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Development of a Banana Peel Waste-Based Bio-Battery as a Learning Media on Voltaic Cell Material

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Abstract: This study aims to develop an experimental-based learning media in the form of a biobattery made from banana peel waste for the topic of voltaic cells. The research method used is the ADDIE development model. The analysis stage was carried out through curriculum review, observation of student needs, and identification of banana peels as a potential electrolyte material. In the design stage, a worksheet was prepared that was integrated with the procedure for making a simple biobattery. The development process included fabricating a biobattery from banana peels, assembling a simple voltaic cell, and creating an interactive learning media. Validation was carried out by material experts and media experts, resulting in an average feasibility score of 0.91 and 0.93, respectively, which are categorized as high. Practicality was assessed through a questionnaire, with small group trials achieving a score of 73.96% (practical) and field trials reaching 94.89% (very practical). Limited trials involving students in grades XI and XII showed that this media not only improved conceptual understanding of voltaic cells but also fostered environmental awareness through the utilization of organic waste. The evaluation results indicate that the biobattery learning media is suitable for use as an alternative tool for contextual and environmentally friendly chemistry practicums.

Keywords: Banana peel; Bio-battery; Biomass energy; Voltaic cell

Introduction

The world is currently facing an increasingly urgent energy crisis, where dependence on fossil fuels such as oil, gas, and coal significantly contributes to climate change. The use of these energy sources not only results in high greenhouse gas emissions but also causes air pollution and ecosystem degradation. According to the Intergovernmental Panel on Climate Change (IPCC, 2021) , the energy sector is responsible for approximately 73% of total global greenhouse gas emissions. Therefore, the search for environmentally friendly energy sources such as solar, wind, and biomass as renewable energy alternatives is crucial for the future.

Biomass energy is energy derived from organic materials such as plants, animals, or waste that are converted into electricity, heat, or fuel, Currently, technologies that utilize organic materials as energy sources—such as bio-batteries—have developed rapidly. The use of bio-batteries contributes to the advancement of sustainable energy and the reduction of waste (Haqiqi, 2023). Unused organic waste can become something useful and environmentally friendly by converting it into bio-batteries (Agustina et al., 2018).

The development of bio-battery technology is gaining increasing attention, especially with the utilization of organic waste such as banana peels. Banana peels are rich in organic compounds that can be converted into energy through bioconversion processes. Research by Alifah et al. (2022) shows that banana peel extract can generate electricity efficiently, making it competitive with conventional energy sources (Rusdiyana et al., 2022). Additionally, a study by Prasetyo & Maharani (2024) revealed that using banana

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peels as raw materials not only reduces waste but also offers an environmentally friendly alternative energy source. According to Alifah et al. (2022), banana peels contain minerals such as potassium and sodium, which can ionize and conduct electricity. Banana peels possess several advantages that make them ideal raw materials for bio-battery development. They contain polyphenols and carbohydrates, which can be converted into electrical energy through bioconversion (Pinasti et al., 2024). The electrolytes in banana peels are capable of ionizing and conducting electricity (Nurannisa, 2021), thus providing optimal durability for the battery (Baktiyar et al., 2021).

A battery is a device that can generate electrical energy by facilitating the transfer of electrons through a conductive medium (Ulfa et al., 2023) from two electrodes (anode and cathode), thereby producing electric current and voltage difference (Muhlisin, 2015). Essentially, the working principle of a battery utilizes redox (reduction-oxidation) reactions, in which the negative electrode (anode) undergoes oxidation, causing electrons on the anode's surface to be released and carried by the electrolyte ions toward the positive electrode (cathode) (Meiliyadi et al., 2023; Nur et al., 2025). This electron transfer results in a potential difference and electric current (Purwanti & Harjono, 2021; Purwanto, 2012). The development of bio-batteries using banana peel waste can be beneficial for communities that still rely on batteries in their daily lives. A battery serves as a means to directly convert the chemical energy stored in active materials (Fatimah et al., 2023) into electrical energy through redox reactions at the electrodes (Fadli et al., 2022). In research, organic waste-based bio-batteries can serve as effective learning media to teach the concept of renewable energy. Twelfth-grade students at Madrasah Aliyah Negeri 3 Pontianak can be directly involved in the process of making bio-batteries using materials that are easily found in their surroundings.

In this study, the material used in the development of the banana peel waste-based bio-battery is the Voltaic Cell. A voltaic cell is an electrochemical cell in which chemical energy from a spontaneous redox reaction is converted into electrical energy (Sutantri, 2022). A voltaic cell also consists of an anode and a cathode, where the transfer of electrons between the anode and cathode generates a movement known as electrical energy (Harahap, 2016). The voltaic cell is considered a complex topic due to its abstract concepts (Nabella & Dwiningsih, 2022). This topic includes factual, conceptual, and procedural knowledge. Moreover, the concept of the voltaic cell can be applied by developing instructional media that relate to everyday life, helping students better understand the material being taught.

Method

Place, Time and Type of Research

The development model used in this study is the ADDIE model (Analysis, Design, Development, Implementation, Evaluation). According to Mulyatiningsih (2016), "The ADDIE model is considered more reasonable and comprehensive compared to other models." This model can be used for various types of product development, including learning methods, media, and instructional materials.

The data collection method is a crucial step in research, as the primary goal of research is to obtain valid data. The data collection techniques used in this study include interviews, observations, validation, expert validation instruments, and student questionnaires.

Data Analysis Techniques

The data collected in this study consisted of both qualitative and quantitative data. Qualitative data were obtained from the expert media validation questionnaires, which included sections for suggestions and comments. Meanwhile, quantitative data were gathered from the evaluation scores provided by the experts and students' responses to the development of the banana peel waste-based bio-battery media. This research was conducted at MAN 3 Pontianak, involving twelfth-grade students in the chemistry subject. Data analysis techniques were employed to determine the validity and practicality of the banana peel waste-based bio-battery media in voltaic cell learning.

The validity analysis of the bio-battery was obtained from the validators' assessments. The bio-battery media is considered valid if it achieves a score between 0.80 and 1.00, which falls under the 'very high' criteria.

Table 1. Validity Score Table

Relevance Score	Relevance Description	Category
1	Not Relevant	Low relevance
2	Not Very Relevant	Moderately Relevant
3	Fairly Relevant	Strong Relevance

Table 2. Validity Criteria

Score	Criteria
0.80–1.00	Very High
0.40–0.79	Medium
0.00–0.39	Low

Analysis of the practicality of the banana peel waste-based bio-battery was conducted using student response questionnaires. The bio-battery is considered practical if the response score meets the criteria of more than 60% (Sugiyono, 2015).

Table 3. Practicality Scoring

Answer Choices	Criteria
Strongly agree	4
Agree	3
Disagree	2
Strongly disagree	1

Table 4. Practicality Criteria

Percentage (%)	Criteria
0–20	Not practical
21–40	Less practical
41–60	Quite practical
61–80	Practical
81–100	Very practical

Based on these criteria, the banana peel waste-based bio-battery is considered practical if the response score reaches a percentage of more than 61 to 80%, categorized as practical (Sugiyono, 2015).

Result and Discussion

Development of Bio-Battery Learning Media
Analysis

The analysis stage is the process of defining what students are expected to learn. To determine this, several activities must be carried out, including: analyzing the problem, analyzing the characteristics of the students, and determining the product to be developed: The analysis stage is the process of defining what students will learn. To determine this, several activities must be carried out, including: conducting a problem analysis, analyzing the characteristics of the learners, and determining the product to be developed; The analysis of student characteristics at MAN 3 Pontianak was conducted based on their cognitive abilities. This analysis involved examining the results of interviews with both chemistry teachers and students. The interview with the chemistry teacher focused on student responses during the teaching and learning process in the classroom, as well as the challenges encountered during the learning process.

Design

This stage aims to design and prepare the learning media. The design stage includes the development of a product design in the form of a bio-battery learning media.

Tools and Materials

The tools used in this study were: used A2 batteries, a knife, a mortar and pestle, a container, and a spatula. The materials used in this study were kepok banana peels and distilled water.

Battery Preparation

Used A2 batteries were prepared. The battery caps and outer casing were opened, then the contents were carefully removed and cleaned.

Preparation of Banana Peel Paste

In the first step, the kepok banana peel waste is thoroughly washed, then dried—either by air-drying or sun-drying. Once dry, the banana peels are cut into small pieces using scissors or a knife. The chopped banana peels are then soaked in a mixture of salt or vinegar and 50 ml of water, and left to sit for 30 minutes. After soaking, the banana peels are blended or pounded until they form a banana peel paste.

Fabrication of Bio-Battery Cell

In the process of making the bio-battery cell, the electrode rod is removed using a knife or pliers. However, before removing the electrode rod, the end of the battery is cut off to separate the cap connected to the electrode from the battery body that contains carbon. The battery is then cleaned of its carbon content by scraping the inside with a screwdriver until all the carbon is removed. Next, the battery is filled with an electrolyte paste made from mashed banana peel waste. Finally, the electrode section is sealed, and the battery voltage is measured.

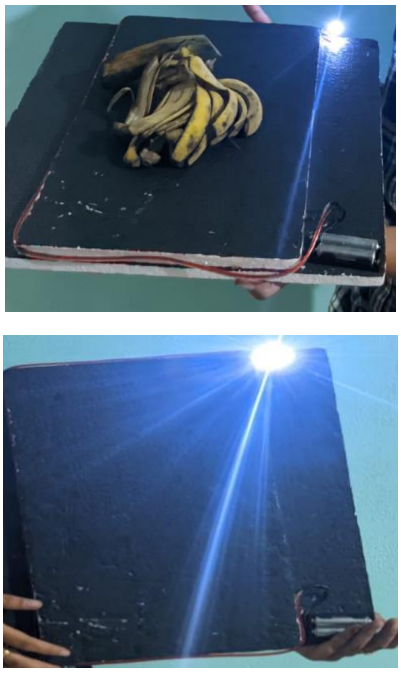

Figure 1. Bio Battery

YouTube link for steps to make a bio battery from banana peel waste, https://youtu.be/B077Psga6NQ

Development

The development stage involves the implementation of the product design that was created during the design phase (Nopita et al., 2024; Pereira et al., 2024). At this stage, instruments such as student response questionnaires are required. The product is developed based on the design and then validated and refined according to feedback and suggestions from three validators (media expert, subject matter expert, and language expert) before being implemented in schools.

Implementation

Small Group Trial

The small group trial is a stage conducted to determine whether the developed bio-battery is suitable for use in the classroom. This trial was carried out with 8 eleventh-grade science students from MAN 3 Pontianak.

Primary Field Trial

The main field test was conducted to measure how well a product achieves its goals and objectives. This field test aimed to obtain the final results of the banana peel waste-based bio-battery learning media. The main field trial involved 30 twelfth-grade science students from MAN 3 Pontianak, who were asked to fill out a questionnaire regarding their responses to the bio-battery media.

Evaluation

At the evaluation stage, student survey responses are assessed to determine the practical suitability of the bio-battery media. The results of this stage are used to analyze whether the newly developed teaching material is feasible to be used as supplementary instructional material for both teachers and students.

Feasibility Analysis

The feasibility analysis was conducted on the bio-battery learning media and the results of its development. This was stated by Awuy et al. (2023) Learning tools being tested must go through a validation stage carried out by various experts, including media experts, subject matter experts, and language experts. However, in this study, validation by language experts was not conducted—only validations by subject matter and media experts were carried out. This was done to determine the effectiveness of the developed tools before they are eventually implemented.

Validation Test Results

The validation results of the bio-battery learning media by six validators, consisting of three media experts and three subject matter experts, obtained an overall average score of 0.91, which is categorized as very high. The validation results of the bio-battery learning media using banana peel waste are presented in Table 5.

Table 5. Results of Validity Analysis of Bio Battery Media

Aspect Assessed	V Aiken	Category of Validity
Understanding the Concept of Bio-Battery	0.91	Very High
Media Quality	0.91	Very High
The practicality of the media	0.92	Very High
Average	0.91	Very High

Based on the validation results by three media experts on three assessment aspects, the instructional media obtained a total score of 55 out of a maximum score of 60. Therefore, the feasibility percentage of the instructional media reached a value of 0.91, which falls into the "Very High" category. This is highly consistent with the characteristics of the bio-battery media and is considered suitable for use.

Table 6. Results of Validity Analysis of Bio Battery material

Aspect Assessed	V Aiken	Category of Validity
Scope of Material	0.92	Very High
Material Accuracy	0.92	Very High
Material Accuracy	0.91	Very High
Completeness of Presentation	0.92	Very High
Presentation Supports	0.96	Very High
Average	0.93	Very High

Based on the validation results by three subject matter experts across five assessment aspects, the instructional media obtained a total score of 123 out of a maximum score of 132, resulting in a feasibility percentage of 0.93. According to the interpretation criteria, the media falls into the " Very High" category and is considered suitable for use as instructional media for the topic of Voltaic Cells.

Practicality Analysis

Results of the Student Response Questionnaire

The students' responses to the bio-battery learning media made from banana peel waste showed a result of 73.96% in the small group trial, which falls into the "practical" category. In the final field trial, the result reached 94.89%, indicating that the media is "very practical" and feasible for use.

Based on the research conducted by Yanasari & Refelita (2017), the results of the teacher assessment questionnaire regarding the feasibility of using banana peels as a substitute electrolyte solution in voltaic cell

experiments showed a cumulative score of 93.75%. This score falls into the "very good" category, within the range of 81 to 100%.

According to research by Purwati (2017), banana peels can be utilized as bio-batteries, thereby reducing banana peel waste, which is often considered less useful by the community. Based on findings by Pulungan et al. (2017), banana peels are capable of conducting electricity, making them a potential replacement for electrolytes in commercial batteries and suitable for use in the development of bio-batteries. Among the various types, Ambon banana peels are considered the most effective for use in battery electrolyte experiments.

Conclusion

The bio-battery learning media utilizing banana peel waste developed in this study is deemed suitable for use as an instructional tool, as it has met the criteria for both validity and practicality. The validity of the media and content aspects showed validity coefficient scores of 0.91 media and 0.93 content/material. respectively, both falling into the high category. The practicality aspect, based on questionnaire responses, reached a percentage of 73.96% in the small group trial (categorized as practical) and 94.89% in the field trial (categorized as highly practical). Therefore, the developed bio-battery learning media is considered effective and practical for use by 12th-grade science students and high school chemistry teachers.

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Conflicts of Interest
The authors declare that there are no conflicts of interest.

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