



Enhancing Secondary Students' Conceptual Understanding of Electrochemistry through Discovery-Based Practicals Using Improvised Materials in Rutsiro District, Rwanda

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Abstract: Many secondary school students experience difficulties in learning electrochemistry due to its abstract concepts and limited opportunities for practical learning, particularly in schools with inadequate laboratory resources. This study investigated the effect of discovery-based practical lessons using improvised materials on students' conceptual understanding, motivation, and learning experiences in electrochemistry in selected secondary schools in Rutsiro District, Rwanda. A mixed-methods approach under a quasi-experimental design was employed involving 120 students divided into experimental and control groups of 60 each. Data were collected using pre-tests, post-tests, student questionnaires, teacher interviews, and focus group discussions. Quantitative data were analyzed using descriptive statistics, paired and independent samples t-tests, Cohen's *d* effect size, and Hake's normalized gain, while qualitative data were analyzed thematically. The findings showed no significant difference between the experimental and control groups before the intervention, $p = 0.3195$, indicating comparable initial conceptual understanding. However, after the intervention, students who participated in discovery-based practical lessons using improvised materials achieved significantly higher post-test scores than those taught through traditional methods, $p < 0.001$ with a large effect size, Cohen's $d = 0.83$. Students reported increased interest, active participation, and improved understanding of electrochemistry. Despite these benefits, teachers identified challenges including inadequate training, limited laboratory resources, insufficient instructional time, and large class sizes. The study concludes that discovery-based practical lessons using improvised materials can effectively enhance electrochemistry learning in resource-constrained schools. Strengthening teacher training and promoting the use of locally available materials are recommended to support practical chemistry instruction.

Keywords: Discovery learning, improvised materials, conceptual understanding, electrochemistry, chemistry education, learner engagement.

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1. Introduction

Electrochemistry is an integral part of chemistry taught at the high school level since it deals with the connection between chemical processes and electric energy. Electrochemistry helps students to understand various

processes that find applications in different industries, energy production, environmental conservation, and even in their everyday lives. Therefore, successful studying of electrochemistry is crucial for scientific literacy and further career opportunities in the field of science and technology. However, electrochemistry is

among the chemistry topics considered very challenging to master by students.

Conceptual problems have been identified consistently in previous researches that students experience in electrochemistry because of the abstractness of its underlying principles. Concepts such as electron movement, migration of ions, oxidation-reduction reaction, and electrode reactions happen at the microscopic level and thus can not be observed by the students (Osman & Lee, 2014). This problem makes it difficult for students to relate their macroscopic observations from experiments, microscopic explanation of chemical processes, and symbols in chemistry (Eggen, 2010). For instance, while students will observe that gas is produced through the process of electrolysis, it becomes difficult for them to give an explanation regarding how ions, electron movement, and specific electrode reactions are involved in the process.

Various instructional approaches have been investigated to address these learning difficulties. Cooperative and group learning strategies have been shown to improve student interaction and conceptual understanding by encouraging discussion and peer support (Acar & Tarhan, 2007). However, such approaches alone may not fully address misconceptions when learners have limited opportunities to directly investigate phenomena and construct explanations from evidence. Similarly, Ali et al. (2022) reported that difficulties in scientific explanation, inappropriate teaching approaches, and inadequate instructional resources contribute to students' ability to memorize electrochemistry concepts without achieving deeper conceptual understanding.

Practical activities provide important opportunities for students to connect theoretical concepts with observable phenomena. However, the effectiveness of laboratory activities depends largely on their design and implementation. Conventional laboratory activities, where students follow predetermined procedures and obtain expected results, often provide limited opportunities for inquiry, reasoning, and conceptual development (Byusa et al., 2021; Doucette et al., 2019). In contrast, inquiry-based and discovery-based practical activities engage learners in generating questions, formulating hypotheses, interpreting evidence, and constructing scientific explanations (Abrahams, 2009; Putri et al., 2024). These principles are consistent with discovery learning theory, which proposes that learners develop deeper understanding when they actively discover relationships and construct knowledge through exploration (Bruner, 1960).

The success of active learning techniques, including inquiry-based learning and discovery-based learning, has been well-established through a variety of scientific education research studies. Several studies have revealed that active learning methods usually result in higher-

quality learning experiences compared to passive learning techniques used by teachers (Freeman et al., 2014). However, the current issue in chemical education is not about finding out whether active learning is more advantageous compared to passive learning. It is now about understanding how to implement active and discovery-based techniques in certain educational settings, especially where there is a shortage of resources.

The lack of laboratory facilities, equipment, and possibilities of conducting experiments are some issues facing the implementation of quality practical chemistry lessons in most of the resource-poor secondary schools. In this situation, improvised materials can become an alternative method for organizing discovery-based practical learning using available materials. Nonetheless, whereas earlier studies have demonstrated the significance of using active learning and inquiry-based practical exercises, few studies have attempted to explore the effectiveness of combining discovery-based practical exercises with improvised materials for enhancing comprehension of abstract chemistry concepts like electrochemistry among students.

Therefore, this study does not seek merely to replicate previous comparisons between active and passive learning approaches. Rather, it investigates whether discovery-based practical lessons supported by improvised materials can enhance students' conceptual understanding of electrochemistry compared with the conventional practical instruction commonly implemented in secondary schools. By focusing on the integration of learner-centered inquiry with locally available materials, the study contributes evidence on how effective chemistry practical instruction can be designed and implemented in resource-limited educational settings.

2. Literature Review

2.1 Theoretical foundation

Constructivist theory of learning and discovery learning theory of Bruner formed the basis for this research. According to constructivism, an individual creates his/her own knowledge through the process of interaction between the new experiences and the old one rather than absorbing the information. Constructivism is applicable to chemistry education since most of the electrochemical processes, like electron transfer and ion migration, happen on microscopic level and cannot be seen. Practical experience helps link observable events to scientific concepts (Eggen, 2010; Osman & Lee, 2014).

Bruner's (1960) discovery learning theory implies that learning is also enhanced when the learner engages in problem investigation, observation, and explanation with proper instructional guidance from teachers. Thus,

guided discovery learning activities give learners the opportunity to discover about electrochemical phenomena, test hypotheses, and refine their knowledge based on evidence. Thus, the current study formulated the hypothesis that discovery learning practical activities employing improvised equipment would improve the students' conceptual understanding of electrochemistry.

2.2 Empirical Review

2.2.1 Diverse challenges involved in learning electrochemistry.

Electrochemistry is considered one of the difficult topics for students to learn because many concepts involve abstract processes that cannot be directly observed. According to the literature review conducted by Acar and Tarhan (2007) and Ali et al. (2022), several misconceptions have been identified among students, and the main reasons behind such misconceptions include incorrect interpretation of scientific language, inadequacy of teaching aids, and traditional ways of teaching. Likewise, Turner et al. (2023) highlighted that electrochemistry involves concepts that require students to connect different levels of chemical representation. Osman and Lee (2014) further reported that students struggle to understand electron and ion movement, differentiate oxidation and reduction processes, and identify the roles of electrodes. Eggen (2010) also emphasized difficulties in linking macroscopic, microscopic, and symbolic representations in electrochemistry learning.

2.2.2 Teaching methods and student understanding.

Research shows that traditional teaching methods are insufficient for effective electrochemistry learning. Students often fail to connect different levels of chemical understanding due to passive learning approaches, where they mainly memorize concepts rather than construct their own understanding. Özkaya et al. (2003) showed that learners perform better when they engage in experimentation and exploration. Active learning methods therefore provide opportunities for students to interact with scientific concepts and improve their conceptual understanding.

2.2.3 The importance of practical activities in chemistry education.

Practical investigations provide learners with opportunities to link theoretical knowledge with actual observations. However, the effectiveness of practical activities depends on how they are designed and implemented. Abrahams (2009) found that structured “cookbook” experiments, where students only follow already provided procedures, provide limited opportunities for reasoning and scientific thinking. In

contrast, inquiry-based and discovery-based practical activities encourage students to predict, investigate, interpret evidence, and construct scientific explanations.

2.2.4 Improvised materials in science education

In resource-limited settings, improvised materials are widely recommended as an alternative approach to support practical science learning. Addisalem et al. (2024) found that locally available materials increase student engagement, promote hands-on learning, and encourage discovery and exploration. In Rwanda, Ngendabanga et al. (2025) found that locally available and improvised materials improve students' understanding and motivation in chemistry learning, although teacher training remains essential for effective implementation.

2.2.5 Curriculum implementation challenges in Rwanda

The Competence-Based Curriculum (CBC) places much emphasis on learner-centered methods and practical learning. However, implementation challenges still exist in science classrooms. Byusa et al. (2021) discovered that classroom practices in Rwandan secondary schools still rely heavily on traditional instructional approaches, which limit learners' active participation. Similarly, Abrahams (2009) argued that practical activities without student involvement do not sufficiently promote scientific thinking. In rural Rwanda, inadequate laboratory facilities limit practical learning opportunities Dusangumukiza et al. (2024). Kwitonda et al. (2022) further noted that traditional instruction limits inquiry-based learning and reduces students' curiosity and engagement.

2.2.6 Electrochemistry learning in resource-limited contexts

The use of improvised materials is particularly important in rural schools such as those found in Rutsiro District, where access to laboratory resources may be limited. Dusangumukiza et al. (2024) found that students perform better in chemistry when hands-on experiments are included, but learning becomes difficult when concepts remain abstract due to inadequate practical resources. However, most studies conducted in Rwanda have focused on general chemistry learning rather than specifically on electrochemistry, creating a gap that requires further investigation.

2.2.7 Research gap

Although extensive research has demonstrated the effectiveness of active and discovery-based learning approaches in improving students' engagement and conceptual understanding in science education, limited

attention has been given to how these approaches can be effectively implemented in resource-constrained chemistry classrooms. Existing studies have mainly examined inquiry-based learning or practical activities conducted using conventional laboratory facilities, while insufficient attention has been paid to the integration of discovery-based practical lessons with improvised materials where standard laboratory resources are limited.

In addition, there are few studies conducted among Rwandan secondary schools, specifically those found in rural settings like that of Rutsiro District, demonstrating the extent to which improvised resources may help in facilitating discovery-oriented practical lessons in abstract chemistry subjects like electrochemistry. This is especially the case considering some of the challenges, which include lack of adequate lab resources, big classes, and teacher-centered teaching practices. However, although the advantages of active learning are well documented, there are few studies which investigate whether the use of locally improvised resources in practical lessons could help students comprehend electrochemical concepts better than conventional practical instruction in resource-limited secondary school settings.

3. Methodology

3.1 Research Design

The study utilized a mixed method quasi-experimental research design to examine the effect of discovery-based practical activities using improvised materials on students' conceptual understanding of electrochemistry. The use of a mixed methods design was necessary because it allowed the researcher to integrate quantitative findings on students' learning outcomes and qualitative information on students' and teachers' experiences during the intervention.

The quantitative part of the study employed pre-test and post-test control group design. Participants were assigned into experimental and control groups. The control group received the conventional chemistry instruction commonly practiced in the participating schools, where lessons followed the prescribed curriculum and included teacher explanations, textbook discussions, guided question-and-answer sessions, and practical activities conducted according to standard laboratory procedures. During practical sessions, students followed predetermined experimental procedures under teacher guidance to verify concepts that had already been taught. Improvised materials were not used, and students had limited opportunities to design investigations or construct explanations independently.

In contrast, the experimental group participated in discovery-based practical lessons using improvised

materials. Students investigated electrochemical phenomena, designed or assembled simple apparatus from locally available materials, discussed observations collaboratively, and constructed scientific explanations, while the teacher acted as a facilitator rather than the primary source of knowledge. Both groups completed a pre-test before the intervention and a post-test after the intervention to determine changes in conceptual understanding.

The qualitative part involved focus group discussions with students and interviews with chemistry teachers to obtain deeper information about their experiences, perceptions, and challenges related to the intervention.

3.2 Study Area

The study was conducted in Rutsiro District, Western Province, Rwanda. The district was selected because many rural schools experience challenges related to the availability of laboratory facilities and science teaching materials. Therefore, the district provided an appropriate context for investigating the possibility of using locally available materials to support practical chemistry learning.

3.3 Participants and Sampling

The target population of the study consisted of secondary school students learning electrochemistry and chemistry teachers teaching electrochemistry in Rutsiro District, Rwanda. The study involved Secondary Three students, who learn electrolysis, and Secondary Six students, who learn electrochemical cells, because these levels cover major electrochemistry concepts in the Rwandan secondary school chemistry curriculum.

The study was conducted in four selected secondary schools, namely College de la Paix, GS Karambira, ES APAKAPE, and GS Mushubati. The schools were selected purposively because they had students learning electrochemistry, available chemistry teachers, willingness to participate, and suitable conditions for implementing the intervention.

The accessible population consisted of 172 students and four chemistry teachers. The sample size was determined using Yamane's (1967) formula at a 5% level of precision. The final sample consisted of 120 students and four chemistry teachers who participated as key informants. Among the students, 60 were assigned to the experimental group and 60 to the control group.

A purposive sampling strategy was used to select schools and chemistry teachers because they possessed the characteristics required for the study. For student selection, stratified random sampling was used. Two

schools were allocated to the experimental group (one boarding school and one day school), while the other two schools were allocated to the control group (one boarding school and one day school).

3.4 Data Collection Instruments

Data were collected using quantitative and qualitative instruments. Quantitative data were collected using an achievement test consisting of pre-test and post-test questions designed to measure students' conceptual understanding of electrochemistry. Qualitative data were collected through focus group discussions with students and interviews with chemistry teachers to obtain information about their experiences, perceptions, and challenges during the intervention.

3.5 Description of the Intervention

The intervention involved the implementation of discovery-based practical activities using improvised materials in the experimental group for a period of four weeks, covering approximately six to eight chemistry lessons. The activities were designed to support students in exploring electrochemical concepts through direct interaction with locally available materials rather than depending mainly on theoretical explanations.

During the intervention, learners worked collaboratively in groups to investigate electrochemical phenomena, make observations, analyze results, and develop explanations based on experimental evidence. The teacher acted as a facilitator by providing guiding questions, clarifying students' ideas, and supporting the interpretation of findings rather than directly demonstrating procedures or providing explanations before students explored the activities.

The improvised materials were selected to replace conventional laboratory equipment and chemicals where possible. Examples included pencils as graphite electrodes, plastic cups as containers for electrolytes, table salt as a source of ions, simple dry cells as power sources, vinegar as an acidic electrolyte, iron nails as metal electrodes, copper wires as conductors, LEDs as indicators of electrical energy, and lemons for demonstrating simple electrochemical cells.

Through these activities, students were able to observe electrochemical processes such as oxidation, reduction, electron transfer, ion movement, and electrical energy production. The use of familiar and affordable materials provided opportunities for learners to connect theoretical concepts with observable chemical phenomena. The

intervention was based on constructivist principles, where students actively constructed knowledge through exploration, discussion, and reflection.

The control group received lessons through traditional teaching methods commonly practiced in the selected schools. Learning mainly involved teacher explanations, textbook discussions, guided questioning and answering, and regular practical activities where applicable. Although students participated in discussions and answered questions, the control group did not receive structured discovery-based practical activities using improvised materials. During practical lessons, students followed teacher instructions and focused on observing and verifying concepts that had already been explained.

3.6 Data Analysis

Quantitative data obtained from the achievement tests were analyzed using the stata software. Descriptive statistics including means and standard deviations were used to summarize students' performance. Inferential statistics, including independent samples t-test and paired samples t-test, were used to determine differences between and within groups. Effect size was calculated to determine the magnitude of the intervention effect.

Qualitative data from interviews and focus group discussions were analyzed using thematic analysis. Responses were coded, categorized into themes, and interpreted to identify students' and teachers' experiences regarding discovery-based practical activities using improvised materials.

3.7 Ethical Considerations

Ethical approval was obtained before conducting the study. Permission was obtained from relevant educational authorities and school administration. Participants were informed about the purpose of the study, and their participation was voluntary. Informed consent was obtained from participants, and confidentiality of the collected information was maintained by using the data only for research purposes.

4. Results and Discussion

4.1 Baseline equivalence of study groups

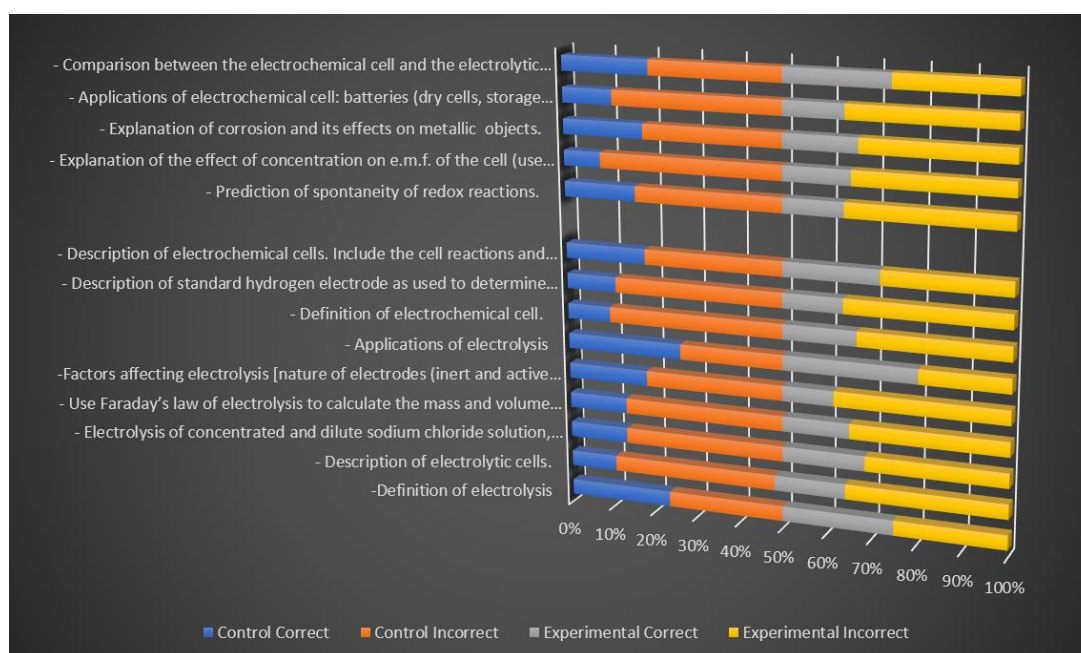
Before the intervention, an independent-samples t-test was conducted to compare the pre-test scores of students in the experimental and control groups. The results are presented in Table 1.

Table 1. Comparison of pre-test scores between the control and experimental groups

Group	<i>n</i>	Mean	SD	Mean Difference	<i>t</i>	<i>df</i>	<i>p</i>
Control Group	60	17.27	4.83				
Experimental Group	60	18.15	4.85	-0.88	-1.00	118	.320

The experimental group obtained a slightly higher mean score ($M = 18.15$, $SD = 4.85$) compared with the control group ($M = 17.27$, $SD = 4.83$). However, the difference was not statistically significant, $t(118) = -1.00$, $p = .320$. This indicates that the two groups had comparable levels of conceptual understanding before the intervention.

Students' performance on individual electrochemistry concepts before the intervention is presented in Figure 1.

**Figure 1: Chart percentage of students' correct and incorrect answers in each topic before instruction.**

4.2 Effect of discovery-based practical activities using improvised materials on conceptual understanding

A paired-samples t-test was conducted to compare students' pre-test and post-test scores after the instructional period. The results are presented in Table 2.

Table 2. Paired-samples t-test results for pre-test and post-test scores.

Test	Mean	SD	Mean Difference	<i>t</i>	<i>df</i>	<i>p</i> -value
Pre-test	17.71	4.84				
Post-test	20.49	5.02	2.78	8.86	119	< .001

The results showed a significant difference between students' pre-test and post-test scores, $t(119) = 8.86$, $p < .001$. The mean score increased from 17.71 ($SD = 4.84$) before the intervention to 20.49 ($SD = 5.02$) after the intervention, with a mean difference of 2.78 marks. This

indicates that students' conceptual understanding of electrochemistry improved after the instructional period. Students' performance on individual electrochemistry concepts after the intervention is presented in Figure 2.

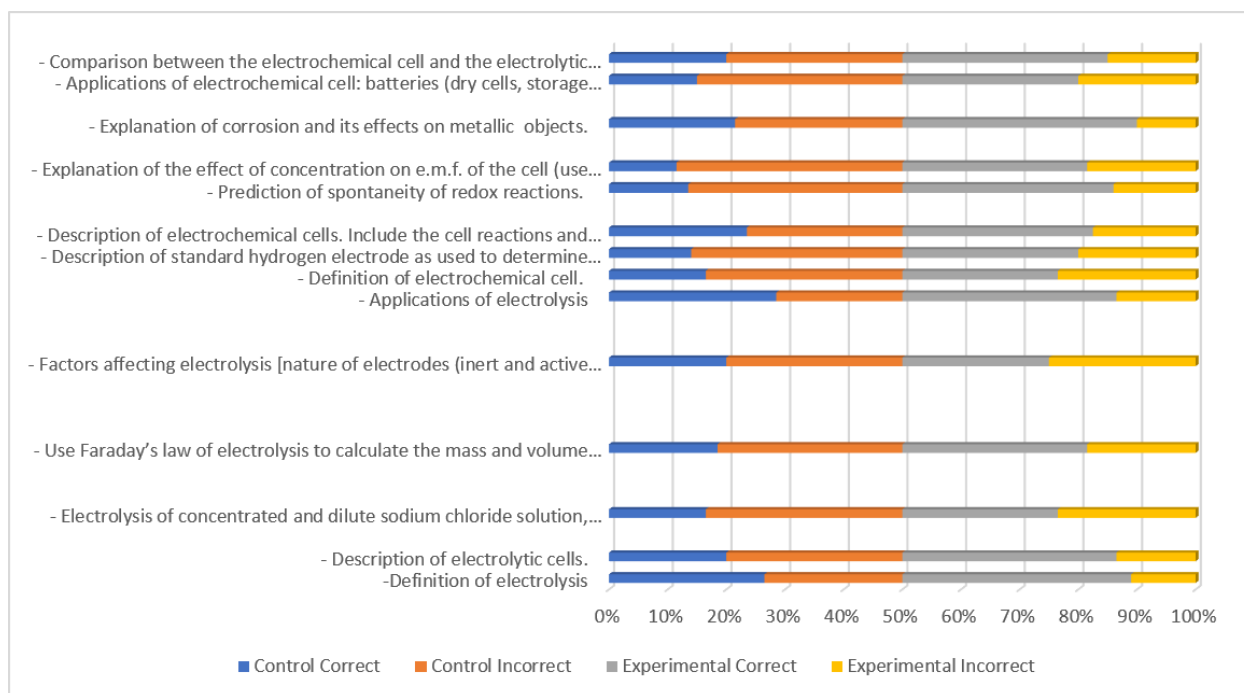


Figure 2 : Percentage of the students' correct and incorrect answers in each topic after instructions

4.3 Improvement within each group

After the intervention, an independent-samples t-test was conducted to determine whether there was a significant

difference between the post-test scores of the experimental and control groups. The results are presented in Table 3.

Table 3. Comparison of post-test scores between the control and experimental groups.

Group	<i>n</i>	Mean	SD	Mean Difference	<i>t</i>	<i>df</i>	<i>p</i>
Control Group	60	18.57	4.73				
Experimental Group	60	22.42	4.59	-3.85	-4.53	118	< .001

After the intervention, students who learned through discovery-based practical activities using improvised materials achieved significantly higher post-test scores than students who received conventional instruction. The experimental group obtained a mean score of 22.42 (SD = 4.59), whereas the control group obtained a mean score of 18.57 (SD = 4.73). An independent-samples *t*-test showed that the difference was statistically significant, $t(118) = -4.53, p < .001$.

4.4 Effect size of the intervention

The magnitude of the difference between the experimental and control groups was examined using Cohen's *d* and Hedges' *g* effect size analysis. The results are presented in Table 4.

Table 4. Effect size analysis (Cohen's *d* and Hedges' *g*).

Effect Size	Estimate	95% Confidence Interval
Cohen's <i>d</i>	-0.827	-1.198 to -0.452
Hedges' <i>g</i>	-0.821	-1.190 to -0.449

The calculated Cohen's *d* value is -0.827 (absolute value: 0.83) which is indicative of large effect size based on the effect size criteria of Lovakov and Agadullina (2021). The negative value of the effect size is due to the calculation of the difference between the means of the two groups as control group minus experimental group. This signifies that the experimental group outperformed the control group.

4.5. Analysis using Hake's Normalized Gain

Hake's normalized gain analysis was conducted to determine the amount of improvement achieved by students from pre-test to post-test compared with the maximum possible improvement. The results are presented in Table 5.

Table 5: Hake's normalized gain analysis

Group	n	M	SD	SE	95%CI Lower	95% CI Upper
Control	60	0.052	0.113	0.015	0.023	0.081
Experimental	60	0.190	0.130	0.017	0.157	0.224
Combined	120	0.121	0.140	0.013	0.096	0.146

Normalized gain scores were higher for the experimental group ($M = 0.190$, $SD = 0.130$) than the control group ($M = 0.052$, $SD = 0.113$). The independent samples *t*-test revealed that the normalized gain score difference between the two groups was statistically significant, $t(118) = -6.223$, $p < .001$. This implies that learners who undertook discovery-based practical exercises using improvised resources gained significantly more than learners under conventional instructions.

4.6 Students' motivation and engagement

The findings as presented in Figure 3 and table 6 suggest that discovery-based practical activities using improvised materials positively influenced learners' motivation, participation, and classroom engagement.

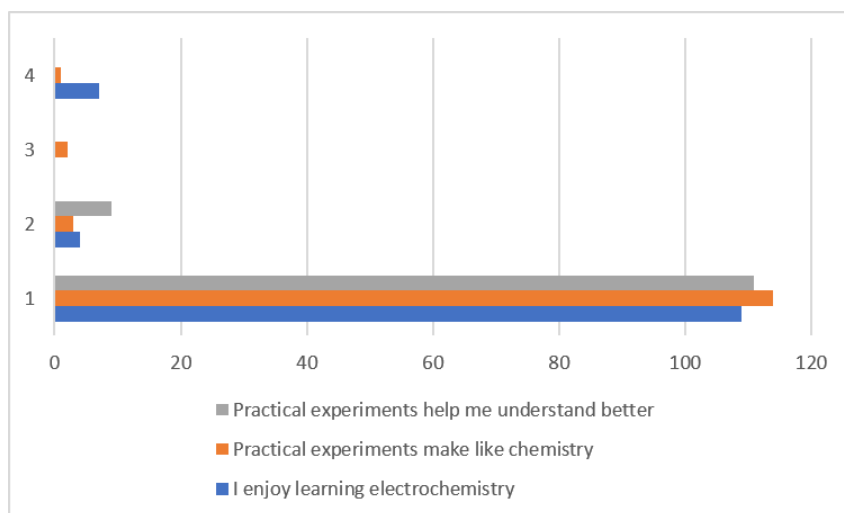


Figure 3: Students' motivation towards learning electrochemistry from likert scale.

Questionnaire findings indicated that students exposed to discovery-based practical activities reported high levels of motivation and engagement.

Table 6: Students' engagement and participation in electrochemistry learning (%)

Response	I actively participate in class discussions and activities	%	I pay attention and stay focused during electrochemistry lessons	%
Strongly agree	52	86.7	47	78.3
Agree	5	8.3	6	10.0
Not Sure	0	0.0	0	0.0
Disagree	3	5.0	7	11.7
Total	60	100.0	60	100.0

More than 90% of learners agreed that practical activities improved their understanding of electrochemistry and increased their interest in chemistry. Similarly, over 85% reported active participation during classroom discussions and practical activities, while more than three-quarters indicated that they remained attentive throughout the lessons.

4.7 Students' experiences with improvised materials

Students expressed positive perceptions regarding the use of improvised materials during practical activities. All participants reported using locally available materials during the experiments, while 90% indicated that these materials helped them understand electrochemistry concepts more effectively. Furthermore, 93.3% reported suggesting different ways of using the available materials, and 80% indicated that they predicted experimental outcomes before carrying out the investigations.

Table 7: Learners' responses on improvised materials and discovery practical activities (Experimental group)

Item	Response	Frequency (n)	Percentage (%)
Used local materials in experiments	Yes	60	100
	No	0	0
Local materials helped understand concepts	Yes	54	90
	No	3	5
	Not sure	3	5
Suggested ways to use provided local materials	Yes	56	93.3
	No	4	6.7
Predicted outcomes before experiment	Yes	48	80
	No	12	20

These findings in table 7 demonstrate that the instructional approach encouraged active participation and inquiry during practical learning.

4.8 Challenges encountered during implementation

The qualitative data suggested that there were four major issues faced when conducting the discovery-based practical work:

- lack of proper training for teachers on how to use improvised materials;
- a lack of some laboratory instruments;
- insufficient time for conducting practical work; and big classes.

Despite the aforementioned problems, both teachers and students found the intervention to be positive. It was noted that the discovery-based practical activities improved independence, cooperation, and understanding of electrochemistry among learners.

4.9 Discussion

4.9.1 Discovery-based practical activities using improvised materials and students' achievement

The results of this study showed that discovery-based practical activities using improvised materials significantly improved students' achievement and

conceptual understanding of electrochemistry compared with conventional instruction. This was demonstrated by the higher post-test scores, greater normalized learning gains, and large effect size obtained by the experimental group. The findings suggest that involving learners in practical investigations enabled them to understand abstract electrochemical concepts through direct observation, discussion, and explanation of scientific phenomena.

These findings are consistent with the studies of Mushimiyamana et al. (2022), Nurhayati and Mahalli (2026), and Simanjuntak (2022), who reported that discovery learning and practical activities improve students' conceptual understanding, academic achievement, and scientific reasoning. The improvement observed in this study can be explained by the fact that discovery-based practical activities provided learners with opportunities to actively construct knowledge rather than depending mainly on teacher explanations. Through observing electrochemical processes such as electron transfer, oxidation-reduction reactions, and ion movement, students were able to connect theoretical concepts with observable phenomena.

Furthermore, the current study extends previous findings by combining discovery-based practical activities with improvised materials in teaching electrochemistry. Unlike studies that mainly investigated discovery learning using conventional laboratory resources, this study demonstrated that meaningful practical learning can also be achieved using locally available materials in resource-limited school contexts. Therefore, the higher achievement of the experimental group indicates that

discovery-based practical activities using improvised materials provide additional advantages compared with conventional teacher-guided practical lessons.

4.9.2 Discovery-based practical activities, students' motivation, and engagement

The findings showed that discovery-based practical activities positively influenced students' motivation, participation, collaboration, and independence during electrochemistry learning. The students actively participated in practical work, group discussions, and problem-solving activities, creating a more learner-centered learning environment.

These findings agree with Yusiran et al. (2019), who reported that inquiry-oriented practical activities promote active learning and critical thinking among learners. Similarly, Ngendabanga et al. (2025) found that practical activities using locally available materials increase learners' interest and confidence in chemistry learning. The positive experiences reported by students in this study may be attributed to the opportunity to interact directly with materials and discover scientific concepts by themselves rather than only receiving information from the teacher.

The use of familiar materials may have also increased students' confidence because learners were able to relate classroom activities with materials available in their daily environment. This suggests that improvised materials do not only solve resource challenges but can also support students' motivation and engagement in chemistry learning.

4.9.3 Teachers' challenges in implementing discovery-based practical activities

Although the intervention produced positive learning outcomes, several challenges were identified during implementation. These included inadequate teacher training on the use of improvised materials, shortage of laboratory equipment, limited instructional time, and large class sizes.

These findings are consistent with Ngendabanga et al. (2025), Dusangumukiza et al. (2024), and Mushimiyamana et al. (2022), who reported that limited resources and inadequate preparation among teachers continue to affect the implementation of practical and learner-centered science teaching approaches. In particular, effective use of improvised materials requires teachers to have sufficient knowledge and skills to select appropriate materials, design activities, and guide learners during discovery processes.

Despite these challenges, teachers in the current study considered improvised materials as a useful alternative

when conventional laboratory resources were unavailable. This implies that providing teacher training on improvisation and discovery-based teaching approaches, together with improving access to instructional resources, may support effective implementation of practical chemistry learning in resource-limited schools.

5. Conclusion and Recommendations

5.1 Conclusion

This study examined the effect of discovery-based practical activities using improvised materials on secondary school students' conceptual understanding of electrochemistry in Rutsiro District, Rwanda. The findings showed that students who participated in discovery-based practical activities achieved significantly higher conceptual understanding, greater learning gains, and better engagement compared with students who received conventional instruction.

The study revealed that the use of improvised materials provided learners with opportunities to actively participate in practical investigations, construct explanations, and connect theoretical electrochemical concepts with observable phenomena. The approach also promoted learner independence, cooperation, and active participation during chemistry learning.

Although challenges related to teacher preparation, availability of laboratory facilities, instructional time, and large class sizes were identified, the findings indicate that improvised materials can provide a useful alternative for supporting practical chemistry learning in resource-limited schools. Therefore, discovery-based practical activities using locally available materials can be considered an effective approach for improving the teaching and learning of electrochemistry.

5.2 Recommendations

Considering the results of this research, there are certain recommendations that could be considered.

1. Chemistry teachers are advised to conduct more discovery learning practices when teaching students complicated issues, like electrochemistry. It will assist them in gaining deeper understanding through experience.
2. Schools and education authorities should also support teachers with regular training focused on practical teaching skills. This includes how to design simple experiments using locally available materials and how to manage practical lessons in large classrooms.

3. In addition, school leaders should ensure that enough time is allocated for practical lessons. Discovery-based learning requires time for experimentation, discussion, and reflection, which cannot be rushed.
4. Even though improvised materials proved effective, schools should still be supported with basic laboratory equipment. Improvisation works best when it complements, not replaces, proper laboratory facilities.
5. Finally, curriculum implementers should continue encouraging learner-centred approaches within the Competency-Based Curriculum, especially in science subjects where understanding depends heavily on practical experience.

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