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Research Article

Development and Validation of an Interactive Pocket Book Based on Sustainable Development Goals to Improve Understanding of Concepts and Sustainability Literacy in Plant Growth and Development Material

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ABSTRACT

Purpose of the study: Integrating the Sustainable Development Goals (SDGs) into biology learning is one way to improve students' understanding of concepts and sustainability literacy. This study aims to develop and validate an SDG-based interactive pocketbook on plant growth and development.

Methodology: The research uses a Research and Development (R&D) method with the 4D model, which includes the stages of define, design, develop, and disseminate. The research subjects consist of one media expert, one material expert, one instrument expert, one biology teacher, and 33 eleventh-grade science students. Data was collected through expert validation sheets, teacher and student response questionnaires, as well as a Two-Tier Multiple Choice (TTMC) test.

Main Findings: The study results showed that the SDGs-based interactive pocket book has a very high level of validity, with media validation at 96.55%, material validation at 94.16%, and instrument validation at 83.65%. The practicality of the media is also considered very high, based on teacher responses at 97.50% and student responses at 94.02%. In addition, the media has proven effective in improving learning outcomes, as shown by the increase in average scores from 38.28 in the pretest to 88.79 in the posttest, with an N-Gain score of 0.83 (83.02%) categorized as high.

Novelty/Originality of this study: The interactive pocket book based on the SDGs is considered valid, practical, and effective as a biology learning tool to enhance concept understanding while also supporting the strengthening of students' sustainability literacy in line with the implementation of the Merdeka Curriculum.

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1. INTRODUCTION

21st-century education isn't just about mastering knowledge, but also about developing critical thinking, creativity, communication, collaboration, science literacy, digital literacy, and sustainability literacy. The rapid development of science and technology requires students to be able to solve problems scientifically and make decisions based on evidence gathered through the learning process [1], [2]. On the other hand, the world today is

facing various global challenges, such as climate change, environmental degradation, pollution, loss of biodiversity, energy crises, and threats to food security. These issues cannot be solved solely through economic or technological approaches, but also require the contribution of education in shaping a generation that has awareness, knowledge, skills, and responsibility towards the environment [3], [4]. Therefore, learning at school needs to be designed so that it not only emphasizes cognitive aspects, but also can instill values of sustainability, so students can connect the concepts they learn with various real-world issues around them.

In response to these various challenges, the United Nations (UN) established the Sustainable Development Goals (SDGs) as a global development agenda consisting of 17 goals aimed at achieving societal well-being and environmental sustainability. The implementation of the SDGs in education is carried out through the concept of Education for Sustainable Development (ESD), which is a learning approach that integrates environmental, social, and economic aspects into the educational process, enabling students to understand the connection between knowledge and everyday life. [5] In biology learning, integrating the SDGs is highly relevant because most biology material is directly related to living things, ecosystems, and human interactions with the environment. Specifically, in the topic of plant growth and development, integrating SDG 2 (Zero Hunger), SDG 12 (Responsible Consumption and Production), SDG 13 (Climate Action), and SDG 15 (Life on Land) gives students the chance to understand that the process of plant growth is not just a scientific concept, but also relates to efforts to increase food productivity, maintain ecosystem balance, reduce climate change impacts, and conserve biological resources [6]. Through this integration, biology learning is expected to improve science literacy and sustainability literacy so that students become aware of applying responsible behavior towards the environment in their daily lives.

However, the material on plant growth and development is still considered one of the topics that students find difficult to understand because it contains concepts that are abstract, complex, and cannot be observed directly. Concepts about how phytohormones work, cell division and enlargement, tissue differentiation, primary and secondary growth, as well as various internal and external factors that affect plant growth require good visualization skills to be easily understood. Based on observations in class XI MIPA at Senior High School Budi Satrya Medan, the learning process is still dominated by lecture methods using textbooks, student worksheets, and PowerPoint presentations as the main learning resources. The use of interactive and technology-based learning media is still relatively limited, so the learning process tends to be one-way. This situation causes some students to memorize concepts more than actually understanding the biological processes that occur. In addition, students also have difficulty connecting the material they learn with various environmental phenomena or emerging sustainable development issues. As a result, students' critical thinking, problem-solving skills, and sustainability literacy have not developed optimally in line with the demands of 21st-century learning and the implementation of the Independence Curriculum.

Based on these conditions, there is a need for an innovative learning media that can help students understand abstract concepts more concretely while also integrating the values of the Sustainable Development Goals (SDGs) into the learning process. One alternative media that can be developed is an interactive pocket book based on QR Codes, which presents material in a concise, systematic, and easy-to-understand way, complete with learning videos, animations, interactive images, practice questions, links to digital learning resources, and technology-based evaluations. Using QR Codes allows students to access a wider range of learning resources without being limited by time and space, supporting a flexible, independent, and student-centered learning process. Besides enhancing the appeal of learning, this media can also connect the concepts of plant growth and development with various real-world issues related to food security, environmental conservation, climate change, and the sustainable use of natural resources. Therefore, developing an interactive pocket book based on the SDGs is expected not only to improve students' understanding of biology concepts but also to strengthen science literacy, digital literacy, and sustainability literacy as preparation for facing global challenges and supporting the implementation of the Merdeka Curriculum, which emphasizes contextual, innovative learning aimed at shaping the Pancasila Student Profile.

The review of various previous studies shows that the development of biology learning media has progressed through the use of pocket books, digital media, and learning tools based on Education for Sustainable Development (ESD). Fitriani & ‘Aini reported that biology pocket books can boost students' interest in learning because they are practical and easy to use [7], Meanwhile, Annam, et al., developed a pocket book on biodiversity material with a very high level of validity [8]. However, both studies were still focused on conventional print media, so they haven't taken advantage of digital technology to enhance learning interactivity, nor have they explicitly integrated the values of the Sustainable Development Goals (SDGs). Meanwhile, Putri and colleagues developed ESD-based learning tools through a website that can improve science literacy, but they haven't created media that is portable, practical, and supports independent learning [9].

Based on the literature review and field findings, there are several research gaps that form the basis of this study. First, the development of biology pocket books is still dominated by print media, so it hasn’t integrated digital technology through interactive features like QR Codes linked to learning videos, animations, digital assessments, and online learning resources. Second, learning media based on the SDGs are still mostly

developed in the form of modules, worksheets, or web-based media, while the development of interactive SDG-based pocket books is still very limited. Third, previous research generally only focused on improving learning outcomes or concept understanding, while sustainability literacy as one of the important 21st-century competencies is still rarely considered as a research output. In addition, no studies have been found that comprehensively integrate plant growth and development materials with SDG 2 (Zero Hunger), SDG 12 (Responsible Consumption and Production), SDG 13 (Climate Action), and SDG 15 (Life on Land) into a single integrated learning media.

Based on this gap, this study offers novelty through the development and validation of an interactive pocketbook based on the Sustainable Development Goals (SDGs), which combines print media with digital technology by using QR Codes, explicitly integrating SDG 2, SDG 12, SDG 13, and SDG 15 into the materials, activities, and learning assessments. It not only measures the validity, practicality, and effectiveness of the media but also the improvement in students' conceptual understanding and sustainability literacy. Thus, this study provides a conceptual contribution to the development of biology learning media based on Education for Sustainable Development (ESD) while offering an innovative, contextual, and relevant media alternative in line with the implementation of the Merdeka Curriculum and the demands of 21st-century education.

2. RESEARCH METHOD

This study uses the Research and Development (R&D) method, adopting the 4D development model proposed by Thiagarajan et al. [10]. This model consists of four stages, namely Define, Design, Develop, and Disseminate. The 4D model is chosen because it has systematic stages in producing learning products that are valid, practical, and effective. In the Define stage, needs analysis was carried out through interviews with biology teachers and the distribution of questionnaires to students. The analysis included initial (front-end) analysis, analysis of student characteristics, content analysis, media needs analysis, analysis of the integration of Sustainable Development Goals (SDGs), and the formulation of learning objectives. The Design stage involved creating a storyboard, designing the look of the interactive pocket book, preparing materials on plant growth and development integrated with SDG 2 (Zero Hunger), SDG 12 (Responsible Consumption and Production), SDG 13 (Climate Action), and SDG 15 (Life on Land), developing interactive features based on Quick Response (QR) Code, and preparing research instruments. Next, in the Develop stage, the product is validated by material, media, and evaluation instrument experts, and then revised based on the validators' suggestions and feedback. After the revision, the product was tested for practicality through a limited trial involving teachers and students. The Dissemination stage is carried out through field testing using a one-group pretest-posttest design to find out the effectiveness of the interactive pocketbook in improving students' understanding of concepts.

The research subjects consisted of one content expert, one media expert, one evaluation instrument expert, one biology teacher, and 33 eleventh-grade science students at SMAS Budi Satrya Medan. The student sample was determined using a total sampling technique because all students in one class were included in the sample. The research instruments included teacher interview guides, student needs analysis questionnaires, content expert validation sheets, media expert validation sheets, instrument expert validation sheets, teacher response questionnaires, student response questionnaires, and concept understanding tests consisting of 10 Two-Tier Multiple Choice (TTMC) questions. The TTMC instruments were used to measure conceptual understanding and to identify student misconceptions. All validation sheets and questionnaires used a four-point Likert scale adapted from [11].

The research data were analyzed both qualitatively and quantitatively. Qualitative data, in the form of suggestions and comments from validators, were analyzed descriptively to inform product improvement. Quantitative data were used to determine the validity, practicality, and effectiveness of the developed media. The levels of validity and practicality were calculated using the following percentage formula:

$$persentase\ validitas = \frac{skor\ yang\ diperoleh}{skor\ makximum} \times 100\% \ldots (1)$$

The results of the data analysis on validity and practicality are then interpreted based on the Riduwan and Akdon criteria, which are listed in Table 1.

Table 1. Validity Test Assessment Criteria

Percentage (%)	Assessment Criteria
80.00–100.00	Very Valid
60.00–79.99	Valid
50.00–59.99	Fairly Valid
00.00–49.99	Invalid

The effectiveness of the interactive pocketbook based on the SDGs is measured using the N-Gain score, which is calculated based on pretest and posttest scores with the formula:

$$N - Gain = \frac{score\ posttest - score\ pretest}{score\ maksimum - score\ pretest} \times 100\% \ldots (2)$$

The N-Gain calculation results are then interpreted based on the criteria of Nasution and Rasyidah (2022), in Table 2.

Table 2. N-Gain Assessment Criteria

N-Gain	Assessment Criteria
g > 0.7	Tall
0.3 < g < 0.7	Busy
g < 0.3	Low

3. RESULTS AND DISCUSSION

This research resulted in a product in the form of an interactive pocket book based on the Sustainable Development Goals (SDGs) on the material of plant growth and development, developed by referring to the 4D model (Define, Design, Develop, and Disseminate) from [10]. Each stage of analysis becomes the foundation for designing an interactive pocketbook that is contextual, relevant, and fits the learning needs.

Define

The define stage is the initial phase in developing an interactive pocket book based on the Sustainable Development Goals (SDGs). Its goal is to identify learning needs, student characteristics, material characteristics, media requirements, and learning objectives. The analysis results from this stage serve as the basis for designing a product that meets user needs. A summary of the needs analysis results is presented in Table 3.

Table 3. Components and Results of the Define Stage Analysis in the Development of an SDGs-Based Interactive Pocket Book

Define Stage Analysis Component	Results of the Define Stage Analysis
Front-End Analysis	Biology learning was still predominantly conducted using lectures, discussions, and presentations, with textbooks, student worksheets (LKS), and PowerPoint presentations as the primary learning resources. The use of interactive learning media and the integration of the Sustainable Development Goals (SDGs) into the learning process had not yet been optimized. Most students perceived the existing learning media as insufficiently engaging and lacking variety.
Learner Analysis	Most students showed interest in the topic of plant growth and development; however, they still experienced difficulties in understanding concepts related to phytohormones, factors affecting plant growth, and primary and secondary growth. Nearly all students owned smartphones and expressed support for the use of interactive learning media.
Content Analysis	The topic of plant growth and development includes several abstract concepts that require learning media capable of presenting visual representations to facilitate students' conceptual understanding.
Media and SDGs Needs Analysis	Teachers and students required learning media that are concise, engaging, and interactive, complemented by illustrations, QR codes, instructional videos, and practice exercises. The analysis also indicated that the topic of plant growth and development is highly relevant for integration with the concepts of Sustainable Development Goals (SDGs).
Learning Objectives Analysis	The learning objectives were formulated based on the Learning Outcomes of the Merdeka Curriculum, aiming to enhance students' conceptual understanding, analytical skills regarding plant growth and development, and their ability to relate these concepts to sustainable development.

Based on Table 3, the results of the front-end analysis indicate that biology learning in schools is still predominantly conducted through lectures, discussions, and presentations, with textbooks, student worksheets,

and PowerPoint presentations serving as the primary learning resources. The use of interactive learning media remains limited, and the integration of Sustainable Development Goals (SDGs) concepts into the learning process has not yet been implemented optimally. Furthermore, most students reported that the learning media currently used are insufficiently engaging and lack variety, thereby limiting their ability to effectively enhance learning motivation. These findings highlight the need to develop more innovative, interactive, and contextual learning media.

The learner analysis revealed that most students showed an interest in the topic of plant growth and development. However, they still experienced difficulties in understanding several abstract concepts, including phytohormones, factors influencing plant growth, and the differences between primary and secondary growth. On the other hand, almost all students own smartphones and expressed support for the use of digital learning media. This condition suggests that the development of a digital interactive pocketbook has considerable potential to increase student engagement while facilitating a better understanding of complex biological concepts. The content analysis further demonstrated that the topic of plant growth and development contains numerous abstract concepts that require learning media capable of presenting illustrations, images, animations, and videos to provide meaningful visual representations. Therefore, the developed learning media are expected to help students understand the subject matter more concretely, systematically, and meaningfully.

Furthermore, the analysis of media needs and the integration of the SDGs showed that both teachers and students require learning media that are concise, engaging, user-friendly, and equipped with illustrations, QR codes, instructional videos, and interactive practice exercises. The findings also indicate that plant growth and development are closely related to the principles of sustainable development, making it highly relevant to integrating with SDG values. Such integration is expected to foster students' awareness of environmental conservation and sustainable development through biology learning. Based on the analysis of learning objectives, the objectives for developing the learning media were formulated in accordance with the Learning Outcomes of the Merdeka Curriculum. These objectives are intended to enhance students' conceptual understanding of plant growth and development, develop their ability to analyze the factors affecting plant growth, and enable them to relate biological concepts to sustainable development issues in line with the principles of the Sustainable Development Goals (SDGs).

The results of the needs analysis at the define stage show that the biology learning process is still dominated by conventional approaches, including lectures, discussions, and presentations, with textbooks, worksheets, and PowerPoint as the main learning sources. This indicates that the use of interactive learning media has not been optimized, so the learning process remains teacher-centered. This finding aligns with various studies showing that biology instruction in high schools is still dominated by printed materials and simple presentations, making it less effective at facilitating active student engagement or helping students visualize complex biology concepts. According to Fauzi et al., learning that combines text, images, videos, and interactive activities can increase attention, motivation, and information retention compared to learning that relies only on verbal delivery. [12]. Thus, the need for more innovative learning media, as identified in this research, is a logical consequence of the 21st-century learning paradigm shift that emphasizes active, collaborative, and technology-based learning.

Analysis of student characteristics shows that most students are interested in the material on plant growth and development, but they still have difficulty understanding abstract concepts such as phytohormones, primary and secondary growth, and factors that affect plant growth. These results support the view that learning difficulties in biology generally occur with material that cannot be observed directly, so visual representations are needed to help the concept-building process [13]. Interestingly, almost all students already have smartphones and support the use of digital learning media. This condition reflects students' technological readiness and can be used to develop mobile-device-based learning media. The results of this study are in line with research by [14], which concluded that using mobile devices in science learning can increase student engagement, motivation to learn, and students' flexibility in accessing materials anytime, anywhere. Therefore, developing digitally based interactive pocket books is a relevant alternative given the characteristics of today's students.

In terms of material analysis, this study found that the material on plant growth and development contains many abstract concepts, so it requires media that can visualize biological processes through illustrations, pictures, animations, or learning videos. This finding aligns with the Cognitive Theory of Multimedia Learning. [15], which explains that students will find it easier to understand concepts when information is presented through a combination of verbal and visual representations. Research by [16] It also shows that interactive learning media that use multimedia significantly improve understanding of science concepts compared to conventional media. Therefore, presenting material through an interactive pocketbook equipped with illustrations, QR Codes linking to learning videos, and interactive practice questions is a suitable strategy to reduce the abstraction level of the material while also improving the quality of learning.

The results of the media needs analysis show that teachers and students want media that is concise, engaging, easy to use, and equipped with illustrations, QR Codes, learning videos, and practice questions. These findings indicate that users not only need media as a way to convey information but also as a learning tool that

can provide an interactive learning experience. This result is consistent with research. [17] which states that digital media that integrates various forms of multimedia can boost intrinsic motivation, learning independence, and students' learning outcomes. In addition, using QR Codes makes it easy to connect printed materials with digital learning resources, supporting more flexible learning that matches the characteristics of today's digital generation.

Another important finding in this study is the need to integrate the values of the Sustainable Development Goals (SDGs) into biology learning. The analysis shows that the material on plant growth and development is closely related to sustainable development issues, particularly biodiversity conservation, food security, and environmental preservation. These results are in line with the recommendations [18] through Education for Sustainable Development (ESD) for 2030 which emphasizes that science learning needs to integrate sustainability issues so that students not only master scientific concepts, but also have awareness, attitudes, and responsibility towards the environment. Research by [19] It also shows that integrating the SDGs into learning can improve students' systems thinking, problem-solving skills, and sustainability literacy. This way, including the SDGs in interactive pocket books not only enriches the learning content but also strengthens the relevance of biology material to global issues faced by society.

Next, the analysis of the learning objectives shows that the development of the interactive pocket book is based on the Learning Outcomes of the Merdeka Curriculum, which emphasizes mastery of concepts, critical thinking skills, and applying knowledge in real-life contexts. This aligns with the characteristics of the Merdeka Curriculum, which prioritize differentiated learning, context-based learning, and strengthening the Pancasila Student Profile. The integration of SDGs into learning media also supports the implementation of this curriculum because it gives students the chance to connect biology concepts with environmental and sustainable development issues through contextual learning activities.

Overall, the needs analysis results in the define stage provide a strong empirical foundation for developing an interactive pocketbook based on the SDGs. Unlike some previous studies that focused more on developing interactive media to improve learning outcomes or motivation, this study integrates three aspects at once: visualizing abstract biology concepts, utilizing digital technology through QR Codes and interactive multimedia, and embedding Sustainable Development Goals values into a single learning medium. The integration of these three aspects makes the developed interactive pocketbook not just a tool for delivering material, but also a way to build students' science literacy, digital literacy, and sustainability literacy in a holistic way. Thus, the results of the analysis at the define stage prove that the development of this media has met the needs of teachers, the characteristics of students, the demands of the Merdeka Curriculum, as well as the direction of 21st-century education development oriented toward sustainable development.

Design

At the design stage, the study produced an initial prototype of an interactive pocketbook based on the Sustainable Development Goals (SDGs), which was developed according to the needs analysis conducted during the define stage. The product was designed in an A6 format (12 cm × 18 cm), making it portable and convenient for students to use both inside and outside the classroom. The visual design predominantly features green and blue color schemes to represent sustainability, while the cover was created in Canva by combining plant illustrations, SDG icons, and the book title to produce an attractive and engaging appearance.

The interactive pocketbook consists of four main sections: the preliminary section, the introduction, the main content, and the closing section. The preliminary section includes the cover, book identity, preface, and table of contents. The introduction provides a description of the book, user guidelines, explanations of the icons and QR codes, and the learning outcomes integrated with the SDGs. The main content consists of six subtopics on plant growth and development, enriched with SDGs Insight features, QR code-based instructional videos, field activities, mini quizzes, reflection activities, and self-assessment. The closing section includes a summary of the material, a glossary, references, the author's profile, and an SDGs-based mini-project titled "Keeping Flowers Blooming Amid Environmental Change," which encourages students to observe, document, and reflect on the environmental conditions in their surroundings.

The findings also demonstrate that the pocketbook integrates four Sustainable Development Goals, namely SDG 2 (Zero Hunger), SDG 12 (Responsible Consumption and Production), SDG 13 (Climate Action), and SDG 15 (Life on Land), into the topic of plant growth and development. This integration is implemented through contextual information presented in the SDGs Insight feature, environment-based learning activities, and instructional videos accessible via QR codes, enabling students to connect biological concepts with issues related to sustainable development. In addition to producing the media prototype, the design stage also generated a comprehensive set of research instruments, including interview guidelines, needs analysis questionnaires, material expert validation sheets, media expert validation sheets, test instrument validation sheets, teacher response questionnaires, student response questionnaires, and a learning achievement test consisting of ten Two-Tier Multiple Choice (TTMC) items. All research instruments were developed using a four-point Likert scale as the basis for implementing the subsequent development (develop) stage.

The development results in the design stage show that creating the pocket book not only focuses on presenting the material but also considers portability, readability, and ease of use. Choosing an A6 size allows students to use the media flexibly in various learning situations. These findings are in line with research [20] which states that a pocket-sized book is easier to carry, increases accessibility, and supports students' independent learning activities. From a visual design aspect, the use of a combination of green and blue colors along with illustrations of plants and SDGs icons gives an identity that is consistent with the sustainability theme. An attractive visual appearance plays a role in increasing the attention and learning motivation of students. This aligns with the opinion [21] that a communicative and aesthetically designed learning media can increase students' interest so that the process of delivering information becomes more effective.

The integration of interactive features like QR Codes, instructional videos, field activities, mini quizzes, reflections, and self-assessments shows that the pocketbook was developed following a 21st-century learning approach that emphasizes active student engagement. These features allow students to gain a more contextual learning experience, not just understanding the concepts of plant growth and development theoretically, but also connecting them to real-world conditions. This approach aligns with the concept of constructivist-based learning, which positions students as active participants in building knowledge through meaningful learning experiences. Another important finding is the success in integrating SDG 2, SDG 12, SDG 13, and SDG 15 into the learning materials. This integration shows that biology materials can be a way to raise awareness about food security, sustainable consumption, climate change, and biodiversity conservation. These results support the findings [22, 23] which explains that integrating SDGs into learning can increase the relevance of the material to real life and shape students' character to care about sustainable development. In addition, the selection of these four SDG goals also aligns with the recommendations [24] which emphasizes the importance of linking biology material with global environmental issues so that learning becomes more contextual and meaningful.

Besides media development, creating complete research instruments shows that the design stage doesn't just produce the initial product, but also prepares systematic evaluation tools to measure the quality of the media and students' learning outcomes. Using validation instruments, response questionnaires, and Two-Tier Multiple Choice (TTMC) tests allows researchers to get comprehensive data on media validity, user responses, and students' conceptual understanding. So, the design stage has laid a solid foundation for carrying out the development stage, both in terms of product development and evaluating the quality of learning media.

Develop

The development stage aims to evaluate the quality of the product through validation by experts and limited trials with users, with the results serving as the basis for assessing the feasibility of the pocketbook before it is implemented on a larger scale. This stage starts with validation by media experts and content experts, followed by product revisions based on feedback from the validators, and ends with a practicality test through response questionnaires for teachers and students. The validation results from the media experts and content experts are presented in Table 4 and Table 5, respectively.

Table 4. Media Validation Results

No.	Assessment Aspect	Total Score	Maximum Score	(%)	Category
1	Graphics	44	48	91.67%	Very Valid
2	Presentation	40	40	100%	Very Valid
3	Interactivity	28	28	100%	Very Valid
Average		37.33	38.66	96.55%	Very Valid

The validation results by media experts are presented in Table 4. According to the table, the graphic aspect scored 44 out of a maximum of 48, with a percentage of 91.67%, falling into the very valid category. The presentation aspect scored 40 out of 40, or 100%, while the interactive aspect scored 28 out of 28, or 100%, both of which are also in the very valid category. Overall, the media validation results obtained an average percentage of 96.55%, classified as very valid. These results indicate that the developed pocket book meets the feasibility standards in terms of graphic design, information presentation, and media interactivity, making it suitable for use in learning.

Table 5. Material Validation Results

No.	Assessment Aspect	Total Score	Maximum Score	(%)	Category
1	Alignment of the Material with the Curriculum	20	20	100%	Very Valid
2	Accuracy and Depth of the Material	19	20	95.00%	Very Valid
3	Material Presentation and Learning Interactivity	25	28	89.28%	Very Valid

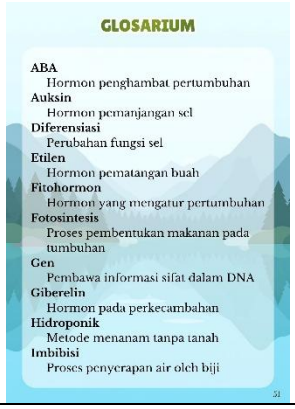
No.	Assessment Aspect	Total Score	Maximum Score	(%)	Category
4	Language Appropriateness	17	20	85.00%	Very Valid
5	Integration of Sustainable Development Goals (SDGs) Values	32	32	100%	Very Valid
Average		22.60	24.00	94.16%	Very Valid

Furthermore, the material expert validation results presented in Table 5 show that the curriculum alignment aspect achieved a score of 100%, while the accuracy and depth of the content obtained 95%, the content presentation and learning interactivity aspect achieved 89.28%, the language aspect scored 85%, and the integration of Sustainable Development Goals (SDGs) values obtained 100%. The overall average score for the material validation reached 94.16%, which falls into the highly valid category. These results indicate that the learning content is well aligned with the Learning Outcomes of the Merdeka Curriculum, demonstrates a high level of accuracy, employs appropriate and effective language, and successfully integrates sustainable development concepts into the topic of plant growth and development.

Although both validation results were categorized as highly valid, the validators provided several recommendations for improvement. These included simplifying the introduction to the SDGs to make it more concise and essential, replacing foreign-language images with Indonesian-language images, revising the SDGs Insight section to focus more specifically on the relevant SDG targets, simplifying student learning activities, and organizing the glossary alphabetically with consistent indentation. All of these recommendations were incorporated during the product revision process, while the complete details of the validators' comments and suggestions are presented in Table 6.

Table 6. Comments from Media Validators and Material Validators

Suggestion	Before Repair	After the Repair
Aligning the choice of font colors in the SDGs introduction section to better match the theme of the book.		
Replacing the illustration images that still use a foreign language and fixing the inconsistent writing format.		

Suggestion	Before Repair	After the Repair
Clarifying and specifying the connection of the material with the SDGs in the SDGs Insight section.		
Simplifying the steps of activities for students and making the font bigger so it's easier to follow.		
Organizing a glossary in alphabetical order and distinguishing the format of terms from their definitions.		

In addition to the product, the evaluation instrument in the form of Two-Tier Multiple Choice (TTMC) questions was also validated before being used in field trials. It consisted of 10 questions that were validated by question experts. Each question has two levels: the first level is the conceptual answer choices, and the second level is the reason choices underlying the answers. The validation results are presented in Table 7.

Table 7. Test-Item Expert Validation Result

No.	Assessment Aspect	Total Score	Maximum Score	(%)	Category
1	Material	23	32	71.88%	Highly Valid
2	Construction	33	40	82.5%	Highly Valid
3	Language	31	32	96.88%	Highly Valid
Average		29	34.67	83.65%	Highly Valid

Based on Table 7, the experts' validation results on the test show that the content aspect scored 71.88%, the construction aspect 82.50%, and the language aspect 96.88%, with an overall average of 83.65%, which falls into the very valid category. These results indicate that the test instruments have met the validity criteria, making them suitable for measuring students' conceptual understanding in the effectiveness test stage. Overall, the validation results shown in Tables 4, 5, and 7 prove that the interactive SDGs-based pocket book and the

developed evaluation instruments have a very high level of validity. With the media validation averaging 96.55%, content validation at 94.16%, and instrument validation at 83.65%, the product is considered very valid and suitable for use in both practicality and effectiveness testing.

The product validation stage is an important step in research and development (R&D) because it aims to ensure that the developed media meets the aspects of content feasibility, design, language, presentation, and usability before being implemented in learning. According to [25], expert validation helps identify product weaknesses in the early stages, enabling revisions that improve media quality before entering the trial phase. In this study, the validation process not only provided feasibility scores but also generated various constructive inputs that served as the basis for product improvement. The revision results showed improvements in visual presentation, writing consistency, the connection of materials to the SDGs, the simplification of learning activities, and a more systematic arrangement of the glossary. These findings indicate that media development is carried out iteratively, resulting in a product that better meets user needs.

Improvements to the visual appearance, such as color alignment, replacing foreign-language illustrations, and increasing font size, show that aesthetics play an important role in enhancing the quality of learning media. The results of this study are in line with research conducted by [26], which states that harmonious visual design, typographic consistency, and the appropriate use of illustrations can enhance the appeal of media and make it easier for learners to understand information. Besides that, [27] Through the Cognitive Theory of Multimedia Learning, it is explained that a good visual design can reduce extraneous cognitive load, allowing students to focus on relevant information. Thus, revisions made in response to validator suggestions not only improve the media's appearance but also enhance the effectiveness of the learning process.

The expert validation results for the media showed that the interactive pocketbook received an average score of 96.55%, categorized as very valid. This score indicates that the graphics, presentation, and interactivity meet the standards for suitable learning media. In fact, the presentation and interactivity aspects even scored a perfect 100%, showing that the media can present information consistently while providing an interactive learning experience through the integration of QR Codes, learning videos, illustrations, and practice questions. These results support the research. [28], which states that multimedia-based interactive learning media can improve the quality of material delivery by giving students the opportunity to explore the material independently. Research by [29] also reported that digital media that integrates various forms of multimedia significantly boosts learning motivation, student engagement, and the quality of the learning experience. Therefore, the high media validation scores in this study indicate that the interactive pocket book meets the characteristics of 21st-century learning media, which emphasize active, technology-based learning.

Expert validation yielded an average score of 94.16% in the very valid category, indicating that the developed material has met the criteria for alignment with the Merdeka Curriculum, conceptual accuracy, material presentation, language use, and the integration of SDG values. The aspects of curriculum alignment and SDG integration received perfect scores (100%), indicating that the book's content aligns with the Learning Outcomes of the Merdeka Curriculum and supports the implementation of Education for Sustainable Development (ESD). These findings are consistent with [30], which emphasizes that sustainable education needs to be integrated into every subject so that students can connect academic concepts to global challenges. [31] It also explains that integrating the SDGs into science learning can improve sustainability literacy, systems thinking skills, and concern for environmental issues. Therefore, the material validation results show that the pocketbook developed not only meets academic standards but also adds value by strengthening education for sustainable development.

Although all aspects received a valid category, the language aspect received the lowest percentage, at 85%. This percentage still falls within the very valid category, but it shows that some areas still need improvement in terms of term consistency, sentence structure, and readability. This result is in line with research [32], which states that the use of simple, communicative language that suits students' characteristics is one of the important factors affecting the effectiveness of learning media. Therefore, revisions to the glossary, simplification of activities, and consistency in writing, as done in this study, are the right steps to improve the quality of the media's language.

In addition to the learning media, the evaluation instrument, in the form of Two-Tier Multiple Choice (TTMC) questions, also demonstrates a high level of validity, with an average score of 83.65%. This result indicates that the instrument meets the aspects of content, construction, and language, making it suitable for measuring students' conceptual understanding. The use of TTMC instruments has advantages over conventional multiple-choice questions because they not only determine whether an answer is correct or incorrect but also identify the conceptual reasons behind students' answers. This aligns with research [33], which states that the two-tier diagnostic test instrument is effective at detecting students' misconceptions in materials science, thereby providing a more comprehensive picture of the level of conceptual understanding.

Overall, the results of the media validation (96.55%), material validation (94.16%), and instrument validation (83.65%) indicate that the developed SDGs-based interactive pocketbook possesses a very high level of validity. These findings are consistent with numerous studies on instructional media development, which

report that products achieving validity scores above 80% are highly feasible for implementation in the learning process. However, this study offers a distinct advantage over most previous research by not only developing a digital interactive learning medium but also integrating Sustainable Development Goals (SDGs) values, QR codes, instructional videos, interactive learning activities, and the TTMC diagnostic assessment instrument into a single, integrated learning package. This integration enables the interactive pocketbook to serve not only as a learning resource but also as a medium that promotes students' scientific, digital, and sustainability literacy. Therefore, the high validation results demonstrate that the developed product has met both theoretical and practical feasibility standards, making it suitable for proceeding to the practicality and effectiveness testing stages.

Following the validation process and revisions based on expert recommendations, the development phase continued with a small-scale field trial. The practicality test was conducted to assess the ease of use and acceptance of the SDGs-based interactive pocketbook on plant growth and development by both teachers and students. Practicality was evaluated using teacher and student response questionnaires after the learning media was implemented in classroom instruction. The results of the practicality test are presented in Tables 8 and 9.

Table 8. Results of the Teacher Response Questionnaire

No.	Assessment Aspect	Total Score	Maximum Score	(%)	Category
1	Attractiveness	20	20	100%	Very Practical
2	Material	24	24	100%	Very Practical
3	Language	22	24	91.67%	Very Practical
4	Integration of Sustainable Development Goals (SDGs)	12	12	100%	Very Practical
Average		19.50	20.00	97.50%	Very Practical

Based on Table 8, the teacher response results indicate that the interactive pocketbook achieved an average practicality score of 97.50%, which falls into the very practical category. The attractiveness aspect obtained a score of 100%, demonstrating that the visual design and presentation of the media were highly appealing and capable of attracting teachers' interest in using it during instruction. The content aspect also received 100%, indicating that the learning materials were well aligned with the learning objectives, easy to understand, and supportive of students' competency development. Meanwhile, the language aspect achieved 91.67%, suggesting that the language used in the pocketbook was communicative, clear, and easy to comprehend. The SDGs integration aspect obtained 100%, indicating that the principles of the Sustainable Development Goals were appropriately incorporated into the learning materials. Overall, these findings demonstrate that, from the teachers' perspective, the SDGs-based interactive pocketbook is highly practical, easy to use, and suitable for implementation in classroom learning.

Table 9. Results of the Student Response Questionnaire

No.	Assessment Aspect	Total Score	Maximum Score	(%)	Category
1	Relevance	19.15	20	97.50%	Very Practical
2	Ease of Use	19.72	20	98.60%	Very Practical
3	Material	19.00	20	95.00%	Very Practical
4	Language	17.18	20	85.90%	Very Practical
5	Integration of Sustainable Development Goals (SDGs)	15.21	16	95.06%	Very Practical
Average		18.05	19.20	94.02%	Very Practical

The student response results presented in Table 9 indicate an average practicality score of 94.02%, which falls into the very practical category. The relevance aspect achieved a score of 97.50%, indicating that the learning materials were highly relevant to students' learning needs. The ease-of-use aspect received 98.60%, demonstrating that the interactive pocketbook was easy to operate, including accessing learning materials, QR codes, instructional videos, and practice exercises. The content aspect received 95.00%, indicating that the materials were easy to understand and effectively supported students' learning of the concepts of plant growth and development. The language aspect achieved 85.90%, suggesting that the language used in the pocketbook was quite simple, clear, and easy for students to understand. In addition, the integration of the SDGs achieved 95.06%, indicating that students were able to understand the relationship between biological concepts and the principles of the Sustainable Development Goals (SDGs) through the developed learning media.

The practicality test results showed that the interactive pocket book based on the Sustainable Development Goals (SDGs) achieved a very high level of practicality, as assessed by both teachers and students. In development research, practicality is an important indicator that a product is not only theoretically valid but also easy for target users to use in real learning situations. According to [34], learning media is considered

practical if it is easy to implement and understand, meets users' needs, and receives positive responses from both teachers and students. Based on this study, the average teacher response reached 97.50%, and the student response reached 94.02%, both falling into the very practical category. These findings show that the developed interactive pocketbook meets the characteristics of learning media that are easy to use (user-friendly) while also effectively supporting the learning process.

Based on teacher responses, the aspects of interest, content, and SDGs integration each received a 100% rating, while the language aspect got 91.67%. These results show that teachers think the media is visually appealing, has content that aligns with learning objectives, and can effectively integrate sustainable development concepts. This finding is in line with research [35], which states that interactive learning media designed with an attractive appearance and systematic material structure can make it easier for teachers to deliver lessons while also reducing the burden of conveying information verbally. In addition, research [36] explains that practical digital media will improve teachers' readiness to implement technology-based learning because such media can be used without requiring complex training. Thus, the high response from teachers in this study shows that interactive pocket books have met teachers' needs as an effective and efficient learning media.

The aspect of SDG integration that received a perfect score (100%) shows that teachers consider the connection between plant growth and development material and sustainable development issues to be presented clearly and in context. This finding supports the recommendation [37] in the Education for Sustainable Development (ESD) for 2030 program, which emphasizes that education needs to integrate sustainability values into all subjects so that students can develop knowledge, skills, attitudes, and responsibility towards the environment. Research [38] also shows that integrating the SDGs into learning helps teachers connect science concepts to real-world problems, making learning more meaningful. Therefore, the results of this study show that interactive pocketbooks not only function as a biology learning medium but also as a tool that supports the implementation of education for sustainable development.

Student responses also showed a very high level of practicality with an average of 94.02%. The ease-of-use aspect received the highest percentage (98.60%), followed by relevance (97.50%), materials (95.00%), SDGs integration (95.06%), and language (85.90%). The high score in the ease-of-use aspect indicates that students did not have any difficulty accessing materials, scanning QR Codes, watching learning videos, or completing practice exercises. These results are in line with previous research [39], which concludes that mobile device-based learning media provide greater learning flexibility because they allow students to access materials anytime, anywhere. Ease of use is also an important factor affecting students' acceptance of technology, as explained in the Technology Acceptance Model (TAM), which states that perceived ease of use increases acceptance and the intensity of use of digital learning media.

The high student response to the material aspect shows that the pocketbook content helps them understand the concepts of plant growth and development, which were previously considered abstract. This finding reinforces the results of the needs analysis in the define stage, which showed that students had difficulty understanding the concepts of phytohormones, primary and secondary growth, and the factors affecting plant growth. After it was developed into an interactive pocketbook with illustrations, QR Codes, learning videos, and practice questions, students gave very positive feedback on how easy the material was to understand. These results are in line with the Cognitive Theory of Multimedia Learning. [40], which explains that combining text, images, and multimedia can improve conceptual understanding because information is processed through both visual and verbal channels simultaneously. Research by [41] also shows that multimedia-based learning media provide a more engaging learning experience, which boosts students' motivation and understanding of concepts.

In terms of language, the teacher gave a score of 91.67%, while the students gave 85.90%. Although this aspect has the lowest percentage among the other aspects, both scores are still in the very practical category. This shows that the language used has been communicative and easy to understand, even though some scientific terms still need adjustment to suit the students' characteristics. This finding is in line with research [42], which states that the use of simple, consistent language that matches students' cognitive development level is one of the factors determining the success of learning media. Therefore, this research shows that the language aspect has met the practicality criteria, even though there is still room for improvement in future development.

The students' response to the integration of the SDGs, at 95.06%, shows that they understand the connection between plant growth and development materials and sustainable development issues. This result indicates that presenting the SDGs Insight features in the pocketbook successfully helped students link biological concepts with environmental issues, food security, and natural resource conservation. These findings support the research. [43], which states that integrating the SDGs into science learning increases environmental awareness, critical-thinking skills, and students' sense of social responsibility. Thus, the media developed not only makes learning easier but also broadens students' perspectives on applying biology in real life.

Disseminate

The dissemination stage is the final phase in the 4D development model, aimed at testing the product more broadly to evaluate its effectiveness in improving students' conceptual understanding. With the instruments

deemed fit for use, the researcher proceeded to conduct an effectiveness test to see the impact of using an interactive pocket book based on the Sustainable Development Goals (SDGs) on students' learning outcomes in plant growth and development material. The effectiveness was measured through a pretest before learning and a posttest after students used the learning media. Before conducting the effectiveness test, the test instruments in the form of Two-Tier Multiple Choice (TTMC) questions were validated by experts and declared suitable for use. The results of the effectiveness test are presented in Table 10.

Table 10. Results of Students' Pre-Test and Post-Test Scores

Pre-Test	Post-Test	N-Gain	(%)	Category
38.28	88.79	0.83	83.02	High

Based on Table 10, the students' average pre-test score was 38.28, while the average post-test score increased to 88.79. These results indicate a 50.51-point improvement in learning outcomes after students participated in learning activities using the SDGs-based interactive pocketbook. This substantial increase suggests that the developed learning media effectively helped students understand the concepts of plant growth and development, which had previously been difficult for them. The level of improvement in learning outcomes was further analyzed using the Normalized Gain (N-Gain) index. The analysis yielded an N-Gain score of 0.83 (83.02%), which falls into the high category. This result indicates that the use of the interactive pocketbook significantly enhanced students' conceptual understanding. The high N-Gain value demonstrates that the media not only improved students' final achievement scores but also effectively strengthened their conceptual mastery through concise, illustrative, and interactive learning materials.

The improvement in learning outcomes can be attributed to the interactive pocketbook's characteristics, which integrate instructional content with illustrations, QR codes, instructional videos, practice exercises, and the values of the Sustainable Development Goals (SDGs). These features provide students with a more engaging and contextual learning experience, enabling them to better understand the relationship between biological concepts and sustainable development issues. Furthermore, the smartphone-accessible format of the pocketbook allows students to learn more flexibly, both inside and outside the classroom.

The effectiveness test results demonstrate that the use of the SDGs-based interactive pocketbook had a positive impact on students' learning outcomes on plant growth and development. The effectiveness of the learning media is reflected in the increase in the average student score from 38.28 on the pre-test to 88.79 on the post-test, representing an improvement of 50.51 points. In addition, the N-Gain analysis produced a score of 0.83 (83.02%), which is classified as high. These findings indicate that the developed media not only improved students' academic performance but also substantially enhanced their conceptual understanding. According to [44], an N-Gain score above 0.70 shows that a learning intervention is highly effective in improving students' understanding of concepts. Therefore, the results of this study demonstrate that interactive, SDGs-based pocket books are an effective learning medium for supporting biology learning.

The significant improvement in learning outcomes shows that presenting material through an interactive pocketbook can overcome the conceptual difficulties previously encountered in the define stage, namely students' difficulties in understanding the concepts of phytohormones, primary and secondary growth, and factors that affect plant growth. Presenting the material in a concise, systematic way, supported by illustrations, images, QR Codes, learning videos, and practice questions, allows students to build a more comprehensive understanding of the concepts. This finding aligns with the Cognitive Theory of Multimedia Learning proposed by [45], which posits that combining text, images, animations, and videos enables learners to process information through both visual and verbal channels simultaneously, thereby improving retention and knowledge transfer. Research [46] also shows that multimedia-based interactive learning media can significantly improve understanding of scientific concepts compared to conventional learning, as students experience more active and meaningful learning.

An N-Gain value of 0.83 also shows that the developed media not only improves the ability to remember information but also strengthens students' conceptual understanding. This is supported by the use of the Two-Tier Multiple Choice (TTMC) instrument, which measures both conceptual comprehension and the scientific reasoning behind students' answers. Unlike regular multiple-choice questions, TTMC can distinguish whether students truly understand the concept or are just guessing. According to [47], the two-tier diagnostic test instrument is more effective at measuring conceptual change because it can detect misconceptions students still hold. Therefore, the increase in post-test scores in this study indicates that using the interactive pocketbook not only improves quantitative learning outcomes but also enhances the quality of students' conceptual understanding.

The success of media in improving learning outcomes is also influenced by the characteristics of interactive pocket books that integrate various multimedia components. QR Codes linked to learning videos allow students to study the material independently, while interactive exercises reinforce understanding of concepts through continuous assessment. These results are in line with research [48], which concludes that

multimedia-based digital media increase learning motivation, student engagement, and learning outcomes because they can create a more interactive learning experience than conventional media. Research [49] also shows that mobile-based learning (mobile learning) offers greater flexibility, allowing students to access materials anytime, anywhere. These findings align with this study's results, given that the interactive pocket book was designed for use on smartphones, thereby supporting learning both inside and outside the classroom.

Besides improving learning outcomes, the interactive pocket book also successfully integrates the values of the Sustainable Development Goals (SDGs) into biology lessons. This integration is achieved through the SDGs Insight feature, which connects plant growth and development to sustainable development issues such as environmental conservation, food security, and the sustainable use of natural resources. These findings support the recommendations [50] in the Education for Sustainable Development (ESD) for 2030 program, which emphasizes that learning needs to build sustainability competencies through integrating global issues into the learning process. Research [51] also shows that integrating the SDGs into science learning can boost sustainability literacy, systems thinking skills, and students' ability to connect scientific concepts to real life. So, the improved learning outcomes in this study not only reflect a better understanding of biology concepts but also the students' growing awareness of the importance of sustainable development.

When compared with previous studies on instructional media development, the findings of this study demonstrate relatively high effectiveness. Numerous studies have reported that the use of digital learning media generally produces N-Gain scores in the moderate to high range, depending on the characteristics of the learning media and the instructional content. In the present study, the N-Gain score of 0.83 falls within the high category, indicating that the combination of a digital interactive pocketbook, interactive multimedia, and the integration of Sustainable Development Goals (SDGs) values made a substantial contribution to improving students' learning outcomes. These findings suggest that presenting learning materials in a contextual and interactive manner is more effective than conventional learning media that rely primarily on text and slide presentations. Furthermore, these results reinforce the findings from the Define stage, which revealed that students require learning media that can visualize abstract concepts and connect them to real-life contexts.

The effectiveness test confirms that the SDGs-based interactive pocketbook meets the criteria of an effective learning medium for improving students' learning outcomes. The increase in the average score from 38.28 on the pre-test to 88.79 on the post-test, accompanied by an N-Gain score of 0.83 (83.02%) in the high category, demonstrates that the developed learning media significantly enhanced students' conceptual understanding. The primary strength of this study, compared with most previous research, lies in integrating interactive multimedia—including QR codes, instructional videos, illustrations, and practice exercises—with Sustainable Development Goals (SDGs) values into a single, concise, smartphone-accessible learning resource. This integration not only improved students' cognitive achievement but also fostered scientific, digital, and sustainability literacy, all of which are essential competencies for implementing the Merdeka Curriculum and 21st-century education.

4. CONCLUSION

This study successfully developed an interactive pocket book based on the Sustainable Development Goals (SDGs) on plant growth and development using the 4D development model. The product developed met very valid criteria, with media validation at 96.55%, material validation at 94.16%, and instrument validation at 83.65%. In addition, the media was considered very practical based on responses from teachers (97.50%) and students (94.02%), and it proved effective in improving learning outcomes with the average score increasing from 38.28 to 88.79 and an N-Gain score of 0.83 (83.02%) in the high category. These results show that the SDG-based interactive pocket book is suitable to be used as a biology learning media that can enhance conceptual understanding while integrating sustainable development values. This research has implications for providing learning media that support the implementation of the Merdeka Curriculum, as well as strengthening students' science literacy, digital literacy, and sustainability literacy. However, this study is still limited to one school, one learning material, and only measures cognitive aspects. Therefore, future research is suggested to involve a wider sample, use an experimental design with a control group, develop media for other materials, and examine its effects on critical thinking skills, creativity, science process skills, and students' attitudes toward Sustainable Development Goals (SDGs) issues.

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AUTHOR CONTRIBUTIONS

Conceptualization, Methodology, Formal analysis, WAZ; Data curation, R; Investigation, WAZ & R; Writing – original draft preparation, WAZ & R; Writing – review and editing, WAZ & R; Validation, WAZ & R. All authors have read and agreed to the published version of the manuscript.

CONFLICTS OF INTEREST

The author(s) declare no conflict of interest.

INFORMED CONSENT STATEMENT

Prior to participation, each subject was provided with a detailed explanation of the study's objectives, procedures, potential risks, and benefits. All participants voluntarily agreed to participate and signed a written informed consent form. All images in this article have been authorized and are the property of the authors.

USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY

The authors declare that no artificial intelligence (AI) tools were used in the generation, analysis, or writing of this manuscript. All aspects of the research, including data collection, interpretation, and manuscript preparation, were carried out entirely by the authors without the assistance of AI-based technologies.

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