Electrifying Educational Games: Enhancing Student Learning with Electrochemistry Board and Card Games

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ABSTRACT

In classrooms where traditional teaching methods prevail, student engagement and comprehension often suffer. Recognizing the significance of innovative learning tools in electrochemistry education, this study set out to evaluate the validity, effectiveness, and practicality of board and card media. Employing an ADDIE-based Research and Development (R&D) approach, we selected 30 students from Class XII MIPA 1 at SMA Muhammadiyah 1 Pontianak using purposive sampling. Validation from experts yielded impressively high scores of 0.90 and 0.83 for the material and media aspects of electrochemistry board and card, respectively. The teaching tools proved highly effective, with an effectiveness score of 0.92, and exceedingly practical, scoring 100% in practicality tests. This research underscores the suitability of the developed board and card media for enhancing electrochemistry learning in high school, particularly within the realm of voltaic cell sub-materials. These findings illuminate the transformative potential of these innovative tools in delivering enriched learning experiences for students.

Keywords: Board and Card Games, Electrochemistry, Learning Media. Students Learning outcomes.

INTRODUCTION

Electrochemistry, a subject taught in the first semester of 12th grade in high school, is both fascinating and highly applicable in our daily lives (Rukisworo, 2021, Sukib & Andayani 2019). This field delves into a wide range of concepts, including redox reactions within voltaic cells and electrolysis (Harahap, 2016; Kurniawan et al., 2017; Panggabean & Silaban, 2015). However, the breadth of these concepts often poses a challenge for students trying to grasp electrochemistry (Asnawi, 2018; Haryani et al., 2014; Pratiwi & Wibowo, 2017, Yerimadesi, 2018). Concepts like voltaic cells (Sutantri, 2022), the role of salt bridges and determining cell potentials

(Dorsah & Yaayin, 2019; Rollnick & Mavhunga, 2014), and the application of oxidation states in redox reactions (Akram et al., 2014) can be particularly perplexing.

The difficulty in understanding electrochemistry can be attributed to monotonous teaching methods that fail to address students' difficulties (Tsaparlis, 2019) and the lack of educational media (Nurul Audie, 2019). As a result, students often find themselves navigating the complex world of electrochemistry with limited support and resources. However, there's hope on the horizon as educators and researchers explore innovative ways to make this captivating subject more accessible and engaging.

Based on interviews conducted with chemistry teachers in secondary schools in Pontianak, preliminary research reveals a concerning fact: students struggle to comprehend electrochemical reactions, often leading to confusion when determining redox reactions. In their teaching process, teachers primarily rely on lecture-style methods, accompanied by conventional resources like textbooks and PowerPoint presentations. This approach stems from the teachers' difficulty in finding suitable teaching aids for electrochemistry, which, unfortunately, results in students' limited engagement.

This sentiment is further echoed by feedback from the students themselves, who express a preference for more interactive and game-based learning experiences. Alarmingly, the learning outcomes in electrochemistry also show cause for concern, with an average achievement rate well below the passing threshold. Approximately 65% of 12th-grade students have yet to reach the minimum passing grade (70). These insights underscore the need for a transformative approach to teaching electrochemistry, one that not only clarifies complex concepts but also ignites students' enthusiasm for this challenging subject.

Learning media serves as a non-personal tool wielded by educators to fulfil the objectives of education (Mahmudah, 2018). Through the use of media, educational goals become attainable by delivering messages clearly and effectively (Asyhari & Silvia, 2016; Nurrita, 2018). Learners are more likely to be engaged and grasp the material when the learning media employed combines enjoyment with a playful approach while staying aligned with the intended learning outcomes (Pratiwi & Wibowo, 2017). In essence, learning media is the bridge that connects educators' wisdom and knowledge with students' curiosity and understanding. When crafted thoughtfully and with creativity, it transforms the learning journey into an exciting adventure, where knowledge is not just imparted but experienced, making the process of education not only effective but also enjoyable.

A multitude of learning media innovations has emerged within the realm of electrochemistry education. These innovations include the development of interactive e-books (Suryani, 2012), the creation of Prezi software resources (Epinur et al., 2014), the crafting of electrochemistry kits (Juwita, 2015), and the advent of Android-based learning apps

(Harianto et al., 2017).Each of these learning tools comes with its own set of strengths and weaknesses.

One undeniable advantage of these learning media innovations is their digital foundation, which offers a dynamic and interactive learning experience. However, in practice, some schools encounter challenges in fully embracing these digital resources due to limitations in internet access and device availability. Consequently, traditional print-based learning media still stand as a viable alternative in the realm of electrochemistry education. In this ever-evolving landscape of educational technology, it's clear that while digital media offers exciting opportunities, we must also ensure inclusivity and accessibility for all students, acknowledging that print-based resources continue to play a crucial role in facilitating effective learning experiences.

Print media, which combines visuals and text, adds an element of attraction that aids learners in comprehending explanations presented through words and visuals (Wenda & Wenda, 2022). Print media can be designed to meet learners' needs effectively (Hafsah et al., 2016). In chemistry education, print media can be used effectively to enhance students' understanding. Electrochemistry board and card is one such print-based learning tool specifically designed for electrochemistry, a subject that hasn't seen this kind of resource before. This research builds upon preliminary work and the initial design of board and card games for learning electrochemistry (Kurniawan et al., 2017), Electrochemistry board and card, as the name suggests, consists of a board and a set of cards designed based on voltaic cell circuits. This learning tool can be used by groups of four students, creating a collaborative gaming environment (Kurniawan et al., 2017). With this learning media, it's expected that students will find it easier to grasp electrochemistry concepts due to problem-solving activities designed into the game. Furthermore, electrochemistry board and card are anticipated to boost students' learning outcomes. It provides an alternative, simple, enjoyable, and interactive teaching aid for educators, aiding students in understanding voltaic cell configurations and potentials effectively.

METHOD

The research was conducted using the Research and Development method. Research and Development is a research method that involves developing or creating a specific product and testing the effectiveness of that product (Mulyatiningsih, 2012; Sugiyono, 2016). In this study, the product developed was the board and card for the topic of electrochemistry.

The participants, their characteristics and their selection methods are described in detail and justified. The research followed the ADDIE development model developed by Dick and Carey, consisting of the stages of Analysis, Design, Development, Implementation, and Evaluation (Mulyatiningsih, 2012; Puspasari, 2019). The analysis phase involved problem analysis, analysis of learner characteristics, and determination of the product to be developed. The design phase included the design of the electrochemistry board and card, the design of how they would be used, and the design of the research instruments. The development phase encompassed the creation of the product, validation by media experts, and validation by subject matter experts. The Implementation phase involved initial field testing and main field testing of the electrochemistry board and card in the learning process. The evaluation phase included measuring the effectiveness of the electrochemistry board and card using the One-Group Pretest-Posttest Design, with pretest and posttest questions as measurement tools.

The subjects in this study were six students from class XII IPA B at SMAIT Al-Fityan Kubu Raya in the initial field test and 30 students from class XII at SMA Muhammadiyah 1 Pontianak in the main field test.

Data collection and analysis pro Data collection techniques included indirect communication, direct communication, and measurement techniques. Data collection instruments included expert media validation questionnaires, expert subject matter validation questionnaires, student response questionnaires, teacher response questionnaires, pretest and posttest questions, and observation sheets. Data analysis was performed using descriptive statistical techniques, and the validity, effectiveness, and practicality of the media were determined based on predefined criteria. Procedures are clearly explained with a reference to the role and competency of the researcher(s).

FINDINGS AND DISCUSSION

Analysis

The problem analysis phase aims to identify the factors contributing to existing issues, thereby necessitating the development of new learning media or products. During this stage, the researcher conducted interviews with teachers and students at SMA Muhammadiyah 1 Pontianak. The problems identified by students at SMA Muhammadiyah 1 Pontianak are as follows: a) The chemistry lessons, particularly the electrochemistry topic with a focus on voltaic cells, primarily utilize traditional learning materials such as chemistry textbooks and PowerPoint presentations; b) The learning media used at SMA Muhammadiyah 1 Pontianak for electrochemistry includes instructional videos sourced from YouTube, PowerPoint presentations, and chemistry textbooks. However, the repetitive use of such media can lead to student boredom, disengagement, and a lack of enthusiasm for learning. Therefore, there is a pressing need for more varied learning resources. Based on student exam scores in electrochemistry, a significant number of students have not achieved passing grades or are below the minimum competency criteria. These findings underscore the urgency of enhancing the learning experience in this subject.

The assessed characteristic of students in this context is their cognitive ability, which was determined based on their performance in chemistry exams, specifically focusing on the electrochemistry topic. The analysis of the material that students need to learn revolves around electrochemistry, with a particular emphasis on the sub-topic of voltaic cells. In this sub-topic, students are expected to: a) Identify the electrodes at the anode and cathode based on the voltaic series, b) Determine the appropriate electrolyte for the anode and cathode electrodes, c) Identify the reactions occurring at the cathode and anode and correctly place them in their respective slots, d) Calculate cell potentials. These cognitive abilities are crucial in mastering the electrochemistry subject, particularly when dealing with voltaic cells, and serve as essential learning objectives for students.

Based on the problem analysis, it has been determined that the media traditionally used by teachers falls short in providing the variety needed for the electrochemistry curriculum. Consequently, there is a clear need for the development of new learning media to facilitate the learning process. Through interviews with students, it was evident that they were in favor of the idea of having a learning medium like the electrochemistry board and card, which could simplify the teaching process.

This demonstrates a consensus between students and educators regarding the necessity and potential benefits of introducing innovative learning tools like the electrochemistry board and card into the classroom. The mutual agreement highlights the anticipation of a more engaging and effective learning experience 081233206616

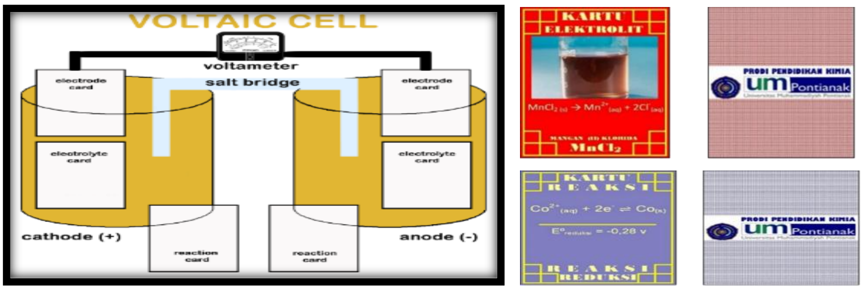
Design

The design phase aims to create the learning media, which in this case is the electrochemistry board and card. The design process commences with the selection and determination of materials to be used for crafting the electrochemistry board and card. The chosen materials include hard cardboard, photo paper, vinyl sticker material, and a plastic box folder. The electrochemistry board and card consist of both a board and a set of cards.

This meticulous selection of materials underscores the importance of ensuring the durability and effectiveness of the learning tool. Crafting the electrochemistry board and card with these materials sets the stage for an engaging and interactive learning experience for students.

The board, made from hard cardboard, measures 35 x 21.5 cm. It features a simple design of a voltaic cell, printed using vinyl sticker material. The design includes a yellow title (Voltaic Cell), a pair of electrodes, electrolytes at each electrode, a light blue salt bridge, a black voltmeter, two slots for electrode cards, two slots for electrolyte cards, and two slots for reduction and oxidation reaction cards. The view of the board's design can be seen in Figure 1. This design represents a visual representation of a voltaic cell, allowing students to interact with and understand the components and processes involved in electrochemistry effectively.

Figure 1: Electrochemistry Board (left) and Card (right) design



A total of 52 cards were designed, divided into four types: electrode cards, electrolyte cards, reduction reaction cards, and oxidation reaction cards, with each type consisting of 13 cards. Electrode cards: These cards contain the voltaic series and play a critical role in determining the proper use of the electrochemistry board and card media. Each card used is placed in the corresponding electrode card slot. The electrode cards are yellow in the background and feature the card type (Electrode Card) at the top. In the middle of the card, there is an image illustrating the electrode, providing a visual representation without the need to view the substance directly (Kavak & Yamak, 2016). Below the image, there is a series of electrodes arranged from low to high standard reduction potentials. This information helps students decide which electrode should be the cathode and which should be the anode. The back of the electrode card is yellow and contains the researcher's logo and institution name.

Electrolyte cards: These cards display the ionization reactions corresponding to each voltaic series. They occupy the second position in the card slot after the electrode cards. The chosen electrolyte card should contain cations from the same element as the electrode card. Electrolyte cards have a red background and feature the card type (Electrolyte Card) at the top. In the middle, there is an image illustrating the electrolyte, providing a visual representation without direct substance observation (Kavak & Yamak, 2016). Below the image, there is the ionization reaction of the electrolyte. The back of the electrolyte card is red and contains the researcher's logo and institution name.

Reduction and Oxidation Reaction Cards: These cards depict reduction and oxidation reactions in the voltaic series. They function to assist students in calculating the cell potential (E0cell) with components from the reduction potential of each card. Reduction and oxidation cards are used after placing the appropriate electrolyte card in the slot. There are 26 cards in total, with 13 reduction reaction cards featuring a light blue background and 13 oxidation reaction cards with a lime green background. Both types of cards contain the same metals: Al, Ag, Ba, Ca, Cd, Cr, Fe, K, Mg, Na, Pb, Sn, and Zn, in reduction and oxidation reactions. The top of the card has the title (Reaction Card), and in the middle of the card, there is a half-reaction along with the reaction potential from the voltaic series, created based on a database (Day & Underwood, 1994). The bottom of the card specifies the card type (Reduction Reaction and Oxidation Reaction) for both types of reaction cards.

This phase involved the actual implementation of the product design created during the design phase. The developed electrochemistry board and card media were then subjected to validation. The validation process involved two media experts and three subject matter experts. The media experts included a chemistry education lecturer from the University of Muhammadiyah 1 Pontianak and a high school teacher from SMA Muhammadiyah Pontianak. The subject matter experts included a chemistry education lecturer from Tanjungpura University and a high school teacher from SMA Muhammadiyah Pontianak. Additionally, the Pre-test and Post-test, student response questionnaire, and the electrochemistry board and card media development sheet were validated by a chemistry education lecturer from Tanjungpura University and a high school teacher from SMA Muhammadiyah Pontianak.

The validation by subject matter experts aimed to determine the validity and suitability of the content in the electrochemistry board and card media. The subject matter experts concluded that the electrochemistry board and card media was suitable for use after implementing suggested revisions and improvements. Similarly, the electrochemistry board and card media were deemed valid based on the feedback and recommended revisions from the media experts. The validation results indicated that the electrochemistry board and card media was valid for use without further revisions, with a validity score of 0.88.

The validation by media experts aimed to assess the overall validity and suitability of the electrochemistry board and card media. The media experts unanimously agreed that the electrochemistry board and card media was suitable for use without any revisions, with a validity score of 0.92.

The student worksheet was validated before use through a validation form. The validation results showed that the student worksheet needed revisions and improvements, as recommended by the validator. The subject matter expert's validation score was 0.83, indicating the student worksheet has a very valid criterion.

The purpose of creating the student worksheet was to facilitate, streamline, and enhance the teaching and learning process, ultimately achieving the desired learning objectives. It is used in conjunction with the electrochemistry board and card media. Students complete the questions in the worksheet while engaging with the game. In this phase, the researcher designed the worksheet, including the cover, objectives, instructions, material description, student activities, and questions. The improvement of student worksheet, Pre-test Post-test a respondent questionnaire after revision can be seen in Table 1 and Table 2.

Table 1: The Improvement of Validation Student Worksheet

Indicator	The Correction
Clarity of content	The information about electrodes, electrolytes, cathodes, and anodes in electrochemistry could not present in student worksheet. It caused of all the essential components, including electrodes, electrolytes, anodes, cathodes, and cell potential values, are already comprehensively provided on the electrochemistry board and card media. The table should be omitted from the student worksheet and replaced with group names, as these details are readily available on the media.

Table 2*:* The Improvement and Criterion of Pre-test Post-test and Respondents Questionnaires After Validation Step

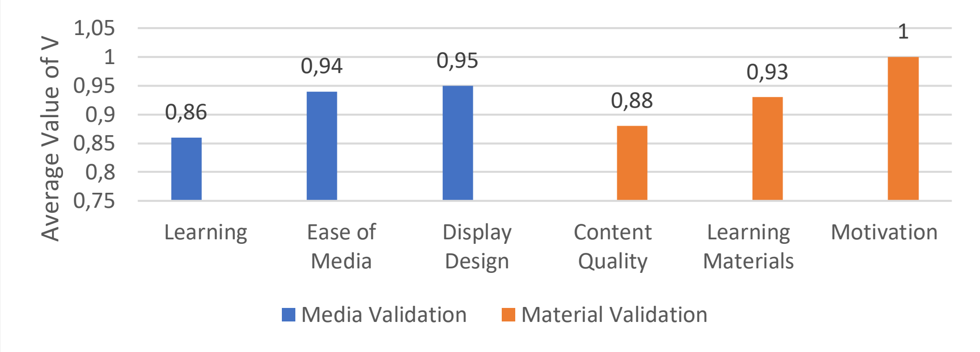
Indicators	The Correction	The Criterion
Pre-test-Post-test	The indicators for each question are elaborated in detail based on their classification and the scores assigned. This serves the purpose of facilitating a comprehensive assessment of both the Pre-test and Post-test questions. By providing a clear breakdown of the indicators, it becomes easier to evaluate and score each question effectively.	0.92
Response questionnaire	It can be used without correction	0.93

The analysis of feedback and suggestions from students regarding the electrochemistry board and card media, as gathered through the student response questionnaire, yielded exceptionally positive results. Based on the comments and recommendations provided by the students during the initial field trial, no revisions were deemed necessary for the electrochemistry board and card media. Suggestions from teacher is All instrument has good performances, and students. The media makes the students understand, have a enjoyable factor, and very creative.

Discussion

The effectiveness test was conducted to assess the role of the electrochemistry board and card media in assisting students in understanding the taught material. In addition to providing comprehension and support for students in grasping the concepts, the electrochemistry board and card media also had an impact on improving learning outcomes in voltaic cells. The effectiveness analysis involved comparing the students' scores before and after using the pre-test and post-test questions in both the initial field trial and the main field trial. The average N-Gain score achieved in the initial field trial and the main field trial was 1.93 (high criteria) and 0.81 (high criteria), respectively. Therefore, it can be concluded that the created electrochemistry board and card media effectively aids in understanding the sub-material of voltaic cells. The percentages of media and content validation can be seen in Figure 3.

Figure 2*:* Percentage of Media and Content Validation



The aspect of practicality can be assessed based on the analysis of the questionnaire responses from students regarding the use of the electrochemistry board and card media. The questionnaire statements include feedback on various aspects of learning, media, and visual communication in the electrochemistry board and card. To determine practicality, field tests were conducted. Data collection from these field tests was conducted after students had used the electrochemistry board and card media. The results of the practicality analysis from the initial field test and the main field test are summarized in Table 4.

Table 4: The Result of Practicality Analysis in Main Field Test

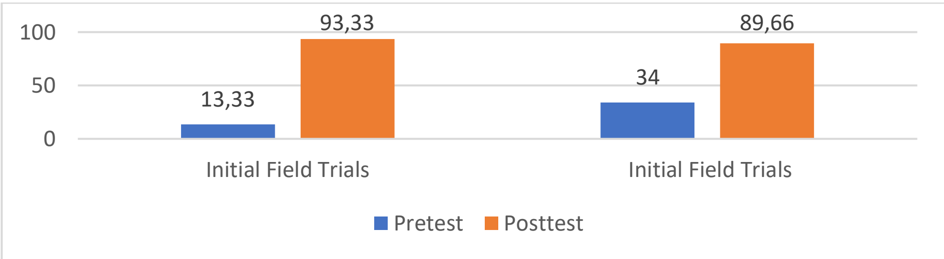
No	Aspects	Percentage
1	The electrochemistry board and card learning media help in understanding the material	100
2	The developed media can stimulate learning motivation	100
3	The electrochemistry board and card learning media are enjoyable to use in learning activities	100
4	The electrochemistry board and card learning media are easy to use	100
5	The electrochemistry board and card media is portable and easy to carry	100
6	After using the electrochemistry board and card media, learning becomes enjoyable and does not lead to boredom	100
7	The appearance of the electrochemistry board and card is visually appealing	100
8	The font used is easy to read	100

The results of the student response questionnaires indicate that, in general, students found the use of the electrochemistry board and card media to be engaging and comprehensible. This can be observed in the summarization of the student response questionnaire practicality percentages for the main field trial, were 100%, respectively, for each indicator in the questionnaire. Practicality results were calculated as percentages based on the Guttman scale calculation.

The practicality results for all 8 statements in both the initial field trial and the main field trial show very practical percentages. Therefore, the development of the electrochemistry board and card media, which has undergone validation, practicality, and effectiveness testing, can be considered suitable for use in teaching. This is because the electrochemistry board and card media received an average percentage score from the provided student response questionnaires falling within the category of "very practical".

The Pre-test and Post-test each consisted of 2 questions with the same indicators but different content. The use of the electrochemistry board and card media improved students' understanding of the electrochemistry material, specifically the sub-topic of voltaic cells, as assessed using the N-Gain formula, which can be observed in Figure 4.

Figure 3: The Percentages of Pre-test and Post-test



The analysis shows an increase in the Pre-test scores in both the initial and main field trials, with a gain of 20.67. However, in the Post-test for both the initial and main field trials, there was a decrease of 3.67. This decrease was due to a larger number of students in the main field trial, leading to less conducive classroom conditions. The overall N-Gain value decreased by 1.12, partly because of differences in the learning conditions between the initial and main field trials.

In the initial field trial, two students answered question (number 2b) incorrectly. These two students made mistakes in determining the cathode and anode. However, in question 1a, with the same indicator but a different set of electrode examples, both of these students answered correctly regarding the cathode and anode. Overall, the students achieved passing scores in the Post-test.

The decrease in N-Gain was also due to the fact that, in the Post-test of the main field trial, seven students could not answer question 1b, two students could not answer question 1c, and two students could not answer question 2b. Students had difficulty understanding how to construct an electrochemical cell reaction. These questions were considered difficult as they involved higher-order thinking (C3) and the most unanswered question was 2b. However, overall, the students achieved passing scores in the Post-test. The average N-Gain score in the initial field trial and the main field trial was 89.66 and 93.33, respectively, indicating a high level of effectiveness. This high N-Gain value is believed to be due to the assistance provided by the use of the electrochemistry board and card media, which facilitated students' understanding of electrochemistry, especially the sub-topic of voltaic cells.

CONCLUSION

The electrochemistry board and card media developed in this research has been deemed suitable for use as a learning tool for the sub-topic of voltaic cells. This media can serve as an alternative for teachers and aid in enhancing students' learning outcomes in electrochemistry, specifically in the area of voltaic cells. Therefore, it is recommended that the completeness of the mad be carefully considered before its use.

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