Analysis of Student Needs in Electrochemistry Learning Based on Culturally Responsive Transformative Teaching (CRTT) in Grade XII MIPA UM Laboratory High School

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Abstract. *This study aims to analyze students' learning needs in electrochemistry learning based on the Culturally Responsive Transformative Teaching (CRTT) framework. CRTT is a pedagogical approach that integrates students' cultural backgrounds and lived experiences into learning to make it more inclusive and meaningful. The research employed a descriptive quantitative method complemented by qualitative data from open responses. A total of 32 Grade XII MIPA students from UM Laboratory High School participated in the study. Data were collected through a validated questionnaire consisting of 15 closed and 5 open-ended items. The results show that 64% of students have a moderate understanding of electrochemistry, with the most difficult subtopics being Galvanic and Electrolysis Cells. Students expressed strong interest (80%) in contextual learning through simple and eco-friendly edukits, as well as enthusiasm for integrating local culture such as keris plating and natural electrolytes from plants. These findings emphasize the importance of developing CRTT-based learning tools that connect chemical concepts with students' cultural realities to foster deeper conceptual understanding, engagement, and transformative learning experiences.*

Keywords: *learning needs, electrochemistry, CRTT, culturally responsive teaching*

INTRODUCTION

Chemistry education plays a vital role in preparing students to face the intellectual and social challenges of the 21st century. It contributes not only to the mastery of scientific knowledge but also to the cultivation of critical thinking, creativity, and cultural awareness. However, in many Indonesian schools, chemistry remains one of the most challenging subjects for students because of its abstract and multi-representational nature. Among the various topics, electrochemistry consistently emerges as one of the most difficult units to master. Students must connect macroscopic phenomena, such as color changes or electrode reactions, with microscopic and symbolic representations of oxidation–reduction processes [6], [9]. This multilevel reasoning. linking visible laboratory observations to invisible electron movements and symbolic equations, creates cognitive complexity that often leads to misconceptions and fragmented conceptual understanding.

Research has shown that many Indonesian students find it difficult to interpret electron flow, determine the direction of current, or identify the role of electrodes in voltaic and electrolysis cells [5], [6]. Observations at UM Laboratory High School, a model school affiliated with Universitas Negeri Malang, reflect similar conditions. Students tend to memorize equations and standard electrode potentials without fully understanding their meaning. This situation is partly caused by limited opportunities for hands-on experiments, as schools often face constraints in laboratory equipment, materials, and time. Consequently, the teaching of electrochemistry tends to rely on lectures and demonstrations using PowerPoint or videos, which are insufficient to promote conceptual understanding.

In Indonesia's current Kurikulum Merdeka, chemistry learning is expected to be student-centered, inquiry-oriented, and connected to real-life contexts. However, classroom practice still tends to be teacher-centered and focused on examination outcomes. Students are treated as passive recipients rather than active constructors of knowledge [1]. As a result, learning becomes decontextualized and disengaged from students' sociocultural realities. This pedagogical gap highlights the need for approaches that not only enhance conceptual understanding but also respect and incorporate students' cultural experiences as legitimate sources of learning.

One promising framework that addresses these challenges is Culturally Responsive Transformative Teaching (CRTT). Grounded in the theories of culturally responsive pedagogy, CRTT emphasizes that effective teaching must be responsive to students' cultural identities, experiences, and community contexts [8], [10]. Culturally responsive teachers recognize cultural diversity as an asset rather than a barrier to learning, using it to promote engagement, relevance, and critical consciousness. The transformative dimension of CRTT further extends beyond representation—it seeks to empower students to connect scientific understanding with personal and community development [2], [8].

In the context of science education, CRTT has shown potential to make abstract concepts more accessible by contextualizing them through culturally familiar examples [3], [4]. Integrating traditional metalworking, herbal extraction, or fermentation practices into chemistry lessons allows students to relate theoretical ideas to tangible local phenomena. Such contextualization not only enhances comprehension but also encourages appreciation of indigenous knowledge systems that have scientific relevance [2]. In the topic of electrochemistry, for example, local practices such as keris plating using electrolysis principles or the use of natural electrolytes from frangipani and noni fruit can serve as authentic and relatable models for explaining redox processes.

Despite increasing interest in CRTT, empirical research on its application in electrochemistry learning is still limited, particularly in the Indonesian context. Previous studies have mostly examined the use of CRTT in general chemistry or environmental topics [3], [4], while very few have focused on students' needs, perceptions, and cultural perspectives in learning electrochemistry. Consequently, there is a lack of empirical data that could guide teachers in designing culturally relevant learning media, such as simple edukits, which integrate science, technology, and local wisdom. Before such tools can be effectively developed, a needs analysis is necessary to understand students' conceptual levels, difficulties, learning preferences, and openness toward culturally contextualized chemistry learning.

This study, therefore, aims to analyze students' learning needs in electrochemistry learning based on the CRTT approach. The research focuses on identifying: (1) students' levels of understanding and the most difficult subtopics in electrochemistry, (2) their preferred learning methods and media, and (3) their perceptions of integrating cultural values into chemistry learning through CRTT. The findings are expected to provide essential insights for developing CRTT-based electrochemistry edukits that are simple, eco-friendly, and relevant to students' local environments.

Moreover, this study contributes theoretically by extending the application of CRTT to the domain of electrochemistry, an area that requires high abstraction and strong conceptual visualization and practically by providing baseline data to design inclusive and contextual chemistry learning models that bridge scientific understanding with students' cultural and social realities.

METHOD

This study employed a descriptive quantitative design supported by qualitative data from open-ended responses. The research was conducted at UM Laboratory High School in September–October 2025, involving 32 students from Grade XII-MIPA 4. Participants were selected using convenience sampling based on their enrollment in the electrochemistry unit during the current semester.

Instrument and Validation

The main instrument was a questionnaire developed in a Google Form consisting of 15 closed-ended items using a five-point Likert scale and 5 open-ended questions exploring students' opinions and suggestions. The questionnaire addressed five aspects:

1. Understanding of electrochemistry concepts,
2. Difficult subtopics,
3. Learning methods and media used,
4. Interest in electrochemistry edukits, and
5. Views on integrating CRTT into chemistry learning.

The instrument was validated for content by two chemistry education lecturers and one high school chemistry teacher, achieving a validation score of 4.0 (good category) on a 1–5 scale. A pilot test conducted with 10 students produced a Cronbach's alpha reliability coefficient of 0.83, indicating good internal consistency.

Ethical Considerations

All participants provided informed consent prior to the study. Data collection was anonymous, and students were informed that their participation was voluntary and would not affect academic evaluations.

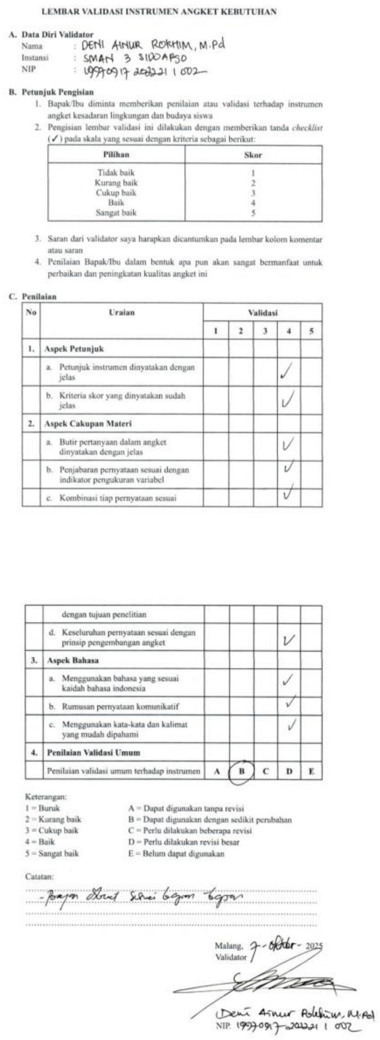
Data Analysis

Quantitative data were analyzed using descriptive statistics (mean scores and percentages) to identify dominant patterns. Open-ended responses were analyzed through thematic analysis, including data reduction, categorization, and interpretation to provide deeper insights into students' experiences and perceptions.

RESULT AND DISCUSSION

This section discusses two key findings: (1) the validation of the needs analysis questionnaire and (2) the results of students' needs analysis related to electrochemistry learning based on the Culturally Responsive Transformative Teaching (CRTT) framework. The interpretation is both quantitative and qualitative to fulfill the reviewer's recommendation for analytical depth and theoretical linkage.

1. Questionnaire Validation Results



LEMBAR VALIDASI INSTRUMEN ANGKET KEBUTUHAN

A. Data Diri Validator
Nama : DENI AINUR ROKHIM, M.Pd
Instansi : SMAN 3 SIDOARJO
NIP : 19970917 202221 1 002

B. Petunjuk Pengisian
1. Bapak/Ibu diminta memberikan penilaian atau validasi terhadap instrumen angket kesadaran lingkungan dan budaya siswa
2. Pengisian lembar validasi ini dilakukan dengan memberikan tanda *checklist* (✓) pada skala yang sesuai dengan kriteria sebagai berikut:

Pilihan	Skor
Tidak baik	1
Kurang baik	2
Cukup baik	3
Baik	4
Sangat baik	5

3. Saran dari validator saya harapkan dicantumkan pada lembar kolom komentar atau saran
4. Penilaian Bapak/Ibu dalam bentuk apa pun akan sangat bermanfaat untuk perbaikan dan peningkatan kualitas angket ini

C. Penilaian

No	Uraian	Validasi				
		1	2	3	4	5
1.	**Aspek Petunjuk**					
	a. Petunjuk instrumen dinyatakan dengan jelas				✓	
	b. Kriteria skor yang dinyatakan sudah jelas				✓	
2.	**Aspek Cakupan Materi**					
	a. Butir pertanyaan dalam angket dinyatakan dengan jelas				✓	
	b. Penjabaran pernyataan sesuai dengan indikator pengukuran variabel				✓	
	c. Kombinasi tiap pernyataan sesuai dengan tujuan penelitian				✓	
	d. Keseluruhan pernyataan sesuai dengan prinsip pengembangan angket				✓	
3.	**Aspek Bahasa**					
	a. Menggunakan bahasa yang sesuai kaidah bahasa indonesia				✓	
	b. Rumusan pernyataan komunikatif				✓	
	c. Menggunakan kata-kata dan kalimat yang mudah dipahami				✓	
4.	**Penilaian Validasi Umum**					
	Penilaian validasi umum terhadap instrumen	A	B	C	D	E

Keterangan:
1 = Buruk; A = Dapat digunakan tanpa revisi
2 = Kurang baik; B = Dapat digunakan dengan sedikit perubahan
3 = Cukup baik; C = Perlu dilakukan beberapa revisi
4 = Baik; D = Perlu dilakukan revisi besar
5 = Sangat baik; E = Belum dapat digunakan

Catatan:
[illegible]

Malang, 7 - Oktober - 2025
Validator

Deni Ainur Rokhim, M.Pd
NIP. 19970917 202221 1 002

Figure 1. Questionnaire Validation Results

Before distribution, the questionnaire was validated by expert reviewers to ensure its quality and appropriateness in assessing students' learning needs and cultural awareness. The validation process evaluated four main aspects: clarity of instructions, content coverage, language use, and overall feasibility of the instrument.

The experts rated each item using a five-point Likert scale (1 = poor to 5 = very good). As shown in Figure 1, all aspects achieved scores in the "good" to "very good" range, resulting in an overall category B (can be used with minor revisions). The feedback suggested small improvements in wording consistency and indicator formulation, which were implemented prior to use.

These validation results confirm that the questionnaire satisfies the standards of content validity and reliability for educational research. Moreover, the instrument aligns with the CRTT perspective by integrating items that explore students' conceptual understanding alongside their cultural experiences, local context, and learning preferences. Such integration is crucial because CRTT emphasizes not only cognitive learning but also sociocultural awareness as a dimension of transformative education [5], [8].

Thus, the validated instrument provides a reliable foundation for identifying gaps in students' conceptual grasp and for designing responsive pedagogical solutions—one of which is the development of a culturally integrated electrochemistry edukit. This directly responds to the reviewer's note requesting detailed clarification of validation procedures and justification for the instrument's quality.

2. Students' Needs Analysis

Based on the questionnaire data processing results, a graph was obtained as shown in Figure 1 below. This graph shows the percentage of students' responses to statements regarding their level of understanding of basic electrochemistry concepts.

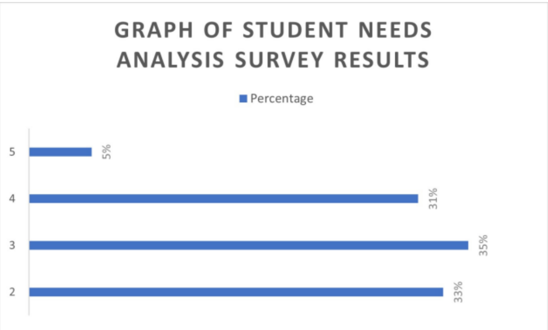


Figure 2. Graph of student needs analysis survey results (Source: Primary research data, 2025)

Description:

The vertical axis shows the Likert scale with a range of 1–5, where:

Score 1 = Do not understand

Score 2 = Do not understand very well

Score 3 = Understand fairly well

Score 4 = Understand

Score 5 = Understand very well

Figure 2 illustrates the survey results obtained from 32 students at UM Laboratory High School. The data show that 35 % of students selected score 3, 33 % score 2, 31 % score 4, and only 5 % score 5. This pattern indicates that the majority of students exhibit moderate learning needs, reflecting partial conceptual understanding and limited contextual connection.

These findings align with previous studies reporting that electrochemistry poses representational and conceptual challenges due to its abstract nature and microscopic–macroscopic transitions [9], [11]. Students often memorize formulas without fully understanding oxidation-reduction processes or the function of electrodes. Qualitative comments revealed that many found it difficult to visualize electron movement or link reactions with observable phenomena, which suggests a gap in representational reasoning.

From a CRTT perspective, such learning difficulties can be addressed by connecting abstract scientific concepts to students' cultural and environmental realities. For instance, learning through culturally familiar examples—such as keris plating, corrosion on traditional metal crafts, or the use of Morinda citrifolia (noni) and Plumeria (frangipani) extracts as natural electrolytes—can bridge theoretical and practical understanding [3], [8], [10]. These examples not only contextualize redox processes but also reinforce cultural pride and ecological awareness, both central to transformative learning.

The moderate average score also reflects limitations in current teaching practices. Based on the open responses, most students experienced teacher-centered instruction, dominated by lectures with limited experimentation. Only a small number had opportunities for inquiry-based activities. This situation supports findings by Eggett [2] and aligns with the reviewer's comment that a more analytical explanation of instructional context was needed. CRTT advocates for a shift from teacher-dominated classrooms to collaborative and dialogic learning, where students' voices and cultural experiences inform lesson design. Incorporating familiar local materials and social practices encourages a sense of ownership and relevance, key elements of meaningful learning [1], [8].

Furthermore, students expressed a high interest in practical and eco-friendly learning tools, particularly edukits. About 80 % of respondents preferred activities involving direct experimentation because they found them more engaging and easier to understand. This reinforces findings by Nugrahnastiti and Kamaludin [7], who reported that contextual hands-on tools enhance students' motivation and higher-order thinking skills. Within the CRTT framework, edukits serve as transformative pedagogical tools—they connect scientific inquiry with cultural identity and sustainability values [10]. Thus, the positive response toward edukits demonstrates students' readiness for CRTT-oriented innovations.

In summary, the distribution in Figure 2 and students' qualitative remarks jointly reveal three essential insights. First, conceptual understanding remains moderate, requiring representational reinforcement. Second, the dominance of traditional teaching restricts inquiry and contextual linkage. Third, students show strong motivation for culturally and environmentally grounded learning experiences.

These insights reinforce the urgency of redesigning chemistry learning that is both conceptually rigorous and culturally responsive.

Synthesizing both figures, the validated instrument (Figure 1) has proven feasible and theoretically grounded, while the needs analysis results (Figure 2) demonstrate a clear direction for pedagogical innovation. The moderate learning needs identified indicate that students require more interactive, culture-based, and practice-oriented learning approaches.

Therefore, the development of CRTT-integrated electrochemistry edukits is strongly justified. Such edukits combine eco-friendly materials, local wisdom, and contextual experiments to foster holistic learning. They help students link macroscopic observations with symbolic representations while appreciating the cultural relevance of science. In alignment with Kurikulum Merdeka, this approach empowers learners cognitively, socially, and culturally—turning chemistry learning into a transformative and inclusive process.

CONCLUSION AND SUGGESTIONS

This study concludes that electrochemistry learning in Grade XII MIPA at UM Laboratory High School remains largely theoretical and teacher-centered, leading to moderate student understanding. Galvanic and Electrolysis Cells are the most challenging subtopics. However, students show strong interest in practical learning through simple and environmentally friendly edukits, and they respond positively to culturally relevant chemistry contexts such as keris plating and the use of natural plant-based electrolytes.

Integrating the CRTT framework can make chemistry more inclusive, contextual, and transformative by connecting abstract concepts to students' cultural environments. Teachers are encouraged to develop simple CRTT-based edukits to foster inquiry, engagement, and cross-cultural awareness.

This study involved a relatively small sample (32 students) from a single school and relied on self-reported data, which may limit generalizability. Future research should experimentally test the effectiveness of CRTT-integrated edukits in improving students' learning outcomes, motivation, and higher-order thinking skills across broader contexts.

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