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Addie-Based Green Synthesis Experiment Module Using Cermai Leaf Extract for 7th-Semester Students in Physics Education Program at UIN Mataram

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Abstract

This study aims to develop a green synthesis experimental module using Cermai leaf extract as a natural material by applying the ADDIE development model for 7th-semester students in the Physics Education Program at UIN Mataram. This study is a research and development (R&D) project comprising five stages: needs analysis, module design, product development, implementation, and formative evaluation. The subjects in this study consisted of 14 seventh-semester students as module users, as well as 3 subject matter experts and 3 media experts as product validators. The analysis results indicated the lack of an experimental module based on natural materials relevant to the concept of green synthesis. During the development stage, the module was validated by three subject matter experts and three media experts, yielding feasibility scores of 0.97 and 0.80, respectively, both falling into the "very suitable" category. A pilot test conducted among students via a response questionnaire yielded a practicality percentage of 95%, categorized as "very good." These findings indicate that the developed module is suitable and practical for use as a physics of materials learning medium and has the potential to support environmentally friendly and contextual laboratory learning.

INTRODUCTION

The development of nanotechnology in the fields of education and research has spurred the emergence of various material synthesis approaches that are safer [1], more efficient [2], and environmentally friendly [3]. One approach currently being widely developed is green synthesis, which utilizes bioactive compounds from plants as reducing agents and stabilizers in the nanoparticle synthesis process [4]. This approach is becoming increasingly relevant because it not only reduces the use of hazardous chemicals [5] but also provides students with a more environmentally friendly scientific experience during laboratory activities [6]. The advantages of this method include simpler procedures [7], lower energy consumption [8], and minimal requirements for synthetic chemicals [9], making it consistent with the principles of laboratory safety and research sustainability.

Green synthesis and biosynthesis are defined as methods for synthesizing compounds that utilize biological materials, such as plant extracts [10], fungi [11], algae [12], and microorganisms [13]. This approach aims to reduce the impact of toxic chemicals commonly used in conventional metal oxide synthesis processes [14]. The use of plant extracts enables the synthesis of metal oxides, serving as both a reducing agent and a capping agent during the process [15], thereby replacing the use of reducing agents based on hazardous materials [16]. Green synthesis methods offer various advantages [17], including being environmentally friendly, low-cost, and requiring relatively low energy consumption [18]. One increasingly popular approach is the use of leaf extracts as reducing agents [19] and stabilizers in nanoparticle synthesis processes [20]. Various types of leaves are known to contain phytochemical compounds [21], such as flavonoids [22], phenols [23], and tannins [24], which play an active role in nanoparticle formation [25]. This makes the method safer [26], more economical, and more sustainable compared to conventional synthesis methods [27].

Cermai leaf extract (Phyllanthus acidus) is a natural material with great potential for use in green synthesis because it contains flavonoids [28], tannins [29], and phenolic compounds [30]. These compounds function as reducing agents capable of converting metal ions intonanoparticles [31], while also acting as stabilizers to prevent the formed nanoparticles from easily agglomerating [32]. These phytochemical characteristics make Cermai leaves relevant for development as laboratory materials in plant-based material synthesis activities [33].

In the context of this study, the synthesized nanoparticles are iron nanoparticles, which are known for their excellent optical and electrical properties and are widely used in sensor applications and functional materials. The synthesis process was carried out using Cermai leaf extract as a natural reducing agent, while the characterization of physical properties focused on electrical properties, specifically material resistivity, measured using the two-point probe method.

Additionally, the experimental module developed in this study includes activity stages ranging from the leaf extraction process, nanoparticle synthesis, to the analysis of the material's electrical properties, thereby providing students with a comprehensive and contextual experimental experience. In the context of higher education, particularly within the Physics Education Program, students require experimental modules that are not only relevant to advancements in materials research but also capable of integrating environmentally friendly approaches into laboratory activities [34]. Experimental modules that combine the concept of green synthesis, the use of Cermai leaf extract, and the analysis of materials' physical properties remain very limited. Additionally, prospective physics teachers need to be equipped with hands-on experience in the material synthesis process so

they can teach modern physics concepts contextually in the future.

Previous research also supports the potential of Cermai leaf extract. According to Enggarwati and Qomriah (2023), Cermai leaf extract exhibits anti-hypercholesterolemic activity, indicating the presence of active metabolites that can be utilized in reduction processes [35]. According to Nisa et al. (2023), Cermai leaf ethanol extract possesses strong antioxidant activity due to its flavonoid and phenolic content, making it a potential natural reducing agent [36]. Furthermore, research by Sudding et al. (2023) indicates that Cermai leaf extract (Phyllanthus acidus L.) contains secondary metabolites such as alkaloids obtained through extraction, fractionation, and identification processes. These processes involve systematic scientific steps, making them suitable for application in laboratory exercises and experiment-based learning [37].

This situation highlights a clear research gap: the absence of an experimental module for Physics Education students that integrates green synthesis based on Cermai leaf extract with the analysis of material physical properties, as well as the lack of an ADDIE-based module that has been tested for validity, practicality, and effectiveness in this context. Therefore, this study aims to (1) develop a green synthesis experimental module based on the ADDIE model using Cermai leaf extract;

(2) assess the module's validity through content expert and media expert reviews; (3) assess the module's practicality based on student feedback; and (4) evaluate the module's effectiveness in enhancing students' understanding of nanoparticle synthesis concepts and the electrical properties of materials.

Additionally, this study aims to systematically describe the implementation process of the ADDIE model, which includes the analysis, design, development, implementation, and evaluation stages in the development of green synthesis-based experimental modules.

METHOD

This study falls under the category of research and development (R&D). The development process follows the ADDIE model, which consists of five main stages: analysis, design, development, implementation, and evaluation. The development flow using the ADDIE model is shown in Figure 1.

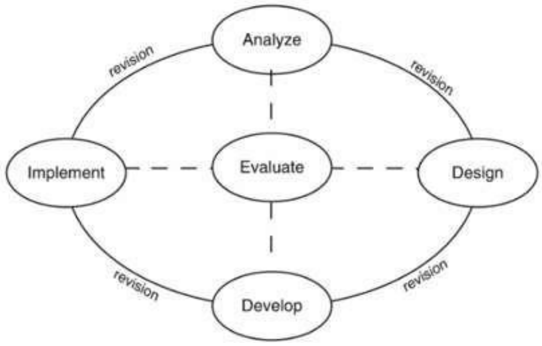


Figure 1. ADDIE Development Steps

Figure 1 illustrates the steps of the development research using the ADDIE model. The first step is conducting a needs analysis to identify student needs. The second step involves designing the product to obtain an initial draft of the experimental module. The third step is developing the product by compiling the module in its entirety, followed by validation by subject matter experts and media experts, and revising the module based on their feedback. The fourth step involves implementing the product through a pilot test with students, accompanied by a response questionnaire. The final step is to evaluate the product by refining the module according to the validators' feedback and analyzing the results of the student response questionnaire so that the module can be improved in areas that still require refinement.

This study was conducted over two months in the Physics Education Program and involved several key stages, such as interviews, including 3 subject matter expert validations and 3 media expert validations, as well as student response questionnaires to ensure the quality of the developed modules. The research subjects were all seventh-semester students. The instruments used included subject matter expert validation sheets, media expert validation sheets, and student response questionnaires. The student response questionnaire is described in detail, covering 10 statement items, the dimensions measured, and the rating scale used. The questionnaire consists of several dimensions, namely material clarity, visual appeal, ease of use, and the module's usefulness in learning. Each dimension is broken down into several statements using a 5-point Likert scale: strongly agree, agree, somewhat agree, somewhat disagree, and disagree. This study employed a descriptive quantitative method, where data were obtained from expert evaluations and student questionnaire responses. The indicators used for each validator were formulated according to their respective fields of expertise. The indicators assessed by the content expert validators and media expert validators are presented in Table 1 and Table 2.

Table 1. Content Expert Validation Indicators

Item	Assessment Indicators
Item 1	Materials align with students' laboratory learning outcomes
Item 2	Materials and scientific processes align with current chemical concepts and principles
Item 3	Green synthesis topics aligned with practical needs and environmental issues
Item 4	Experimental procedures are clear and can be carried out by students in the laboratory
Item 5	Formulas for resistivity and dielectric constant are presented in detail and can be applied
Item 6	Students understand the relationship between nanoparticles and their electrical properties

Item 7	The material is sufficiently in-depth and appropriate for the students' level of understanding
Item 8	The assessment questions encourage students to analyze the relationships between experimental variables
Item 9	The module fosters scientific values such as critical thinking, laboratory work, and environmental awareness

Table 2. Media Expert Validation Indicators

Item	Assessment Indicators
Item 1	The layout of tables, images, and formulas supports understanding
Item 2	Font, spacing, and font size make it easy for students to read
Item 3	Images of experimental procedures clarify the steps of the lab
Item 4	Heading formats and numbering are consistent throughout the module
Item 5	The sequence of the module content is easy to follow and not confusing
Item 6	The module is easy to use independently or with instructor guidance
Item 7	The observation tables and evaluation questions encourage student engagement
Item 8	Attractive, professional, and dynamic visual presentation

All assessment results were analyzed using a 1-to-5 Likert scale. The product rating scale can be seen in Table 3.

Table 3. Product Rating Scale

Score	Category
5	Very Good
4	Worth It
3	Fairly Good
2	Not Recommended
1	Unacceptable

After obtaining the data from the expert validation results, the researchers then processed the data using Aiken's formula to determine the product's feasibility level. Subsequently, the calculation results were classified into feasibility categories according to the established criteria. Presented below is Aiken's formula for calculating the product's feasibility level along with the feasibility criteria for the developed module.

Aiken's Formula:

$$V = \frac{\sum s}{n\,(c-1)} \quad (1)$$

Table 4. Product Acceptability Criteria

Range	Category
0.68–1	Highly suitable
0.34 – 0.67	Suitable
0 – 0.33	Not suitable

Table 4 presents the product feasibility criteria used to determine the evaluation categories following the subject matter expert validation and media expert validation processes. Assigning these categories helps illustrate the level of feasibility of the developed product, thereby determining whether the product is suitable for use.

Next, to determine the practicality of the experimental module, a student response questionnaire was used. Data processing employed a percentage formula to determine the product's practicality level. The results were then classified into practicality categories based on the established criteria. The following presents the percentage formula along with the practicality criteria for the developed product.

Percentage Formula:

$$Persentase \frac{skor\ total}{skor\ maksimal} x\ 100\ \% \qquad (2)$$

Table 5. Product Practicality Criteria

No	Level Achievement	Category
1	90–100%	Excellent
2	75–89%	Good
3	64–74%	Fair
4	55–63%	Poor
5	0–54%	Very low

Table 5 presents the product feasibility criteria used to determine the rating categories following the subject matter expert validation and media expert validation processes. Assigning these categories helps illustrate the level of feasibility of the developed product so that it can be determined whether the product is suitable for use.

RESULTS AND DISCUSSION

The analysis phase is the initial step aimed at identifying needs [38], user characteristics [39], and existing problems in the learning process [40]. In this study, the analysis phase was conducted through interviews with the lecturer in charge of the Materials Physics course to obtain firsthand information regarding learning conditions in the Physics Education Study Program. The interview results indicated that, to date, no experimental modules utilizing natural materials have been available, particularly those integrating the concept of green synthesis into laboratory activities. This finding underscores a genuine need for the development of natural-material-based experimental modules, so that the modules developed can provide a more contextual, relevant, and up-to-date learning experience aligned with advancements in environmentally friendly materials research.

The design phase is a planning process aimed at producing an initial product design that meets the needs identified in the analysis phase [41]. In this phase, the researcher begins to determine the module's structure, design the flow of experimental activities, and compile key components such as supporting materials and the module's initial layout. All designs are systematically organized to ensure the module is easy to understand, engaging, and relevant. The result of this design phase is a preliminary draft of the green synthesis experimental module using Cermai leaf extract, which will later be developed and refined in the next phase.

The development phase is the process of creating the product based on the design developed in the previous design phase [42]. In this phase, researchers begin to fully realize the experimental module in a more comprehensive form, encompassing content, visual presentation, and the completeness of supporting components. The quality of the initial module version was then tested through a validation process by experts to ensure that the materials, media, and presentation within the module met the standards of suitability. The results of the expert validation were subsequently revised to ensure suitability for use; the experts' suggestions and feedback were then addressed and incorporated, as shown in Tables 6 and 7.

Table 6. Revisions to the Experimental Module Based on Expert Content Validators

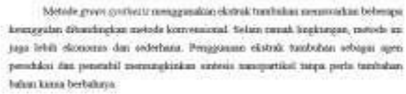
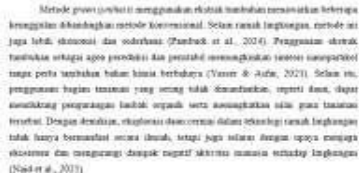
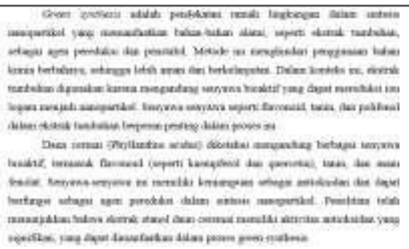
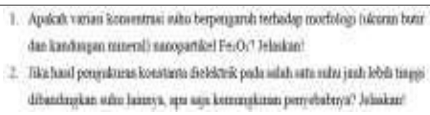
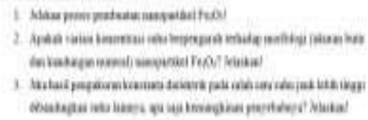
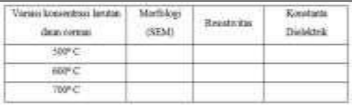
Input from Content Expert Validators	Before Revision	After Revision
Add information related to environmental issues		
	The previous experiment module did not include environmental issues	After revision, environmental issues have been added to the module
Add references for each theoretical framework cited		
	The previous experimental module did not include references for each theoretical framework cited	After revision, references for each theoretical framework have been included, making the module more focused
Add evaluation tasks in accordance with the objectives of the lab		
	Before the revision, there were only two evaluation questions	After revision, there are 3 evaluation questions that align with the objectives of the lab

Table 7. Revision of the Experimental Module Based on Feedback from Media Experts

Input from Media Expert Validators	Before Revision	After Revision
Image resolution needs to be improved further		
	Before revision, the image resolution still appears blurry and unclear	Before revision, the image resolution still appears blurry and unclear

Rewrite the table to make it clearer what is being varied		
	Before the revision, the module table only showed the temperature variations used	Before the revision, the module table only showed the temperature variations used

Variasi konsentrasi larutan daun cermai	Morfologi (SEM)	Resistivitas	Konstanta Dielektrik
500°C			
600°C			
700°C			

Variasi			Morfologi (SEM)	Resistivitas	Konstanta Dielektrik
Daun Cermai	Fe_3O_4	Suhu			
2 gr	2 gr	500° C			
2 gr	2 gr	600° C			
2 gr	2 gr	700° C			

During the validation process, the researcher involved three subject matter experts, namely lecturers from the Physics Education program at UIN Mataram. The assessment used a questionnaire with a 1 to 5 Likert scale with the following descriptions: 1 = Not Acceptable, 2 = Somewhat Unacceptable, 3 = Acceptable, 4 = Acceptable, and 5 = Very Acceptable. This assessment was conducted to evaluate the suitability of the developed experimental module. Table 4 presents the detailed results of the expert validation.

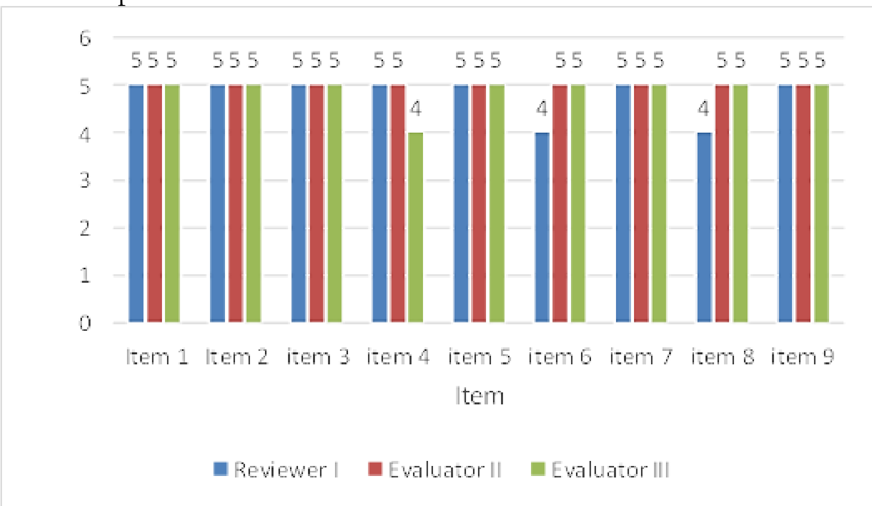


Figure 2. Results of Expert Validation of Materials

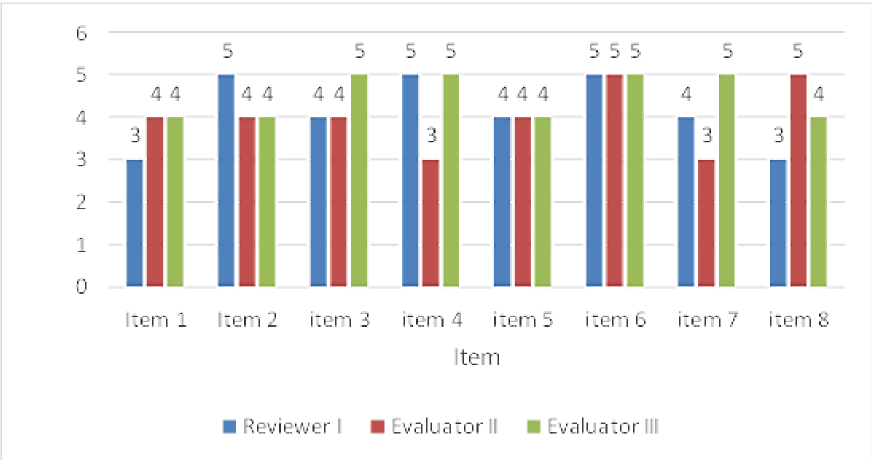


Figure 3. Results of Media Expert Validation

Based on the validation results in Figure 2, the expert evaluation of the content indicates that nearly all items received high scores in the 4–5 range. This indicates that the developed content is conceptually accurate and has excellent content suitability, although minor revisions are still needed for some items.

Furthermore, the results of the media expert validation in Figure 3 show that the evaluation scores range from 3 to 5, with a predominance of scores of 4 and 5. This indicates that the appearance, layout, and usability of the media were rated as good, with a few minor notes regarding improvements to the visual aspects. Overall, the product was deemed suitable for use in learning. The average results of the content expert and media expert validation can be seen in Table 8.

Table 8. Expert Validation Results

No	Expert Validator	Rating	Category
1	Content	0.97	Highly Recommended
2	Medium	0.80	Very Good
	Average	0.885	Highly Appropriate

Based on Table 8, the validation results conducted by subject matter experts and media experts indicate that the developed module falls into the "Highly Suitable" category for use. Subject matter experts assigned a score of 0.97, indicating that the content, depth of material, and alignment with learning objectives were rated as excellent and highly relevant. Meanwhile, the media expert gave a score of 0.80, indicating that the module's visual presentation, design, appeal, and readability also fall into the "Highly Recommended" category. When averaged, the overall score reaches 0.885, so the experimental module is generally deemed highly recommended as instructional material to support the learning process. These results confirm that the module has met quality standards in terms of both content and media before being pilot-tested with students.

The implementation phase is the process of applying the developed product to actual learning situations [43]. In this phase, the experimental module, which had been validated by experts, was then pilot-tested to determine its practicality and applicability for users—specifically, seventh-semester students in the Physics Education Program. This trial aims to ensure that the module is truly usable, easy to understand, and capable of supporting students in conducting green synthesis experiments using Cermai leaf extract.

During the implementation phase, seventh-semester students in the Physics Education Program at UIN Mataram began testing the developed experimental module. The trial took place on November 6, 2025, at the UIN Mataram integrated laboratory under the direct supervision of the researchers. At this stage, students not only read and understood the module's content but also directly carried out practical activities in accordance with the steps outlined in the module. The purpose of these practical sessions was to determine to what extent the module could assist students in understanding procedures, concepts, and the analysis of experimental results, both independently and in groups. Through this activity, an initial assessment was obtained regarding the module's effectiveness in supporting experiment-based learning processes.

Figure 4. Experimental Module Trial

The evaluation phase is the final stage in the ADDIE model, aimed at assessing the effectiveness of the learning outcomes or the developed learning product [44], the module developers conduct an evaluation process to determine the quality and practicality of the module after implementation. The evaluation used is formative evaluation, which is conducted during the development process to improve and refine the product before it is used more widely. In this stage, the researcher distributes a student feedback questionnaire to gather input regarding the clarity of the material, the visual appeal, ease of use, and the module's effectiveness in helping students understand experimental procedures. The results of this formative evaluation serve as a crucial foundation for examining every aspect, such as the clarity of instructions, visual appeal, ease of use, and content relevance to provide a more detailed picture of the module's quality. Thus, this detailed analysis highlights the strengths and weaknesses of the module across each indicator, making the evaluation results more informative and serving as a basis for more targeted improvements, thereby enabling the experimental module to achieve optimal quality.

The results of the student response survey aim to determine the practicality of the experimental module that has been developed. The survey analysis results show that the module received a score of 95%, which falls into the "very good" category. This percentage indicates that students found the module easy to understand, clear in presenting the steps, and helpful in conducting laboratory activities independently. Additionally, this positive feedback reflects that the content, layout, and usage instructions within the module were deemed relevant, effective, and supportive of the learning process. Thus, the results in Table 5 confirm that the experimental module has a high level of practicality and is suitable.

Students also noted that the module was engaging, easy to follow, and helpful in understanding laboratory concepts, although some suggested adding illustrations and example problems to make the material clearer. This qualitative data provides a deeper insight into the module's strengths and weaknesses, serving as a foundation for future product improvements.

CONCLUSIONS

Based on the research results, it can be concluded that the development of the green synthesis experiment module using Cermai leaf extract using the ADDIE model successfully produced a module that is suitable and practical for use in Materials Physics learning. The analysis phase indicated a real need for natural-material-based experiment modules in the Physics Education Program. During the design and development phase, the module was successfully designed and validated by a content expert with a score of 0.97 and a media expert with a score of 0.80, both of which fall into the "highly feasible" category. Furthermore, the results of the implementation through a pilot test with seventh-semester students showed a practicality level of 95% in the "very good" category, indicating that the module is easy to use, engaging, and helps students understand the concept of green synthesis. Thus, the developed experimental module has met the criteria for feasibility and practicality and can be recommended as an innovative teaching material for laboratory-based learning in the Physics Education Program.

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