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DEVELOPMENT OF ENVIRONMENTALLY FRIENDLY CRTT INTEGRATED ELECTROCHEMICAL EDUCATIONAL KITS AS LEARNING MEDIA FOR PARTNER SCHOOLS OF SMA LABS UM

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Abstract

This study aims to develop environmentally friendly electrochemical edukits integrated with the Culturally Responsive Transformative Teaching (CRTT) approach. This study involved 32 grade XII MIPA students at SMA Laboratorium UM with a pretest and posttest design. This study shows a significant increase in learning outcomes after using the edu-kit. The data obtained also meets parametric tests, indicating an increase in conceptual understanding of electrochemistry material. The edu-kit helps create more active, contextual learning that is closer to students' lives because they can relate electrochemistry concepts to real situations, environmental awareness, and local cultural values. Overall, the electrochemistry edukit not only improves students' cognitive understanding but also strengthens cultural relevance and sustainability values in chemistry learning.
Key words: edukit, electrochemistry, CRTT, learning media, learning outcomes

INTRODUCTION

Chemistry requires a high level of abstract thinking and logical reasoning, so many concepts are difficult for students to understand because these processes cannot be observed directly, especially in electrochemistry. This condition makes it difficult for students to connect theoretical concepts with real phenomena, resulting in learning that tends to rely on memorization rather than conceptual understanding, which ultimately leads to low achievement and decreased student motivation [2]. Electrochemistry plays an important role in everyday life, such as in batteries, metal plating, and renewable energy conversion [8]. However, limitations in learning media and teaching aids restrict students' ability to visualize the electrochemical processes that occur at the microscopic level, which is important for meaningful learning [5].

One way to overcome these challenges is to use edukits as a learning medium. Edukits are a collection of tools designed to support practical and conceptual learning, enabling students to actively conduct experiments, observe real changes, and understand conceptual meanings[1]. Research shows that edukits can help improve understanding of abstract concepts through direct experience [8]. The edukits developed in this study are designed to be environmentally friendly by utilizing natural materials such as noni fruit as electrolyte and electrode components, thereby reducing chemical waste and promoting sustainable laboratory practices.

Effective learning media not only supports conceptual understanding, but must also relate the knowledge being learned to the cultural context and life experiences of students. The Culturally Responsive and Transformative Teaching (CRTT) approach is a learning method that emphasizes the relationship between learning materials and students' cultural values, daily lives, and community experiences [1]. In other words, CRTT can help students learn science through contexts that are close, familiar, and relevant to their identities. This approach also fosters an inclusive attitude, appreciates cultural diversity, and encourages critical awareness of environmental and social issues [6]. Through CRTT, students not

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only learn scientific concepts but also develop important values such as collaboration, sustainability, and creativity in utilizing local natural resources [10].

A combination of an environmentally friendly edukit and the CRTT approach offers an integrated solution: the edukit provides concrete and experimental visualization of electrochemical concepts, while CRTT contextualizes learning within culture and environmental responsibility, enabling a holistic and meaningful learning experience. However, research integrating CRTT with eco-friendly electrochemical edukits is still very limited, and most existing studies only focus on cognitive improvement without addressing cultural relevance or sustainability. Therefore, innovation in developing learning media that merges scientific understanding, cultural responsiveness, and environmental awareness is urgently needed.

This study aims to develop and evaluate the effectiveness of environmentally friendly electrochemical edukits integrated with the Culturally Responsive Transformative Teaching (CRTT) approach in improving student learning outcomes and fostering cultural awareness and environmental responsibility in chemistry education.

METHOD

This study used the Research and The 4D (Define, Design, Develop, Disseminate) research and development (R&D) method consists of three stages, namely Define, Design, and Develop. This is in line with the research limitations, which only extend to the development stage. This model was chosen because it has proven to be effective in educational research and is widely used to develop learning aids (Ade Rahayu, 2025). The research was conducted at LAB UM High School with 33 students in grade XII IPA as subjects.

The data collection instruments consisted of test and non-test instruments. The test instruments consisted of pre-tests and post-tests to measure learning improvement and the effectiveness of the environmentally friendly electrochemical edukit integrated with Culturally Responsive Transformative Teaching (CRTT). The non-test instrument consisted of Likert-scale questionnaires to measure media practicality and user needs. The test instruments were declared valid by expert judgment and their reliability was tested using Cronbach's Alpha. Descriptive statistics such as mean and standard deviation (SD) were used to give an overview of learning performance improvements.

The development process of electrochemical teaching media in this study was carried out using the following systematic procedures:

1. The Define

   The Define stage is carried out to determine the basic requirements in analyzing product requirements in research conducted through questionnaire distribution. The subjects used were 12th grade science students to find out their perceptions and needs regarding learning media on electrochemistry material. The requirements analysis was calculated using a Likert scale with the following categories index:
   0% – 19.99%: Strongly Disagree
   20% – 39.99%: Disagree
   40% – 59.99%: Somewhat Disagree
   60% – 79.99%: Agree
   80% – 100%: Strongly Agree
2. The Design

   The design stage included the development of a voltaic cell experiment edukit using noni fruit extract as an environmentally friendly electrolyte, designed to avoid the use of hazardous synthetic chemicals. The edukit integrates the CRTT pedagogy to connect scientific concepts with local cultural values and environmental awareness. Research instruments (pretest–posttest questions and practicality questionnaires) were also designed according to the learning outcomes of the Merdeka Curriculum and validated using a Likert scale.
3. The Develop

   The develop stage includes product revisions based on expert advice, small-scale trials, and the implementation of main trials through pretesting, experimental learning using edukits, and posttesting. Learning effectiveness is analyzed using N-Gain and the Paired t-test, or Wilcoxon if the data is not normally

distributed, while practicality is analyzed through a Likert scale questionnaire.

This study did not include a control group, which may limit the ability to rule out external factors influencing learning outcomes, such as maturation or testing effects. Therefore, results should be interpreted with consideration of these internal validity limitations.

RESULTS AND DISCUSSION

The Define stage was carried out by distributing a needs analysis questionnaire to students to identify the initial conditions of electrochemistry learning, students' perceptions of the use of experimental media, and their needs for learning innovation. Based on the questionnaire data, 75% of students (on a scale of 60%-79.99%) showed interest in electrochemistry edukits as a practical medium that is easy to use, interesting, and helpful in understanding abstract concepts such as redox reactions and electrochemical cells.

The results of the needs analysis show that students have a high interest in using edukits as a medium to support electrochemistry learning. In addition, students revealed that electrochemistry material has been difficult to understand due to the lack of adequate experimental facilities. This finding is in line with research over the past 5 years, which confirms that the availability of adequate practical media plays an important role in reducing students' cognitive load and improving their understanding of abstract concepts [13]. The lack of experimental media in the classroom makes electrochemistry learning tend to be abstract, so students need media that allows them to directly explore how electrochemical cells work. Therefore, portable, safe, and affordable edukits are considered capable of helping students learn independently or in groups, as well as overcoming the gap in experimental facilities in schools. These findings provide a strong basis for the next stage of development to ensure that the designed edukit truly meets the needs, characteristics, and learning context of students.

The Design stage in this study included the process of designing an electrochemical cell experiment kit that uses noni fruit extract as an environmentally friendly electrolyte. At this stage, the physical design of the kit was planned, including the shape of the container, the size of the components, safety aspects, and ease of assembly so that students could conduct the experiment independently. In addition, the researchers determined the most suitable types of tools and materials for voltaic cell experiments, such as electrodes, connecting cables, multimeters, and other supporting materials that are safe and easily obtainable. After that, all tools and materials were purchased to ensure their suitability for the experiment. Evaluation tools in the form of pretest and posttest questions were also developed to measure students' understanding of electrochemical concepts, as well as practical questionnaires to assess the need for the use of edukits by teachers and students. Then, all these instruments were validated by experts using a Likert scale, covering aspects of content suitability, clarity, construction, and relevance to learning outcomes in the Merdeka Curriculum. This stage demonstrated a structured development process because it not only included the creation of physical products but also the preparation of valid evaluation tools. The use of noni fruit reinforced the environmentally friendly nature of this edukit. After the validation process, the experts stated that the research tools were suitable for use with some revisions.

During the Development stage, the quality of the previously designed measurement tools and educational products was tested through statistical analysis. First, a reliability test was conducted on the questions to ensure that the learning outcome measurement tools had good consistency using Cronbach's Alpha coefficient. The results showed a reliability value of 0.743, which is classified as high ($\alpha > 0.70$). This indicates that each item has a good level of consistency, so that the learning outcome measurement tool is suitable for measuring student understanding, both before and after treatment. High reliability also illustrates that the change in scores is due to the treatment given, not the instability of the measurement tool.

Of the 25 items developed, only 20 were declared valid and reliable based on the results of content validity testing and instrument reliability testing. Therefore, only these 20 items were used in the pretest and posttest. Reducing the number of

questions is a common procedure in instrument development, as questions that do not meet the validity and reliability criteria need to be eliminated to ensure the quality of the data produced [12]. Selecting valid and consistent questions is important so that the instrument is truly capable of accurately measuring students' abilities without producing measurement bias.

Table 1. Test of Reability

Cronbach's Alpha	N of Items
0.743	20

Next, normality tests were conducted using Shapiro–Wilk karena jumlah siswa hanya 32 kare, to determine the distribution of pretest and posttest data. Both scores showed significance values greater than 0.05 (Pretest = 0.069; Posttest = 0.156), so it can be concluded that the data is normally distributed. This normal distribution allows the use of parametric tests such as the paired sample t-test for effectiveness analysis. Data normality also indicates that measurements were consistent without extreme outliers, although normality itself does not indicate learning quality. Therefore, the impact of learning is still analyzed from score changes and subsequent statistical test results.

The normal distribution of data corresponds to the description of the class conditions during the learning process. The pretest and posttest scores are evenly distributed without any extreme values, indicating that the students' abilities are within a relatively homogeneous range and that there are no groups of students who are significantly behind or significantly ahead. This indicates that the learning process took place in a conducive and controlled manner, with stable student participation from start to finish. The normality of the data also reflects classroom conditions in which the test instruments work consistently and students take the tests under reasonable conditions of understanding, without any disturbances that cause drastic deviations in scores. Thus, the results of the effectiveness analysis in the next stage can be interpreted more accurately because stable classroom conditions support the reliability of the data obtained.

Table 2. Test of Normality

Class (Result)	Kolmogorov-Smirnov Sig.	Shapiro-Wilk Sig.
Pretest	0.054	0.069
Posttest	0.162	0.156

A homogeneity test was then conducted using the Levene Test to evaluate the similarity of variances between pretest and posttest scores. A significance value of 0.278 (> 0.05) indicates that the variances of the two data groups are homogeneous. Although homogeneity is not a mandatory requirement for paired tests, these results reinforce the interpretation that changes in student scores are caused more by treatment than by differences in ability distribution. Variance stability also indicates that the samples have relatively similar ability characteristics both before and after learning.

Homogeneity results describe a relatively uniform class in terms of initial abilities and learning development. The class tends to be evenly matched and is not dominated by excessive differences in ability. There are no groups of students who experience extreme spikes or drops in scores, resulting in dynamic learning. This condition indicates that learning takes place in an equitable environment, where all students have the same opportunity to understand the material and engage in experiments using electrochemical educits. With good variance homogeneity, improvements in learning outcomes can be trusted to originate from the effectiveness of learning, rather than from disparities in ability among students in the class.

Table 3. Test of Homogenity

		Sig.
Result	Based on Mean	0.278
	Based on Median	0.242
	Based on median and with adjusted Df	0.242
	Based on trimmed mean	0.268

Descriptive statistics show that students' average scores improved after participating in learning using edukit. The average pretest score of 69.06 increased to 74.69 on the posttest. This increase indicates an improvement in understanding of electrochemistry concepts after

students engaged in environmentally friendly edukit-based experiments. Furthermore, this increase supports the feasibility of using parametric analysis because the data meets the assumptions of normality and homogeneity, and the paired samples are suitable for the characteristics of the paired t-test.

Table 4. Test of Paired Samples Statistics

		Mean
Pair 1	Pretest	69.06
	Posttest	74.69

A paired sample t-test was then used to determine the effectiveness of the edu-kit in improving student understanding. The analysis results show a t-value of –2.150 with $p = 0.039 < 0.05$, which means there is a significant difference between the pre-test and post-test scores. The calculated t-value is higher than the table t-value, proving that the use of electrochemical edukits has an impact on improving student learning outcomes. This significant improvement is in line with the CRTT principle, whereby the use of natural materials such as mangosteen and integration into the local cultural context can increase student engagement, motivation, and relevance of learning.

The t-test results are consistent with the classroom conditions, where most students in the class experienced an increase in understanding after participating in learning using edukit. These conditions indicate that the experimental activities were effective and able to help students connect abstract electrochemical concepts with real-life experiences through the use of local materials. The absence of extreme values or striking differences in change between students indicates that the improvement occurred evenly across the class. This indicates that the learning environment was conducive, students were actively engaged, and the edukit succeeded in creating an inclusive learning experience for both high-achieving students and those who had previously experienced difficulties. Thus, the t-test not only demonstrated statistical effectiveness, but also illustrated the positive classroom dynamics that supported the learning process.

CONCLUSION

The findings indicate that the The environmentally friendly CRTT integrated electrochemistry edukit has been proven effective in improving student learning outcomes and supporting more meaningful and contextual learning in line with the Merdeka Curriculum. In addition to having an impact on cognitive improvement, the use of this edukit also fosters environmental awareness and student appreciation of local cultural values, demonstrating its potential as a transformative learning medium capable of connecting scientific concepts with real life.

Although the results are promising, this study has limitations because it uses a single-group design and involves a relatively small sample size, which limits the generalization of the findings. Future research could involve a larger and more diverse school population and use a comparative experimental design to strengthen the evidence regarding the effectiveness of the edu-kit. Implementation in more partner schools could help validate its potential as a learning innovation that can be applied more widely and sustainably.

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