Development of Phytoremediation Module Based on Research Results

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Abstract: This study aims to develop and examine the validity of module development based on the research outcome on Phytoremediation. This phytoremediation material was one of the topics in the Biotechnology course studied by Biology Education students. The research method used research and development with the ADDIE model, namely analysis, design, development, implementation, and evaluation. However, this research was conducted until the development stage. The data were the percentage of product validity from validation sheets and the responses obtained from validation results by material and media experts. Limited trials were subsequently conducted on students of Biology Education who had taken Biotechnology classes. The data analysis technique used qualitative and quantitative descriptive analysis. The validation results based on the material experts were 79.74% (very valid), while based on the learning experts, it was 97.50% (very valid). Then, the results of small group trials obtained a percentage of 90.70% (very valid). moduleModules development was very valid and feasible to be implemented. This module was expected to raise the students' effectiveness in attending lectures because the source of teaching materials was more applicable.

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Introduction

Increasing environmental problems due to limitations of learning sources that support the solution of environmental problems. Learning sources and education processes should be a medium to build student's attitudes and caring for the environment provide insufficient information about environmental problems. The Ministry of Environment and Forestry states that the materials and implementation methods of environmental education are less supportive of solving environmental problems in the respective regions (Prasetiyo & Perwiraningtyas, 2017). Thus, environmental-based learning is required to solve these problems. The development of media or teaching materials, as well as educational methods containing materials about problems and the solution of environmental problems, are necessary (Prasetiyo & Perwiraningtyas, 2017). Achievement in creating quality human resources is influenced by two factors: internal and external factors. External factors can be obtained from the teaching materials used by students in the learning process. The use of teaching materials aims to assist students in obtaining information.

One of the teaching materials that students can use is a module (Wasiatus et al., 2016) teaching materials are the resources a teacher uses to deliver instruction, and each teacher requires a range of tools to draw upon in order to assist and support student learning. These materials play a large role in making knowledge accessible to a learner and can encourage a student to engage with knowledge in different ways (Rozalinda et al., 2018). The module is one of the learning resources that are arranged systematically with the aim that students can study independently (Mustika et al., 2023). The benefits of using modules in learning are (1)

helping to instill a sense of responsibility for the material to be studied; (2) making learning more effective and efficient because it is tailored to understanding and abilities; (3) encouraging students to study independently; and (4) helps achieve a consistent understanding of the material for each student (Darwis et al., 2019). The selection of the type of instructional media to be utilized is one of the factors that plays a crucial role in achieving the learning objectives (Mutiara D Cahyani dan Tania A Gusman, 2023).

Biotechnology is a compulsory subject at the Department of Biology Education, Islamic Universiti of Riau. This subject focuses on the environment and techniques to overcome environmental problems. However, after interviewing some students who have taken Biotechnology, it was found that the teaching materials were limited, including the materials about phytoremediation. Phytoremediation is a sub-material for students to understand and apply biotechnology in their environment and to overcome the problems that exist in the environment with plants. It is in accordance with what (Desti et al., 2020) expressed that module for Biotechnology subjects for biology students can help students understand learning materials in the learning process.

Based on the interview, it was revealed that it is difficult to find the teaching materials and books used as alternative sources for learning biotechnology as well as the ones that contain environmental problems. The student learned from articles, national and international journals, and other various scientific books. Unfortunately, students had difficulty to understand the material because the explanation of the research stages was generally short and lacking in detail. As a result, students needed to collect many sources. In addition, the language utilized in the books and journals is usually intricate, so the students should read them repeatedly. Moreover, students need more time to translate and understand the articles, especially international articles.

The novelty of this research lies in the developed module that originates from the results of our research, which is incorporated into a specific discussion chapter. Additionally, the research undertaken is also derived from the Riau province region. The limited teaching materials for the Biotechnology class are feared to result in ineffective lecture activities. As a result, the materials are difficult to understand and easily forgotten by the students. It is in line with what (Sukasni & Efendy, 2017) expressed that Biotechnology is thought to be one of the most difficult disciplines, and students detest it. The lack of references has an influence on the learning process in this case. It is a difficulty that students in Indonesia confront.

There was a need for the development of teaching materials that include environmental problems as a source of independent learning for students to understand the materials easily and increase awareness of efforts to preserve the surrounding environment. The development of creative and attractive teaching materials, as well as materials appropriate to the environment, society, and culture, were required to improve education quality. This statement is supported by the results of research by (Wasiatus et al., 2016) which reveal that the developed environmental biotechnology module effectively improves students' learning outcomes. Conversely, the use of conventional materials can reduce the learning quality. The purpose of developing this module based on environmental research results is to enable students to better understand the surrounding environmental conditions, making them more sensitive to the environment. Learning with modules that are linked to real-life issues is expected to be more meaningful for students.

Research Method

This research was conducted at FKIP Universitas Islam Riau. This research method used research and development with the ADDIE model, which Dick and Carry developed.

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This model consisted of five stages: *analyze*, *design*, *develop*, *implement,* and *evaluate* (Mulyatiningsih, 2014). However, this research was conducted until the development stage, which was small group trials. This research was limited to the development stage due to time constraints. The implementation and evaluation stages will be continued in the subsequent research to achieve more optimal results. The instruments in this research were validation sheets and students' response questionnaires. The validation sheets and questionnaires consisted of columns showing the scores of the aspects validated. The results of validation were analyzed to find out the validity of the product developed by using qualitative and quantitative descriptive analysis. (Akbar, 2013) proposes the formula for analyzing the validity level from the expert validators, users, and group tests; it is stated as below.

$$P = \frac{Tse}{TSh} \times 100\%$$

Description:

P = Percentage of validity

Tse = Total empirical score (achieved)

TSh = Maximum expected total score

After the analysis and obtaining the percentage, the results were adjusted or confirmed by the validity criteria displayed in Table 1.

Table 1. Validation Criteria of Product Evaluation Results

Scale Percentage	Criteria
76% - 100%	Very valid, or can be used without revision
51% - 75%	Valid, or can be used with minor revision
26% - 50%	Invalid, it is recommended not to be used because it needs a major revision
0% - 25%	Invalid, or may not be used.

Source: researchers' modification from (Akbar, 2013) and (Riduwan, 2015)

Results and Discussion

Conceptually, the existence of this phytoremediation module becomes one of the teaching materials that can provide additional information regarding methods or the use of plants in addressing environmental pollution. Additionally, this research can also stimulate further studies in the field of phytoremediation. The practical implications of a developed phytoremediation module can be used as an educational tool to enhance the understanding of students, practitioners, or the general public about the importance of phytoremediation in addressing environmental pollution issues. It can raise awareness of natural solutions to environmental problems, and It serves as a practical guide for professionals or practitioners in the environmental field, providing step-by-step instructions on the implementation of phytoremediation. Policymakers can utilize this information to design and implement more effective policies related to environmental pollution management. It can promote sustainable practices by introducing plant-based solutions to address environmental pollution. It supports environmentally friendly and sustainable approaches to dealing with negative environmental impacts. There may be stimulation of innovation and technological development related to phytoremediation. It can encourage new research and development in the use of plants to clean the environment from various types of pollutants. It is in accordance with what (Istiqomah et al., 2022) expressed, statement that the material on environmental pollution presents contextual issues that are closely related to the daily lives of learners. In its application, learners will focus on solving actual environmental problems. This aligns with the opinion of (Parmin & Peniati, 2012) stating that published research results in journals are

suitable references for module development because they are more applicable and meet contemporary criteria, making them effectively used in teaching. It is in accordance with what (Maison et al., 2019) said that instructors will need to provide learning resources that will help students reach the learning objectives that they must meet in the Biotechnology Subject. It implies that the lecturer plays a critical role in the learning process. It is consistent with the belief that instructors have a critical influence on the educational process and results.

Analysis Phase

At this phase, the researchers conducted literature studies and interviews with students who had taken Biotechnology class. The stage of curriculum analysis were accomplished to determine the materials developed for teaching by analyzing Semester Learning Plan (RPS) in Biotechnology class. (Tia Yuliana, Milya, 2020) stated that RPS analysis can be carried out to determine the suitability of the content and lecture materials needed in module development. It aligns with the findings of (Budiman et al., 2022), which emphasize that needs analysis is an initial foundation for developing curriculum content, teaching materials, and teaching methods that can enhance student motivation and success. It is in line with the statements by (Cahyadi, 2019) and (Fauziah et al., 2021) where the preliminary analysis aims to gather initial data as the foundation for module development. The following are results of the analysis:

1) Learning sources: The application of biotechnology in the environmental field.
2) Materials: Bioremediation, phytoremediation, biofuel, and waste treatment.
3) Expected ability: Students master the concepts and are able to understand applications about biotechnology and the environment.

Teaching materials developed for phytoremediation include various plants that can be used as phytoremediators, phytoremediation mechanisms, and wastes that can be overcome by phytoremediation also, phytoremediation can be used as the information and solutions for environmental problems caused by the waste of PETI (illegal gold mining) activities in Riau Province. The module on phytoremediation can also be applied as a source for students to find out problems in the surrounding environment. Based on the results of interviews, most students merely recognized the environmental problems in Riau, which were limited to air pollution as a result of forest fires and oil palm.

The next step was the analysis of learning sources through interviews based on the learning experiences of students who had taken Biotechnology. This development aims to align with students' needs and enhance their understanding. It is consistent with the assertion made by (Ardiansyah et al., 2016) that modules developed by educators can be adjusted to students' characteristics, such as social environment, culture, geography, pre-existing skills, interests, and backgrounds. The results of the interview revealed that teaching materials that could be used as an alternative learning resource were still limited. This limitation demanded that the students find learning sources from articles and national and international journals. Consequently, the students needed a considerable amount of time to understand the material since they had to translate sources. Needs analysis not only aids in evaluation but also helps identify requirements for introducing changes that align with students' needs (Boroujeni et al., 2013). It is in accordance with what (Wijana, 2015) said that student needs analysis is important to be a point of view in teaching because it is through needs analysis that the lecturer, students, teaching materials, and teaching procedures can all be connected harmoniously to improve the learning process of students and to build the character and soft skills of students, as well as to support students in learning.

Design Phase

At this stage, product design was conducted in accordance with the subject matter and the final ability, which had been classified into more specific indicators and learning objectives. The materials included in the module were the results of this research, which were supported by relevant previous research and various facts about phytoremediation, phytoremediator plants, PETI, and environmental problems that can be overcome by phytoremediation.

Table 2. Design Module

No	Module Components		
1.	*Cover*		
2.	Introductory Section	1) Preface 2) Table of Contents 3) Introduction 4) Concept Map	
3.	Core Section	1) Learning Activity 1: Phytoremediation 2) Learning Activity 2: Box Waste 3) Learning Activity 3:Phytoremediation Application with Fragrant Root 4) Practicum Worksheet	Each learning activity consists of: (1) Descriptions of Material (2) Summary (3) Media Sources (4) Individual Quiz
4.	Closing Section	1) Follow Up 2) Expectations	
5.	Bibliography		
6.	Glossaries		
7.	Answer Keys		
8	Back Cover		

Source: Researchers' modification from (Fitriyati et al., 2015) and (Ristekdikti, 2017)

Development Phase

The steps at this stage were:

1) Module validation

It aimed to examine the concept, the precision of the concept, grammar, and the format of the presentation of the module. Module validation was conducted by reviewing the materials for Biotechnology courses from the experts who were competent in their fields.

2) Module Revision

The revision was conducted based on the inputs and validation results from experts. It was completed to compose more feasible modules so that it could be tested on groups of students.

3) Small group trials

The trials were made to test the modules to students taking Biotechnology course by providing assessments, comments and inputs to the module. The results of small group trials were utilized to revise the product design.

Data presented in this study were the analysis results of the percentage of the validation results derived from the material experts, learning experts, and the results of a limited trial with a small group of students equipped with comments and suggestions.
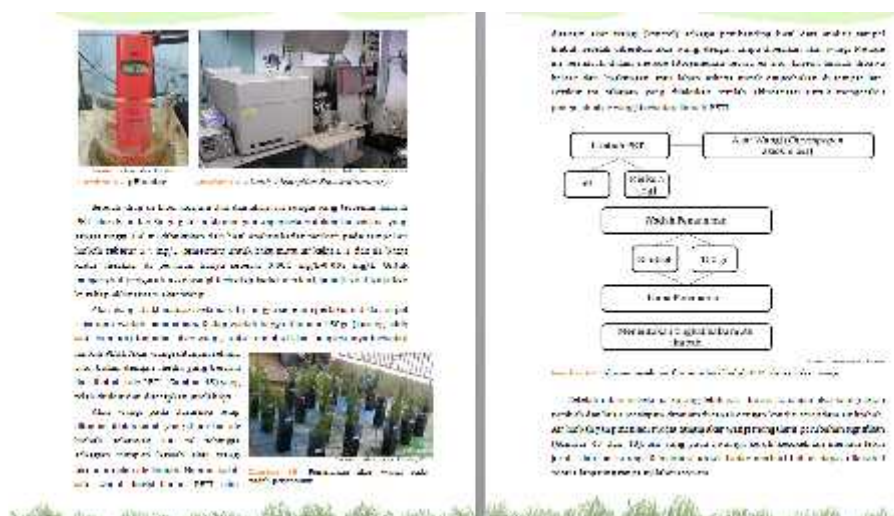
Figure 1. Module Content that Incorporates Environmental Research Results

Results of Module Validation by Material Experts

In this study, the material expert validator who evaluated the product was one of the postgraduate lecturers at Islamic University of Riau who had the expertise in the field of Biotechnology.

Table 3. Quantitative Data of Product Validation Results from the Material Expert

No	Aspect	Average Percentage (%)	Category
1	Conformity of the Principle of Teaching Materials Development	91.67	Very Valid
2	Content Suitability	77.27	Very Valid
3	Presentation	75	Valid
4	Language	75	Valid
	Average score	**79.74**	**Very Valid**

The expert validation was conducted once because the evaluation results of the module were categorized as very valid. The product evaluation by the material validator covered four aspects: Conformity of the Principle of Teaching Materials Development, Content Suitability, presentation, and language. The highest percentage was found in Conformity of the Principle of Teaching Materials Development, with an average of 91.67% (very valid). That is because the module contains materials related to the learning achievements listed in the RPS of the biotechnology course; it provides materials sequentially and provides adequate materials in accordance with the objectives to be achieved. It is in accordance with the statement of Sungkono (Lasmiyati ; Idris Harta, 2014) that the material in the module is selected and developed based on the competencies to be achieved and systematically designed to achieve learning objectives.

Furthermore, it can be seen that the presentation aspect obtained the lowest percentage, which is 75% (valid). The module is presented systematically and consists of an introduction, contents, evaluation, and closing in accordance with the guidelines for the preparation of learning (Ristekdikti, 2017) The materials provided in the module were presented sequentially, completed with questions and answers and illustrations related to the materials. This agrees with (Wahyuni & Puspari, 2017), who found that the modules developed must be presented coherently and logically; it should be supported with illustrations that are appropriate to the material, practice questions in each chapter, concept

maps, summaries at each end of the chapter, answer keys at the end of the book, and references to tables and figures. It follows the statement of (Fauziah et al., 2023), which states that a module is considered valid in terms of the presentation components when the module's presentation techniques are systematic and the latest research results support the content within the module. The delivery of learning in the module is systematic. A systematically presented module provides ease of use and understanding of the material being studied, allowing students to optimize their learning both in the classroom and independently during lectures.

Then, the language aspect of the product also obtained a percentage of 75% with a valid category. The module did not use complicated terms without explanation in the glossary; conversely, it utilized simple sentences and was easy to understand. It is in accordance with the rules of the National Education Standards Agency (BSNP) that the language used in the module must be in accordance with the development of students' thinking, grammar, and spelling used based on Indonesian language rules (EYD). In addition, the module should apply accurate and appropriate terms, symbols, scientific names and foreign names (Wahyuni & Puspari, 2017)). Based on the validation results from the material expert, the modules obtained an average of 79.74% (valid) and to be used with minor revisions.

Validation Results from Learning Experts

In this study, the validator who assessed the products was one of the lecturers in Biology Education FKIP University of Riau who had the expertise in the field of education.

Table 4. Quantitative Data Results of Product Validation by Learning Experts

No	Aspects	Average Percentage (%)	Category
1	Module Format	100	Very Valid
2	Language	100	Very Valid
3	Presentation	87, 50	Very Valid
4	Graphic	100	Very Valid
5	Benefits	100	Very Valid
Average		**97.50**	**Very Valid**

The validation from the learning experts was conducted gradually, with one assessment in the last two meetings. In other words, the module was revised according to the comments of the learning expert. Then, it was evaluated in order to obtain the feasibility of the module being developed. The validation by the learning expert included five aspects, namely the module format, language, presentation, graphics, and benefits.

Four aspects of the product obtained a percentage of 100% (very valid), namely the module format, language, graphics, and benefits. The format aspect got a value of 100% because the titles were clear, easy to understand and described the contents. Besides, the high percentage was also because this product contained learning outcomes that were expected to be mastered by students after using the module. Learning outcomes were included in the module and presented in the introduction. This is based on guidelines for the preparation of teaching modules from (Ristekdikti, 2017), that the introduction to the module should include a brief description, relevance and learning outcomes.

In addition, sub materials were arranged systematically to make it easier for students to understand the material order. This module also contained a concept map at the beginning of the module. Concept maps can describe content and provide important information between topics so that modules can be easily understood by students. Furthermore, the language aspect also obtained a percentage of 100% (very valid) since the language fulfilled

good and correct Indonesian rules; the information conveyed was clear and easy to understand and the language was utilized effectively and efficiently (clearly and briefly). The module must be written communicatively, according to the standard Indonesian and the students' development stage. It should not to use complicated terms without including them in the glossary (Wahyuni & Puspari, 2017).

Furthermore, the graphic aspects got a percentage of 100% (very valid). This is because the modules are in accordance with the standard module sizes that have been set. The module has a thickness of more than 40 pages and a size of 21 cm x 29.7 cm (A4 size) (according to one of the module formats by UNESCO contained in the teaching module preparation guide). In addition, the layout, type, and size of letters on the cover are also good, even though there are no specific rules about it. It is supported by the results of the validation which shows that there is no need to do a major revision of the layout, type, and size of letters on the cover even though there are improvements to the title. Similarly, the aspect of benefits got a percentage of 100% (very valid) because the module can be used as an alternative teaching material for students. The module also contains practical worksheets that students can use to do phytoremediation test practicum, which is equipped with steps and guidelines for writing the practicum report.

The presentation aspect obtained the lowest percentage for, 87.50% (very valid). The materials contained in the module were presented coherently, from basic concepts to more complex concepts. This result confirms the statement (Wahyuni & Puspari, 2017) hat the materials in a module must be presented in a complete, coherent, and logical manner, supplemented by supporters such as illustrations in accordance with the material discussed. The presentation aspect in this module has been fulfilled because the materials are presented completely and systematically, according to the guidelines for the preparation of learning tools (Ristekdikti, 2017). Hence, based on the results of validation with this expert, it can be concluded that the learning module in the phytoremediation material is very valid and feasible to use and tested.

Results of Limited Trials

The trial was conducted on 6th-semester students at the Biology Education Study Program FKIP UIR. It was intended to obtain an overview of students' responses to the prototype of the module through comments and suggestions as well as students' assessment of the product.

Table 5. Results of Analysis of Questionnaire Student Responses to Module

No	Indicators	Average Percentage (%)	Criteria
1	Module Format	89.58	Very Valid
2	Language	85	Very Valid
3	Presentation	91.41	Very Valid
4	Display	93.75	Very Valid
5	Benefits	93 , 75	Very Valid
	Average	**90.70**	**Very Valid**

The trials in small groups of students obtained an average percentage of 90.70% with a very valid category and without major revisions.

Table 6. Qualitative Data from the Small Group Trial Results of Students

Respondents	Comments and Suggestions
1	The module is excellent, but it's better to improve the *cover*
2	It is better to enrich the materials.
3	This module is good. Both writing and drawing can be applied.
4	The module is quite interesting and easy to understand.
5	It should be just one type of quiz.

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6	It should be noted not to use monotonous colors. Pay attention to errors in printing, typing and spelling.
7	The module is excellent and interesting
8	There are a number of images with *backgrounds* darkso the picture quality is not good

The module was designed according to the learning tools guidelines of (Ristekdikti, 2017) and RPS of Biotechnology course, various relevant reference books, and research journals. The final product was validated by several experts, such as material experts and learning experts and then it was tested on the students in small groups. This validation aimed to determine the level of eligibility, errors and deficiencies in the module as well as the responses and suggestions from experts and students so that the module is valid as teaching materials. The module assessment by students included five aspects: module format, language, presentation, display and benefits.

The results for the aspect of appearance and benefits are as much as 93.75% (very valid). The aspect of display obtained the highest score because the module applied standard font types and sizes in writing scientific papers, the layouts are attractive and related to the materials, and it was also completed with fully colored-illustrations or images. The results of this analysis indicate that the display aspect in the module has been fulfilled because the display is attractive and is accompanied by quality images.

Furthermore, the aspect of benefit also got the highest average percentage, which was 93.75% (very valid). This module consisted of various features that make it easier for students to use the module without guidance from the lecturer. It means that the module is used as a source of independent learning. According to (Prastowo, 2015) a good module has instructions for learning, exercises and worksheets as well as an evaluation of the material that has been presented in the module.

The language aspect was categorized as very valid even though it obtained the lowest percentage of 85% among other aspects. The module developed in Bahasa Indonesia was quite simple. It only used complicated terms by including them in the glossary, and there were no glaring errors in the module, including typographical errors and typos or wrong letters. It is supported by (Prastowo, 2015) who asserts that readability in textbooks includes five things, namely using good and correct Indonesian, terminology obeying EYD, clarity of the language used, language suitability, and readability. The same thing was also stated by(Nurul Laili Rahmawati , Sudarmin, 2013) that communicative language will make students understand the learning material. A similar statement is also made by (Winatha, 2018) which stated that e-modules using everyday conversational language or simple language can create the impression that the user is directly communicating with the teaching material.

Based on the results of the trial, students gave positive responses to the module because teaching materials specifically for biotechnology courses were very limited and the modules developed had material presentations that were easily understood by students, accompanied by proportional images of good quality. Another advantage of the module is that there is a brief description of the strengths and weaknesses of the module, as well as learning outcomes so that students know the abilities that must be achieved. The module also provides clear instructions for using the module. In addition, the module is equipped with research results and discussion of problems in the environment around students, as well as worksheets that contain detailed practicum guidelines along with the format of writing the report. A variety of information and clear instructions on what to do can help students use the

module when they study independently so that they can improve their understanding of the phytoremediation material and its application.

Conclusion

Based on the results of the research, it can be concluded that the prototype of learning modules developed for phytoremediation material is categorized as very valid, and it can be used as an alternative for independent learning. The results of module validation from the material experts was 79.74% (very valid), the result from learning experts was 97.50% (very valid), and the average result of the feasibility test was 90.70%, which was categorized as valid.

Recommendation

The recommendation for further research can make variations in the types of phytoremediation plants, the duration of the phytoremediation process, and the effectiveness of other heavy metals. Furthermore, Biology lecturers can be done to determine the effectiveness of the product by implementing modules that have been developed in lectures and by evaluating learning outcomes after using the module.

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