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Sustainability-Oriented Physics Textbook for Prospective Elementary Teachers

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ABSTRACT

Education for Sustainable Development (ESD) is important in science teacher education because it connects disciplinary knowledge with sustainability issues. However, learning materials integrating basic physics concepts, contextual investigations, and sustainability-oriented activities for prospective elementary school teachers remain underexplored. This study aimed to develop an ESD-oriented textbook on Basic Physics Concepts and examine its content validity and practicality. A research and development approach using the Analysis, Design, Development, Implementation, and Evaluation (ADDIE) model was employed. Participants included three expert validators, two lecturers, and 100 prospective elementary school teachers. Data were collected through validation and practicality questionnaires and analyzed using Aiken's V and percentage analysis. The textbook integrates conceptual explanations, visual representations, contextual examples, investigative activities, reflective questions, and Sustainability Action tasks. The results showed a mean Aiken's V of 0.87, indicating high content validity based on the study's criteria. Lecturer and student assessments yielded practicality scores of 83.93% and 87.83%, respectively, reflecting favorable user perceptions. The findings provide preliminary evidence of the textbook's content validity and perceived practicality. The textbook offers an instructional resource connecting basic physics learning with ESD principles. Further research should examine its contribution to prospective teachers' sustainability competencies.

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1. INTRODUCTION

Learning Natural Science (Physics) in elementary school teacher education not only aims to equip students with conceptual mastery, but also to develop the ability to connect scientific knowledge with everyday life phenomena and sustainability issues. Prospective teachers need to understand how the concepts of energy, changes in energy forms, and

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resource utilization can be explained through contextual, evidence-based, and environmentally relevant learning experiences. This need aligns with Education for Sustainable Development (ESD), which positions education as a means to develop knowledge, skills, values, and actions that support sustainable development [1], [2]. In this context, learning Natural Science (Physics) has the potential to support the Sustainable Development Goals (SDGs), especially SDG 4 on quality education and SDG 12 on responsible consumption and production [3]. Integrating ESD into physics learning is particularly relevant in teacher education because prospective elementary school teachers are expected not only to understand scientific concepts but also to develop the capacity to communicate sustainability-related issues through meaningful learning experiences. Consequently, physics teaching materials need to provide opportunities for students to connect scientific principles with environmental contexts and responsible resource utilization.

Despite this relevance, translating ESD principles into concrete learning materials for elementary school teacher education remains an important pedagogical consideration. Physics concepts such as energy, energy transformation, and energy utilization can be presented theoretically, but their educational value can be extended through contextual examples, scientific investigations, and reflective activities related to sustainability. Without these connections, students may encounter difficulties in relating abstract physics concepts to observable phenomena and their implications for everyday life. From a teaching-material development perspective, this highlights the importance of integrating conceptual explanations, contextual illustrations, investigative activities, and reflective components into a coherent learning resource. In addition, the quality of such materials needs to be considered in terms of content appropriateness, readability, visual presentation, learning activities, and the relevance of the sustainability contexts presented. The use of appropriately designed visual elements can also assist in the presentation of information and the relationships between concepts in learning [4].

Previous research on the development of teaching materials provides a foundation for developing learning resources that integrate context, technology, and user needs. Sari et al.'s research developed an interactive digital comic based on local environmental wisdom for flood literacy in elementary school social studies [5]. Fitriani et al.'s research developed GeoGebra-assisted teaching materials to help overcome learning barriers and support understanding of fraction concepts through an Educational Design Research approach [6]. Although these studies address different subject areas and learning objectives, they illustrate two relevant approaches to instructional material development: incorporating contextual and environmental knowledge into learning resources and utilizing appropriate technological media to support conceptual understanding. However, neither study directly addresses the integration of basic physics concepts and ESD principles within a textbook designed for prospective elementary school teachers. Furthermore, the studies cited here do not demonstrate how scientific explanations, physics investigations, sustainability reflection, and responsible resource-use activities can be systematically combined in one learning resource. This distinction provides a specific point of departure for the present

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study without assuming that previous research has comprehensively addressed or failed to address all aspects of ESD-oriented science textbook development.

Accordingly, the research gap addressed in this study concerns the development of an integrated learning resource that connects basic physics concepts, contextual scientific phenomena, and ESD-oriented learning activities within the context of elementary school teacher education. Rather than assuming documented deficiencies in existing textbooks or established student learning difficulties at Universitas Samudra, this study focuses on developing and evaluating a textbook that incorporates these components into a structured instructional resource. To address these needs, this research developed an ESD-Oriented Textbook on Basic Physics Concepts for Pre-service Elementary Teachers. The book was designed by combining concept descriptions, illustrations and visual media, contextual phenomena, activity sheets or investigations, reflective questions, and Sustainability Action activities. One of the contexts used was an experiment on converting solar energy into kinetic energy through mini solar panels, direct current dynamos, and propellers. This experimental context provides an opportunity for students to observe and investigate energy transformation while discussing the educational relevance of renewable energy utilization and responsible resource use. The product development was further evaluated through expert validation and practicality assessment by lecturers and students of the Elementary School Teacher Education Program at Universitas Samudra.

The originality of this study lies in the design of a single ESD-oriented physics textbook that brings together basic physics concepts, contextual phenomena, investigative activities, reflective questions, and sustainability-oriented actions for prospective elementary school teachers. Unlike the previously cited studies, which focus on digital comics for flood literacy and GeoGebra-assisted mathematics materials, this study specifically addresses the integration of physics content and sustainability contexts within teacher education materials. The research does not simply position sustainability as supplementary information, but uses it as a context to connect physics concepts to real-life challenges. Its contribution to SDG 4 is reflected in the development of a learning resource intended to support the quality of prospective teacher education, while its connection to SDG 12 is addressed through learning activities that encourage consideration of responsible consumption and resource utilization. These contributions are presented as the educational orientation of the textbook rather than as demonstrated impacts on the achievement of the SDGs. Based on this direction, this research aims to develop a valid and practical textbook. Specifically, the study examines the validity of the textbook through expert assessment and its practicality based on evaluations by lecturers and students. The effectiveness of the textbook in improving learning outcomes or sustainability competencies is not assumed from the outset, but requires further empirical testing..

2. METHOD

2.1. Research Design

This study uses a research and development method with the ADDIE model, which consists of five stages: Analysis, Design, Development, Implementation, and Evaluation

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[7]. The ADDIE model was chosen because it provides a systematic procedure for identifying learning needs, designing products, developing teaching materials, testing products, and evaluating the results of the development. The study focuses on the development of a textbook on Basic Concepts of Elementary School Physics Science oriented to Education for Sustainable Development (ESD) for students of the Elementary School Teacher Education Study Program (PGSD) at Universitas Samudra.

Product development is directed at integrating physics science concepts with contextual phenomena, investigative activities, reflection, and sustainability-oriented actions. The development of teaching materials also considers the needs of prospective elementary school teachers to understand scientific concepts while connecting them to everyday life issues. Studies on learning media to support scientific literacy demonstrate the relevance of using learning resources that encourage student engagement and the application of scientific concepts in real contexts [8]. However, this study specifically evaluates the validity and practicality of the developed textbook, rather than testing its effectiveness through an experimental design.

The ADDIE model was operationalized through five sequential stages, with each stage producing specific outputs that informed the subsequent development process. The Analysis stage focused on identifying the instructional requirements for the textbook. The Design stage translated these requirements into a textbook structure and instructional specifications. The Development stage involved preparing and validating the textbook through expert assessment. The Implementation stage involved the limited use of the developed textbook by lecturers and students to obtain feedback on its practicality. Finally, the Evaluation stage involved analyzing the validation results and user responses to determine the validity and practicality of the product. Accordingly, implementation in this study refers to a product tryout for practicality assessment and does not represent an experimental test of learning effectiveness.

2.2. Research Location, Participants, and Procedure

This research was conducted at the Elementary School Teacher Education Study Program (PGSD), Universitas Samudra. The research participants consisted of three expert validators, two lecturers, and 100 PGSD students. The three validators were involved in assessing the validity of the developed textbook, whereas the two lecturers and 100 students participated in the practicality assessment. The lecturers provided evaluations from an instructional and pedagogical perspective, while the students provided responses based on their experience of using the textbook.

The development procedure followed the five stages of the ADDIE model, as described below.

1. Analysis

The Analysis stage focused on identifying the instructional requirements for developing an ESD-oriented textbook on basic physics concepts for prospective elementary school teachers. The analysis was directed toward the relevance of physics content to the PGSD curriculum, the integration of contextual phenomena and sustainability principles, and the learning activities needed to support conceptual

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understanding. The results of this stage served as the basis for determining the textbook content, learning objectives, and instructional components to be developed.

2. Design

The Design stage involved preparing the conceptual and instructional framework of the textbook based on the requirements identified during the Analysis stage. The design included the organization of basic physics concepts, the sequence of topics, contextual illustrations, investigative activities, reflective questions, and Sustainability Action activities. Particular attention was given to connecting physics concepts with everyday phenomena and sustainability issues. An experimental activity involving mini solar panels, direct current dynamos, and propellers was incorporated to illustrate the transformation of solar energy into kinetic energy. The output of this stage was the initial textbook design, including its content structure and planned learning activities.

3. Development

The Development stage involved translating the initial design into a complete textbook. The developed product incorporated conceptual explanations, illustrations and visual media, contextual examples, activity sheets or investigations, reflective questions, and Sustainability Action activities. The initial textbook was subsequently submitted to three expert validators for assessment of its content and overall suitability. The expert validation results were analyzed using Aiken's V index. Feedback and recommendations from the validators were used as the basis for revising the textbook before the practicality assessment. The output of this stage was a revised textbook that had undergone expert validation.

4. Implementation

The Implementation stage involved a limited tryout of the revised textbook involving two lecturers and 100 students from the PGSD Study Program at Universitas Samudra. The lecturers and students were asked to assess the textbook using structured response questionnaires. The assessment focused on the practicality of the textbook from the perspectives of its intended users. The lecturers evaluated its suitability as a learning resource, while the students provided responses regarding their experience of using the developed materials. This stage was intended to obtain information about the usability and practicality of the textbook rather than to measure changes in student learning outcomes or sustainability competencies.

5. Evaluation

The Evaluation stage involved analyzing the results obtained from expert validation and the practicality assessment. Expert assessment data were analyzed using Aiken's V index to determine the content validity of the textbook. Meanwhile, lecturer and student response data were analyzed using percentage scores to describe the practicality of the developed product. The findings from these analyses were used to determine whether the textbook met the established validity and practicality criteria. The evaluation in this study was therefore limited to product quality assessment and did not include an experimental evaluation of learning effectiveness.

The chronological relationship between the five ADDIE stages and their respective outputs is presented in Figure 1.

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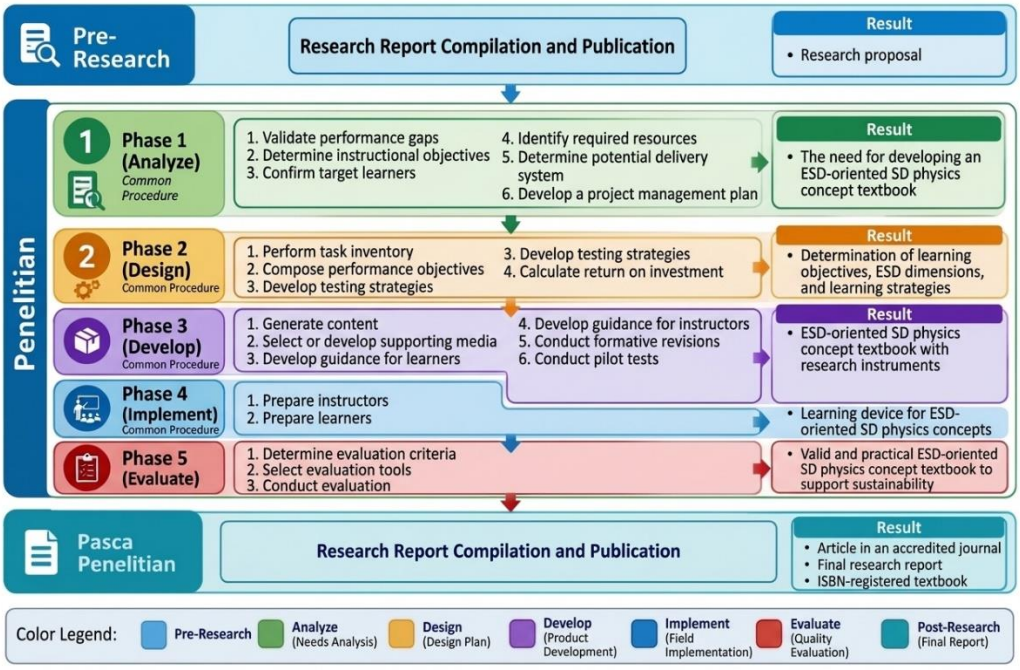

Figure 1. Procedure for Developing an ESD-Oriented Textbook on Basic Physics Concepts

2.3. Data Collection Techniques and Research Instruments

Data collection was conducted using a closed questionnaire technique, namely a questionnaire that provides structured answer choices so that respondents choose the answer that best suits their assessment [9]. This technique was used to obtain quantitative data regarding the quality of textbooks through three instruments, namely: an expert validation questionnaire sheet filled out by three validators, a lecturer response questionnaire sheet, and a student response questionnaire sheet.

The three questionnaires served different assessment purposes. First, the expert validation questionnaire was used to assess the validity and suitability of the textbook based on expert judgments. Second, the lecturer response questionnaire was used to assess the practicality of the textbook from an instructional and pedagogical perspective. Third, the student response questionnaire was used to obtain information about the practicality of the textbook from the perspective of its intended users.

The expert validation questionnaire provided the assessment data for calculating Aiken's V, whereas the lecturer and student response questionnaires provided the data for calculating the practicality percentages. The use of structured answer choices allows responses to be collected uniformly and analyzed quantitatively.

2.4. Data Analysis Techniques

The data were analyzed quantitatively using Aiken's V index and percentage score analysis. Aiken's V index was used to analyze content validity based on expert assessment of the assessed aspects [10]. Percentage score analysis was used to describe the assessment

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scores obtained compared to the maximum score, then interpret them based on the established criteria [11].

The validity analysis was conducted using Aiken's V index to determine the level of agreement among the three expert validators regarding the assessed aspects of the textbook. The index was calculated using the following formula:

$$V = \Sigma s / [n(c - 1)]$$

where $s = r - lo$, r represents the score assigned by each validator, lo represents the lowest score on the assessment scale, n represents the number of validators, and c represents the number of categories in the assessment scale. The resulting Aiken's V value was interpreted according to the validity criteria established for the study.

The practicality analysis was conducted using percentage score analysis based on the responses of two lecturers and 100 PGSD students at Universitas Samudra. The percentage was calculated using the following formula:

$$P = (f / N) \times 100\%$$

where P represents the percentage score, f represents the total score obtained, and N represents the maximum possible score. The resulting percentages were interpreted using the predetermined practicality criteria to describe the extent to which the textbook was considered practical by lecturers and students.

The results of both analyses were used to determine the validity and practicality of the developed textbook. No inferential statistical analysis or experimental comparison was conducted because the study focused on product development and quality assessment rather than testing the effectiveness of the textbook.

3. RESULTS AND DISCUSSION

3.1. Results

The development of the Elementary School Physics Basic Science Concepts textbook oriented towards Education for Sustainable Development (ESD) was conducted through the five stages of the ADDIE model: Analysis, Design, Development, Implementation, and Evaluation. The resulting product, entitled ESD-Oriented Textbook on Basic Physics Concepts for Pre-service Elementary Teachers, was designed to support prospective elementary school teachers in understanding basic physics concepts and relating them to everyday phenomena and sustainability issues. The textbook combines conceptual explanations, visual representations, contextual examples, investigative activities, reflective questions, and Sustainability Action tasks. The results presented in this section cover the characteristics of the developed product, its contextual learning activities, and the findings of expert validation and practicality assessments. The main components and instructional functions of the developed textbook are summarized in Table 1.

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Table 1. Characteristics of the ESD-Oriented Textbook

No	Product components	Learning function	Linkages to SDGs
1	Description of the concept and examples of phenomena	Helping students understand physics concepts and relate them to everyday life.	Supporting contextual science learning as part of SDG 4.
2	Illustrations, diagrams, tables, infographics, and photos	Visualizing phenomena, relationships between concepts, and observational data.	Supporting access and understanding of science information.
3	Activity and investigation sheets	Directing students to observe and study phenomena.	Opening up spaces for evidence-based learning and problem-solving.
4	Energy and environmental cases	Connecting physics concepts with energy use and environmental issues.	Provides learning context related to SDG 7, SDG 12, and SDG 13.
5	Sustainability Action and reflection	Encourage students to plan simple actions and consider the reasons behind the actions.	Potential to link knowledge with responsibility and sustainability practices.

As presented in Table 1, the textbook integrates three main instructional dimensions: conceptual understanding, scientific investigation, and sustainability-oriented reflection. The sustainability orientation is embedded in the learning activities rather than presented exclusively as supplementary information. In particular, the energy and environmental cases provide contexts for discussing resource utilization, while the Sustainability Action component encourages students to consider possible applications of scientific knowledge in everyday situations. These components represent the intended instructional characteristics of the product and do not constitute direct evidence of changes in students' sustainability competencies.

One contextual example presented in the textbook is an experiment on converting solar energy into kinetic energy using mini solar panels, a direct current (DC) dynamo, and a propeller. The activity introduces students to the transformation of solar energy into electrical energy and subsequently into mechanical energy. Through this activity, students can examine the functions of the experimental components, observe the movement of the propeller under different operating conditions, and discuss the relevance of renewable energy utilization. The activity also provides a contextual basis for discussing responsible energy use, particularly in relation to SDG 7 and SDG 12. An example of this contextual ESD-oriented learning activity is presented in Figure 2.



Figure 2. Contextual ESD-Oriented Physics Learning Activity Using a Solar Energy Conversion Experiment

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Figure 2 illustrates how the textbook connects the explanation of energy transformation with an observable scientific activity. The experimental context is intended to facilitate discussion of renewable energy and responsible resource utilization. However, the inclusion of this activity does not establish that students have developed renewable energy literacy or changed their energy consumption behavior, as these outcomes were not measured in this study.

The evaluation of the textbook involved three expert validators, two lecturers, and 100 PGSD students. Expert validation was conducted to assess the content validity of the textbook, whereas lecturer and student assessments were used to examine its practicality from the perspectives of instructional users and prospective teachers. The aggregate assessment results are presented in Table 2.

Table 2. Summary of Textbook Quality Assessment

No	Evaluation aspects	Data source	Results
1	Product validity	Three expert validators	0,87
2	Practicality of textbooks	Two lecturers teaching the course	83,93%
3	User response	100 PGSD students	87,83%

As shown in Table 2, the textbook obtained a mean Aiken's V value of 0.87 from expert validation. The lecturer assessment resulted in a practicality score of 83.93%, while the student response reached 87.83%. These findings provide preliminary quantitative evidence concerning the content validity and perceived practicality of the developed textbook. The scores should be interpreted within the scope of the assessment instruments, respondents, and evaluation procedures used in this study.

3.2. Discussion

3.2.1. Content Validity of the ESD-Oriented Textbook

The developed textbook obtained a mean Aiken's V value of 0.87 based on assessments by three expert validators. This result indicates a favorable level of expert agreement regarding the assessed content of the textbook. Aiken's V reflects expert judgments of the relevance and appropriateness of the assessed content; it should therefore be interpreted as evidence of content validity rather than construct validity in the psychometric sense. The value should also be considered in relation to the number of validators and the rating scale used in the assessment. Because the detailed rating-scale classification and aspect-level scores are not presented, the result is interpreted here as an aggregate indication of expert agreement rather than assigned a more specific validity category.

The development of the textbook was informed by research emphasizing the importance of integrating scientific concepts, appropriate learning resources, and contextual learning experiences. Asthania et al. discussed the role of technology and learning resources in supporting science learning in elementary schools [12]. This perspective provides a rationale for incorporating visual representations and contextual learning resources into the present textbook. However, the relevance of this previous

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research concerns instructional design considerations and does not independently establish the validity of the textbook developed in this study.

A more direct comparison can be made with Hanifah et al., who developed and evaluated an Education for Sustainable Development (ESD)-based e-module on low-carbon energy and assessed its content feasibility, ESD alignment, scientific literacy, visual presentation, and language [13]. Their work provides a relevant reference for considering both disciplinary content and sustainability integration during the development of educational materials. Nevertheless, an ESD-oriented e-module and a textbook for prospective elementary teachers represent different instructional products and educational contexts. The findings of Hanifah et al. therefore support the rationale for comprehensive product assessment rather than serve as direct evidence of the validity of the present textbook.

The theoretical considerations underlying the textbook design also involve cognitive development and inquiry-based learning. Piaget's cognitive development perspective provides a general rationale for presenting scientific concepts through contextual examples and opportunities for reasoning. However, the assumption that all prospective elementary school teachers consistently operate at the formal operational stage is not warranted. Their ability to reason about abstract physics concepts may vary according to prior knowledge, experience, and familiarity with scientific representations. Accordingly, the textbook incorporates contextual examples and investigative activities as instructional design strategies to support the interpretation of scientific phenomena rather than as evidence that students' cognitive development or conceptual understanding has improved.

Research on inquiry-based science education also provides a rationale for incorporating investigative activities. Hofstein and Mamlok-Naaman discussed the educational role of laboratory work in science education, emphasizing the relationship between practical activities and science learning [14]. Husnaini and Chen compared guided inquiry-based virtual and physical laboratories involving Indonesian secondary school students and reported differences in their contributions to conceptual understanding and inquiry self-efficacy [15]. These studies support the pedagogical relevance of investigation and practical experiences, although their educational settings and participant characteristics differ from the present study. In particular, findings from secondary school laboratory research cannot be directly generalized to the use of a textbook among prospective elementary school teachers.

The inclusion of inquiry sheets, discussion activities, and contextual examples also reflects the instructional principle of scaffolding associated with Vygotsky's sociocultural perspective. These features were designed to provide structured guidance as students engage with scientific concepts and sustainability issues. Roth and Lee's discussion of science learning in relation to community participation and cultural tools provides a theoretical basis for connecting scientific knowledge with social contexts [16]. Similarly, Rahayu et al. reported the benefits of scaffolding in guided inquiry learning for physics conceptual understanding [17]. However, the present study assessed the textbook through expert judgments and user responses rather than direct measurements of scaffolding

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effectiveness. Thus, these theoretical and empirical perspectives explain the design rationale, not a demonstrated learning outcome of the developed textbook.

Overall, the Aiken's V result of 0.87 provides preliminary support for the content appropriateness of the developed textbook according to the participating experts. The result should be interpreted within the scope of the three-validator assessment and the specific criteria applied. It does not independently establish the textbook's effectiveness, its construct validity, or its ability to improve scientific literacy and sustainability competencies.

3.2.2. Practicality of the Textbook for Lecturers and Students

The practicality assessment produced a score of 83.93% from two lecturers and a student response score of 87.83% from 100 PGSD students. These results indicate favorable perceptions of the textbook among the participating respondents. The student response percentage was 3.90 percentage points higher than the lecturer assessment. This difference suggests that the two respondent groups provided somewhat different overall evaluations, although the scores alone do not establish statistically significant differences between their perceptions.

The interpretation of these percentages should take into account the assessment instruments and the practicality classification criteria applied in the study. Because the detailed indicator-level scores and classification thresholds are not available, the results are reported as aggregate percentages without assigning a more specific practicality category.

The textbook incorporates visual representations, contextual illustrations, diagrams, and investigative activities. These features were included based on the principles of multimedia learning and cognitive load theory developed by Mayer [4] and Sweller [20]. The design intention was to organize information in a way that supports navigation, connects verbal explanations with visual representations, and reduces unnecessary complexity when students engage with physics concepts. Nevertheless, the present study did not measure cognitive load, information-processing efficiency, or learning performance. Therefore, it cannot be concluded that the textbook actually reduced extraneous cognitive load or optimized germane cognitive load.

Wati examined the practicality of a higher-order-thinking-oriented mathematics physics textbook integrated with philosophical values through lecturer and student assessments [21]. This study provides a relevant comparison in terms of evaluating instructional materials from both lecturer and student perspectives. However, differences in subject matter, instructional objectives, and product characteristics need to be considered when interpreting the respective practicality results. The similarity lies primarily in the use of user assessments to examine the usability of developed teaching materials.

Listianingsih et al. discussed the role of instructional media and learning resources in supporting student engagement and ease of use [8]. Hufri et al. evaluated the practicality of physics learning tools by considering the perspectives of educators and students [22]. Marisda et al. also examined the usability and practicality of an interactive flipbook-based physics e-book involving lecturers and prospective physics teachers [23]. Together, these studies provide a comparative basis for considering content organization, visual

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presentation, instructional guidance, and user experience when developing learning resources. However, their findings should not be interpreted as direct confirmation of the present textbook's practicality because the products, assessment instruments, and participant contexts may differ.

The practicality scores in this study should also be interpreted within several methodological limitations. First, the lecturer assessment involved only two respondents, which limits the representativeness of lecturer perceptions. Second, the questionnaire responses were self-reported and may have been influenced by social desirability or familiarity with the researchers and the instructional context. Third, the practicality assessment does not necessarily demonstrate that the textbook can be implemented without difficulty during regular lectures because the extent and duration of actual classroom use were not established in the reported results. Fourth, the study did not report reliability evidence for the lecturer and student questionnaires.

Consequently, the results provide initial evidence of perceived practicality among the participating lecturers and students, rather than definitive evidence of operational effectiveness in different instructional settings. The comparison with conventional textbooks or claims that the developed product is theoretically superior is also not warranted because no comparative textbook assessment was conducted.

3.2.3. Potential Relevance to Sustainable Development Goals

The ESD orientation of the developed textbook is reflected in its content and learning activities rather than in directly measured contributions to Sustainable Development Goal (SDG) attainment. The most explicit connections concern SDG 4 (Quality Education) and SDG 12 (Responsible Consumption and Production). The textbook supports the educational dimension of SDG 4 by providing structured physics learning materials for prospective elementary school teachers. Its relationship with SDG 12 is reflected in activities that invite students to consider resource utilization, energy consumption, and responsible actions in everyday contexts [2].

The Sustainability Action component is particularly relevant because it encourages students to move beyond reading scientific explanations toward considering possible actions related to resource use. Examples include examining energy utilization in everyday environments and formulating simple suggestions for more responsible practices. Such activities are intended to introduce sustainability-related reflection and decision-making. However, the study did not assess the quality of students' action plans, their actual implementation, or subsequent changes in behavior.

Research on ESD in higher education emphasizes the importance of integrating sustainability principles into educational experiences and teacher preparation [18], [19]. These perspectives provide a theoretical basis for positioning sustainability as an integral component of teacher education materials. Research on teacher education also emphasizes the importance of developing ESD competencies and preparing prospective teachers to translate sustainability principles into educational practices [25], [26]. These studies reinforce the relevance of incorporating sustainability-related content and learning experiences into teacher preparation. However, they should not be interpreted as empirical

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evidence that the present textbook has increased ecological awareness or sustainability competencies.

Crespo-Martín et al. examined sustainability-related knowledge, attitudes, and behavior among prospective primary school teachers and highlighted the importance of considering the relationship between knowledge and actual sustainable practices [24]. Their findings are relevant to the present study because they suggest that sustainability-oriented educational resources should ideally provide opportunities for reflection and action, rather than focus exclusively on knowledge acquisition. Nevertheless, the present research has not yet measured these competencies.

The Sustainability Action activities included in the textbook are intended to provide opportunities for prospective teachers to connect conceptual understanding with sustainability-oriented decisions and actions. This orientation is consistent with research emphasizing the development of teachers' professional action competence, including the integration of sustainability-related knowledge, skills, and attitudes into teaching practice [27]. A recent scoping review also highlights the relevance of action competence in research on pre-service teachers' ESD competencies, supporting the need for learning experiences that extend beyond conceptual understanding [28]. These perspectives provide a basis for further developing the textbook's reflective and action-oriented activities, although the present study did not assess the development of such competencies.

The connection with SDG 7 (Affordable and Clean Energy) is provided by the solar energy conversion experiment, which introduces the transformation of solar energy into electrical and mechanical energy. This activity offers an opportunity to discuss renewable energy and its potential applications. Research involving pre-service physics teachers has also examined ESD-related competencies in physics learning assessment, including thinking skills associated with sustainability issues [29]. This provides a relevant disciplinary context for connecting physics learning with sustainability-oriented reasoning. Similarly, SDG 13 (Climate Action) may be introduced as an additional discussion context when the textbook explicitly addresses the relationship between energy utilization, environmental impacts, and climate change. However, the presence of a solar energy experiment alone is insufficient to demonstrate climate literacy or climate action competencies. These connections should therefore be understood as potential curricular extensions rather than measured contributions of the current research.

The inclusion of inquiry-based activities also provides opportunities for prospective elementary teachers to connect scientific concepts with instructional practices and contextual problems. Schwarz's research on modeling-centered scientific inquiry in elementary teacher education offers a relevant reference for considering how scientific modeling and inquiry can be incorporated into teacher preparation [30]. Nevertheless, the present study did not investigate whether the textbook improved prospective teachers' inquiry competence or their ability to design similar learning experiences for elementary school pupils.

The principal contribution of the textbook at this stage is the provision of a learning resource that integrates basic physics concepts with contextual investigations and sustainability-oriented reflection for prospective elementary school teachers. Whether

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these components contribute to improved ESD competencies, energy literacy, or responsible consumption practices remains an empirical question for subsequent research.

3.2.4. Study Limitations and Future Research

Several limitations should be considered when interpreting the findings. First, the content validation involved only three expert validators, limiting the breadth of expert perspectives represented in the assessment. Although the Aiken's V value of 0.87 provides information about expert agreement, it does not establish all dimensions of textbook quality or psychometric validity. Second, the practicality assessment involved only two lecturers and 100 students from one university, which limits the generalizability of the findings to other teacher education institutions. Third, the practicality data were obtained through self-reported questionnaires, and the study did not report reliability evidence for these instruments.

Fourth, the study did not include an experimental design or pretest-posttest measurements to examine the effectiveness of the textbook in improving physics conceptual understanding, scientific literacy, or learning outcomes. Fifth, no specific instrument was used to measure ESD competencies, including sustainability knowledge, attitudes, values, or behavior. Sixth, the evaluation did not independently examine the contribution of individual ESD components, such as investigative activities and Sustainability Action tasks, to students' sustainability-related understanding. Finally, the extent and duration of actual textbook use in regular lectures require further documentation to establish its practicality under authentic instructional conditions.

Future research should involve a broader range of teacher education institutions and a larger panel of experts to strengthen the evaluation of the product. Further studies should also examine the reliability of the assessment instruments and conduct field trials under regular lecture conditions. An experimental or quasi-experimental design could subsequently be used to investigate the textbook's potential contribution to physics conceptual understanding and scientific literacy. In addition, specific ESD competency instruments could be employed to examine whether the contextual investigations and Sustainability Action activities support sustainability-related knowledge, attitudes, and behavior. These investigations would provide additional empirical evidence beyond the initial validity and practicality findings reported in the present study.

4. CONCLUSION

This study developed an ESD-oriented textbook on Basic Physics Concepts for pre-service elementary school teachers and examined its content validity and practicality. The findings indicate that the textbook meets the study's criteria for content validity and perceived practicality, based on expert assessments and responses from lecturers and students. Its theoretical contribution lies in integrating basic physics concepts with contextual phenomena, investigative activities, sustainability-oriented reflection, and responsible resource utilization within elementary teacher education. Practically, the textbook can serve as an additional learning resource for lecturers and prospective teachers seeking to incorporate Education for Sustainable Development (ESD) into physics

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instruction. However, the evaluation was limited to three expert validators, two lecturers, and students from one institution, relying primarily on expert judgments and self-reported responses without measuring instructional effectiveness or sustainability competencies. Future research should examine the implementation of the textbook across different institutions and investigate its contribution to pre-service teachers' sustainability competencies, particularly their sustainability-related knowledge, attitudes, decision-making, and responsible actions, using appropriate research designs and validated instruments.

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