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Development of Booklet on Phytoremediation of Tapioca Wastewater Using Aquatic Plants as a Learning Resource for Environmental Change

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Abstract

This study developed a learning resource booklet on phytoremediation of tapioca wastewater using aquatic plant. The development research employed the Research and Development (R&D) method using the ADDIE model. Conducted at Laboratory of the Biology Department UNNES and SMA Negeri 1 Sigaluh,. The research aimed to create a valid, practical, and effective learning tool. Two validators assessed the booklet's validity, while teachers and students evaluated its practicality via questionnaires. Student learning outcomes, measured through pre- and post-tests, determined effectiveness. The booklet demonstrated high validity, achieving 92,86% for content and 90% for media. Practicality was also high, with teachers rating it 81,25% and students 89,69%. Critically, the booklet significantly improved student learning outcomes. Average pre-test scores of 32,09 rose to 79,55 on the post-test, with 80% of students achieving mastery, exceeding the school's minimum classical completeness criteria. These results confirm the booklet's effectiveness in enhancing student understanding of environmental change, specifically phytoremediation. The conclusion of this research is that the booklet on phytoremediation of tapioca industry liquid waste using aquatic plants is highly valid, practical, and effective as a learning resource for the material on environmental change.

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INTRODUCTION

Education is a crucial long-term investment for the progress of a nation. In facing global challenges, education is key. Quality education will equip individuals with the skills and knowledge to create a sustainable future. According to Mujidiatama and Husamah (2024), through education, students can develop their character, skills, and knowledge that will influence the direction of social, economic, and environmental development in the future. The core of education is a dynamic teaching and learning process, which involves interaction between teachers, subject matter, and students.

An effective teaching and learning process requires optimal interaction between all teaching components. This interaction can be facilitated in various ways, one of which is by providing adequate facilities and infrastructure. Learning resources are one of the facilities that must be owned by educational units, according to the Association for Education and Communication Technology in Samsinar (2019), defining learning resources as anything that can be used in the learning process, whether in the form of data, humans, or objects. The results of an interview with Septyaningsih S.Pd, a Biology teacher at SMA Negeri 1 Sigaluh, Banjarnegara Regency, indicated the need for learning resources as supporting infrastructure for the learning process at school. The learning resources used are still limited to textbooks and LKS (Student Worksheets) provided by the school. The limited availability of interesting and interactive learning resources hinders the creation of a conducive learning environment. In addition to creating a conducive learning environment, relevant learning resources are expected to hone students' critical thinking skills.

In biology learning, utilizing local environmental issues in Banjarnegara Regency will serve as a bridge to connect learning materials with students' real-life experiences. One topic that can be linked to the environment is environmental change. A potential water pollution issue in Banjarnegara Regency is water pollution caused by tapioca waste. The selection of this ecological problem is also influenced by the teacher's need for learning resources that raise environmental issues around students. The presence of schools near the Serayu River makes this river a focal point of water pollution problems in Banjarnegara.

Booklets have proven to be effective learning resources in creating an enjoyable learning atmosphere for students (Fitriasih et al., 2019). As concise, clear, and well-written sources of information, booklets are both efficient and effective tools for learning (Pralisaputri et al., 2016). Employing Booklets as a learning resource can increase the effectiveness of student learning outcomes in the learning process (Nurani et al., 2022). An attractive Booklet design with varied visuals, as well as brief and clear information delivery, can increase students' interest in learning. The flexibility of the Booklet size and format allows students to study the material anytime and anywhere. Employing Booklets as an additional learning resource can significantly improve student learning outcomes in biology subjects.

The utilization of research findings as a biology learning resource, aligned with the Merdeka Curriculum's learning outcomes, aims to equip students with the ability to respond to global issues and actively contribute to problem-solving. This research-based learning resource will be visualized in the form of a booklet. By reading the booklet, students will acquire knowledge about solutions to pollution problems and can generate new ideas for addressing environmental pollution. Thus, learning will run more smoothly and students will be more active in class, this happens because they understand the material being studied better. Based on the review above, the researcher conducted a study entitled "Development of a Booklet for Phytoremediation of Tapioca Liquid Waste with Aquatic Plants as a Source of Learning Environmental Change."

RESEARCH METHOD

The type of research used in this study is research and development (Research and Development), which is a method for producing certain products and testing product effectiveness. This research model uses the ADDIE model, the ADDIE model is an abbreviation for Analysis, Design, Development, Implementation, and Evaluation. The research method used to obtain field data is experimental research. Field data is in the form of environmental pollution parameter data on tapioca waste. Experimental research

was conducted by placing aquatic plants in a tub filled with tapioca liquid waste then, waste pollution parameter data before and after the phytoremediation process for 10 days will be examined in the laboratory. The field data will be used as material for developing the booklet.

Booklet validation was carried out by experts at Semarang State University, in the form of validation by material and media experts. The practicality of the materials was evaluated through a teacher response test and a small-scale student test involving grade X students. Data collection and product trials, including an effectiveness and critical thinking ability test, were conducted with 25 grade X students at SMA Negeri 1 Sigaluh from February to May 2024. The results of the validation test and practicality test were carried out using a questionnaire according to the established indicators. The scores obtained were then averaged and converted into percentages based on the established categories, from very valid to invalid for the validation test and very practical to impractical for the practicality test. Valid and practical booklet indicators are used as learning resources if they have validity and practicality percentage assessment results of more than >80%.

The booklet effectiveness test and students' critical thinking skills were carried out using question instruments. The One Group Pretest-Posttest research design is a type of research that involves only one group and is measured twice, where a single group was assessed both before (pretest) and after (posttest) the implementation of the booklet intervention. The effectiveness test was carried out on 25 grade X students. The indicator that the booklet is effectively used as a learning resource is if the classical completeness percentage is >80%, and the student's critical thinking ability indicator must have a minimum N-Gain value with medium category.

RESULTS AND DISCUSSION

The booklet is based on research concerning the phytoremediation of tapioca liquid waste by aquatic plants. The data results show a decrease in water pollutant parameters, data is used as the main information in compiling the booklet. The booklet also provides visual documentation of the research, including photographs accompanied by complete descriptions and relevant information. In addition to containing information on the phytoremediation of aquatic plants on tapioca liquid waste, the booklet product also contains general material on environmental pollution, equipped with discussion activities and small experiments to train students' cognitive aspects.

Booklet Validity

The Validation was performed to confirm the product's alignment with its intended purpose. This involved a two-part validity test, specifically assessing both material and media validity through expert review. The Likert scale on the questionnaire is used to measure the validity of the booklet product. The score results are then averaged and converted into a percentage. The following table is an analysis of the results of the booklet product validity test.

Table 1 Booklet Validity Test Result

Description	Maximal score	Score obtained	Percentage (%)	Category
Material Expert	56	52	92,86 %	Very Valid
Media Expert	40	36	90 %	Very Valid

The results of the material validation obtained a percentage score of 92.86% which indicates that the Booklet developed is included in the very valid category. The material assessment aspects used to assess the validity of the Booklet include material/content, linguistic, and contextual aspects. The content of the material or information contained in the Booklet is the material needed by students in the material on environmental change, suitability with learning achievements in the independent curriculum, and the

relevance of the material to environmental issues around students. Material experts provide suggestions to add more general material so that students have a strong foundation before entering the main problem. Istifarida et al., (2017) emphasized that learning media as a source of learning must contain clear and complete content or information so that the learning and teaching process of the material is delivered effectively. Media experts obtained an assessment result of 90%, which signifies that it is considered very valid in media. Aspects assessed by media experts include design and appearance aspects. Media experts provide suggestions to replace the image on page 1 with an image that eliminates the environmental pollution situation and add numbers to each image sequentially. This is in line with Surasmi's research (2016) which emphasizes the importance of multi-representation in learning, where the combination of text, images, and graphics can improve students' memory.

Based on the analysis of material experts and media experts, the Booklet on phytoremediation of aquatic plants on tapioca liquid waste is suitable for use with revisions.

Practicality of Booklet

The practicality test of the booklet was obtained through the assessment of teacher and student responses, using the Likert Scale on the response assessment questionnaire. The recapitulation of the results of the practicality test of the booklet by teachers and students can be seen in the following Table 2.

Table 2 Bookler Practicality Test Result

Description	Maximal score	Score obtained	Percentage (%)	Category
Teacher	80	65	81,25 %	Very Pratical
Students	280	251	86,69 %	Very Pratical

The results of the teacher response questionnaire assessment, the practicality value obtained was 81,25% and was categorized as very practical. The results of the student response test assessment of the Booklet as a learning resource were 89,69% included in the very practical category. Based on the two response tests, it can be concluded that the Aquatic Plant Phytoremediation Booklet on Tapioca Liquid Waste is very practical to use as a learning resource on environmental change material. A learning medium as a learning resource is said to be practical if it is easy to use and understand by both teachers and students. Learning becomes more meaningful, interesting, fun, and useful for students and is able to increase their creativity in learning (Milala et al., 2022).

Effectiveness of Booklet

The effectiveness of the booklet product was tested in a large-scale test on 25 grade X students at SMA Negeri 1 Sigaluh. Effectiveness was measured based on cognitive aspects and increasing students' critical thinking skills. The instrument used to test effectiveness was in the form of questions used for the pretest and posttest. The results of classical completeness can be seen in the following Table 3.

Table 3 Classical Completion From Pre-test and Post-test Result

Description	Class X	
	Pre-test	Post-test
Mean	32,09	79,55
Number of students who completed	0	20
Number of students who did not completed	25	5
Classical Completense (%)	0 %	80 %

Data on student learning outcomes after going through the learning process using Booklet as one of the learning resources, the average posttest score increased compared to the pretest. In the pretest, the average score was 32.02 out of 25 students and no students got a score above the KTTP, while in the posttest, the average was 79.55 out of 25 students with 20 students getting a score above the KTTP. The results of the posttest obtained by students had a completeness score of 80%.

Based on the classical completeness value of students, it can be said that the use of the Booklet on phytoremediation of tapioca industrial liquid waste with aquatic plants is effective in improving student learning outcomes. Aspects in the learning process must be considered to achieve learning objectives. One important aspect is the provision of relevant learning materials and following technological developments. The use of learning media as a diverse learning resource can improve the quality of students' understanding of the material presented (Widuri & Ristiono, 2024).

The improvement of students' critical thinking skills was analyzed per indicator according to Ennis' critical thinking indicators which include: providing simple explanations (elementary clarification), building basic skills (basic support), concluding (interefence), providing further explanations (advanced clarification) and developing strategies and tactics (strategy and tactics). The analysis of students' critical thinking skills per indicator can be seen in the following Table 4.

Table 4 Scores for Each Critical Thinking Skill Result

No	Maximal score	N-Gain	Category
1	Elemertary Clarification	0,75	High
2	Basic Support	0,64	Medium
3	Interefence	0.60	Medium
4	Advanced Clarification	0,57	Medium
5	Strategy And Tactics	0,74	High
	Mean	0,66	Medium

The N-Gain analysis on the indicators providing simple explanations and developing strategies and tactics has the highest N-Gain value. Other indicators have a moderate N-Gain value, ranging from 0.57 to 0.64. The average overall N-Gain value is in the medium category with a value of 0.66. The observed N-gain suggests a medium enhancement of students' critical thinking capacity. A positive correlation exists between critical thinking proficiency and learning outcomes; thus, increasingly positive learning outcomes are indicative of successful critical thinking skills development. (Widiya and Radia, 2023).

Based on the results of the study and the data that has been analyzed, the booklet can be declared valid, practical, and effective for use as a learning resource on environmental change material. This booklet facilitates the development of students' analytical skills in addressing environmental challenges, their capacity to formulate innovative solutions, and their ability to translate this knowledge into tangible environmental preservation efforts. The selection of booklet media as a learning resource will increase students' interest in learning, this happens because the booklet is equipped with more attractive colored images and complete information so that students will find it easier to understand the material and not get bored during the learning process.

CONCLUSION

Based on the research results, there was a decrease in pollutant parameters in tapioca liquid waste after the phytoremediation process with aquatic plants used as materials for developing booklets. The development of the phytoremediation booklet of aquatic plants on tapioca liquid waste is valid and practical to be used as a learning resource and is effective in improving learning outcomes and students' critical thinking skills on environmental change material.

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