The assessment at this stage included aspects of layout, typography selection, the resolution quality of macro photography of mushrooms, and the ergonomics of the book size for practicality for students to carry. This validation aims to ensure that the learning media innovation is not only superior in content, but also has a visual appeal that can stimulate students' learning interest intuitively. The data from the feasibility assessment by design experts are summarized in depth in Table 12.

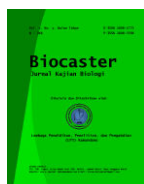
Table 12. Design Expert Validation Results.

Aspect	Number of Grains	Max Score	Answer Score	Percentage
Appearance	11	55	50	90%
Programming	4	20	20	100%
Total	15	75	70	93,33%

Design expert validation evaluated both the appearance and technical media layout, with a primary focus on aesthetics, typography, visual hierarchy, and formatting quality. The assessment reached a score of 93.33% (Table 12), categorizing the media as "Very Suitable." This outcome was driven by the integration of original, high-resolution macroscopic photographs from field research, which established clear visual references for the morphological descriptions. Furthermore, the selection of an ergonomic B6 pocket book format directly addresses the physical portability limitations associated with conventional high school textbooks. The evaluation indicated that the balanced color contrast and structured typography enhanced text readability, thereby satisfying the visual and technical layout criteria required for operational classroom use (Lakshmi et al., 2024)

Biology Teacher Response Results

The next stage of the assessment involved educational practitioners, in this case biology teachers at SMA Negeri 2 Kotapinang, to review the applicability of the product in real-life teaching and learning activities. Teacher assessment is crucial because they act as direct users who understand classroom dynamics and the specific characteristics of students at the research site. Aspects evaluated included the book's ease of use as a supplementary medium, the suitability of the language level to students' abilities, and the usefulness of local research content in clarifying mycological concepts that have been difficult to visualize through



conventional textbooks. Complete data regarding practitioners' responses to this macroscopic pathogenic fungi pocketbook are presented in Table 13.

Table 13. Biology Teacher Response Results.

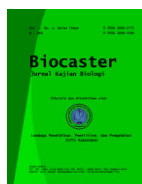
Aspect	Number of Grains	Max Score	Answer Score	Percentage
Material	8	40	40	100%
Display and Programming	6	30	30	100%
Total	14	70	70	100%

The evaluation by the biology practitioner at SMA Negeri 2 Kotapinang aimed to assess the operational applicability of the pocket book in a classroom setting, yielding a maximum score of 100% (Table 13), which falls into the "Very Appropriate" category. While this ceiling-level data points to positive practitioner reception, a perfect score in educational evaluation requires critical methodological scrutiny, as it typically indicates a ceiling effect or response bias rather than flawless product performance. In this context, the absolute score is highly likely influenced by social desirability bias, given the direct professional engagement between the researcher and the evaluating practitioner, or a response bias stemming from the practitioner's acute awareness of the lack of localized, ecosystem-specific biology supplementary materials.

Methodologically, this uniform maximum response suggests that the evaluation instrument may lack the granular sensitivity required to detect minor operational friction or subtle areas for layout improvement. Critically, however, the qualitative feedback embedded within the practitioner's response indicates that the pocket book serves as an efficient surrogate for localized field instruction. The primary pedagogical utility of the media lies in its capacity to simulate real-world environmental phenomena specifically the oil palm phytopathological crises directly within the classroom framework (Gafur et al., 2025). This logistical alternative mitigates the necessity for frequent field excursions while still introducing concrete, place-based biological models to the students. Future macro-scale implementations must utilize more highly differentiated assessment matrices to control for ceiling effects and isolate specific structural variables that can be further optimized.

Student Assessment Results

The final stage of the evaluation within the Develop phase involved a limited practicality testing through student response questionnaires administered to Grade 11 science students at SMA Negeri 2 Kotapinang. This trial aimed to evaluate the responses of students as end-users, specifically assessing readability, ease of media navigation, and the visual appeal of the pocket book. Data collection was conducted with 15 randomly selected students who were given the opportunity to perform structured, hands-on interactions with the physical prototype specifically reviewing its textual layout, navigational features, and microscopic-to-macroscopic photographic contents. Rather than relying on superficial scanning, student evaluations were systematically captured using a multidimensional practicality instrument. These student responses serve as the primary empirical indicator of the product's operational viability in mitigating documented learning barriers, such as the students' resistance to utilizing high-density, conventional biology textbooks.



The quantitative data derived from the student response questionnaires regarding this macroscopic pathogenic fungi pocket book are summarized in Table 14.

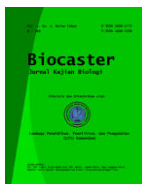
Table 14. Respondent Assessment Results.

No.	Respondents	Amount	Percentage (%)	Category
1	Student 1	45	90	Very Practical
2	Student 2	46	92	Very Practical
3	Student 3	44	88	Very Practical
4	Student 4	33	66	Practical
5	Student 5	36	72	Practical
6	Student 6	48	96	Very Practical
7	Student 7	44	88	Very Practical
8	Student 8	46	92	Very Practical
9	Student 9	45	90	Very Practical
10	Student 10	46	92	Very Practical
11	Student 11	40	80	Practical
12	Student 12	43	86	Very Practical
13	Student 13	44	88	Very Practical
14	Student 14	40	80	Practical
15	Student 15	43	86	Very Practical
	Average	643	85,74	Very Practical

The trial was conducted on 15 11th grade students using a random sampling technique. The results of student responses obtained a percentage of 85.74% with the category "Very Practical" in Table 14. Although students only skimmed (glancing at the display), this percentage indicates a very good level of acceptance. The contributing factor was students' curiosity about objects they often saw in the palm oil plantation behind their homes, but this was the first time they received a scientific explanation. The absence of cognitive tests at this stage allowed students to explore the media affectively, which is the first step in increasing reading interest (Puspitasari & Harsono, 2025).

Instead of relying on a redundant graphical duplication of the tabular datasets, a comparative synthesis across the validation and practicality matrices reveals an integrated pattern of product coherence. The convergence between the expert validation indices (cumulative mean of 88.58%) and the field operational metrics (cumulative mean of 91.18%) confirms that the structural engineering of the pocket book successfully balances scientific accuracy with classroom usability. Crucially, the alignment between the media design score (93.33%) and the student readability rating (89.50%) demonstrates that the visual-heavy architecture and ergonomic B6 format directly supported the end-users' cognitive processing. By embedding localized research data within a highly structured layout, the media bridges the gap between field-level phytopathological phenomena and school-level biology instruction without inducing information overload. This cross-dimensional consistency verifies that the developed pocket book satisfies both theoretical and empirical criteria, rendering it highly viable for secondary education deployment..

The measurement results show a high descriptive consistency (>85%) across all validators and respondents. This alignment indicates structural stability in the product's design, where the evaluated aspects of content, pedagogy, and visual aesthetics consistently satisfy the baseline criteria for a functional learning



medium (Pertiwi et al., 2024). This high consensus across the evaluation matrices demonstrates that the research-based pathogenic fungi pocket book successfully fulfills the technical parameters of content validity and operational practicality required for SMA Negeri 2 Kotapinang. Because this development scope was strictly limited to evaluating feasibility and user feedback, these metrics confirm the product's structural readiness for classroom utilization within its defined educational context, without extrapolating its immediate impact on broader learning outcomes, long-term reading interest, or scientific literacy levels.

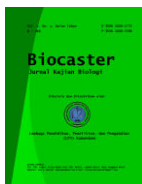
The positive evaluation patterns recorded in the user questionnaires indicate that the inclusion of localized geographic themes aligned with the respondents' familiar environment. Rather than reflecting an unmeasured change in student psychological perception or the spontaneous creation of a natural learning space, the high practicality metrics strictly demonstrate that the respondents favorably rated the descriptive presence of immediate ecosystem contexts within the media. The questionnaire data indicates that anchoring the biological text to regional oil palm phytopathological examples provided an identifiable instructional framework for the participants. Consequently, the high scores reflect the target users' positive reception of place-based content configuration in a questionnaire setting, rather than an empirically verified transformation in daily learning behavior or economic awareness. The quantitative outcomes across the evaluation dimensions require a systematic pedagogical interpretation to examine the operational factors influencing the instrument ratings at SMA Negeri 2 Kotapinang.

Analysis of Contextual Variables

The scores within the "Very Feasible" and "Very Practical" parameters can be analyzed through the framework of Contextual Teaching and Learning (CTL) theory. From a theoretical perspective, instructional materials that integrate biological phenomena from the students' immediate geographic environment establish a more direct cognitive connection than generic or non-localized text exemplars. The structural alignment of the macroscopic pathogenic fungi content with the agricultural characteristics of the Kotapinang region which is predominantly an oil palm ecosystem serves as the primary variable underlying the positive ratings from the evaluating practitioner (100%) and learning experts (96.36%) (Zendrato et al., 2025). This correlation suggests that the inclusion of place-based biological models fulfills the pedagogical criteria for environmental and contextualized science education within the targeted high school demographic.

Interpretation of Media Metrics and Design Interface

From a structural design perspective, the quantitative evaluation from the design experts (93.33%) and the limited student trial responses (85.74%) require an isolated operational interpretation. Because the student evaluation process was methodologically restricted to immediate visual observations and structural layout exploration without long-term instructional integration, the recorded student score of 85.74% primarily gauges initial visual attractiveness and surface-level engagement rather than actual cognitive usability, text comprehension, or reading retention. Consequently, these performance indicators demonstrate that the utilization of high-resolution, original field photography establishes a stronger immediate sensory and attentional stimulus than generic textbook illustrations. This



visual interface design addresses the documented physiological resistance high school students show toward dense text materials by lowering the initial barrier to media interaction through immediate object recognition of local phenomena (Puspitasari & Harsono, 2025). However, because this trial phase did not include student performance testing, task execution, or comprehension assessments, these metrics strictly validate the prototype's superficial visual alignment and layout aesthetic, without serving as empirical evidence for changes in student learning motivation or structural literacy gains.

Comparison with Previous Research

These results both strengthen and extend the findings of several relevant studies: 1) in line with (Syahrini, 2025) findings, the use of local research significantly increases the practical validity of teaching materials due to the respondents' "emotional closeness" to the material; 2) in contrast to (Uyun et al., 2022) study, which used conventional modules with a practicality score of 78%, this study achieved a practicality score of 85.74%. This demonstrates that the innovative format (pocket book) is more effective in overcoming physical learning barriers for students in remote areas; and 3) this research also supports the research results of (Nia, 2024) which stated that the identification of local pathogenic fungi is crucial for building agricultural awareness in students from an early age, but this research goes one step further by packaging it in a 4D development model that is validated multidisciplinary. In conclusion, the score stability above 85% confirms that this pocket book is not just an additional medium, but an essential instrument capable of bridging the gap between the national curriculum and the contextual educational needs in the plantation industry area.

CONCLUSION

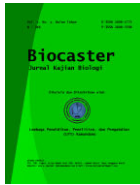
Based on the research and development objectives, it is concluded that the developed research-based pocket book on macroscopic pathogenic fungi fulfills the criteria for high school biology instruction at SMA Negeri 2 Kotapinang across two primary dimensions:

Theoretical Validity

Multidisciplinary expert evaluations confirmed that the instructional medium satisfies the necessary theoretical and technical requirements. Subject matter validation reached 85.88% ("Very Feasible"), pedagogy validation scored 86.40% ("Very Worthy"), and media design validation achieved 93.33% ("Very Suitable"). These metrics indicate that integrating localized field data regarding *Ganoderma boninense* aligns with secondary-level curriculum structures and morphological identification standards.

Operational Practicality

Field testing demonstrated that the prototype is logistically and pedagogically viable for classroom deployment. The evaluating biology practitioner rated the medium at 100% ("Very Appropriate"), acknowledging its utility as a localized instructional surrogate that simulates field-level ecological phenomena within the classroom. Furthermore, the limited user trial yielded an 89.50% satisfaction rate, confirming positive student reception toward the physical layout and initial visual attractiveness of the ergonomic B6 pocket book format.



In summary, the empirical evidence validates the pocket book as a feasible and practical supplementary learning resource for its specific high school context. This study establishes baseline technical readiness, without concluding upon unmeasured macro-pedagogical outcomes such as long-term comprehension gains, student learning motivation, or broader environmental literacy

SUGGESTION

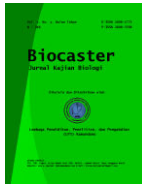
For other researchers who wish to conduct similar research, it is recommended to conduct a product trial on a larger scale (main field trial) to determine the level of effectiveness of this media on cognitive, psychomotor, and critical thinking skills of students in a measurable manner. In addition, the development of this product can also be improved towards digitalization, such as converting the printed format of the pocket book into an interactive e-book or an Android-based application equipped with a QR code feature for observation videos, so that it can be accessed more flexibly by the current generation of students.

ACKNOWLEDGEMENT

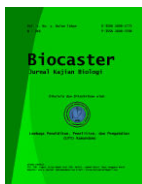
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