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Enhancing Students' Scientific Communication Skills in Electrochemistry through an Ethno-STEM–Based POE2WE Model

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Abstract

Students' scientific communication skills in electrochemistry have not developed optimally because learning tends to emphasize cognitive aspects. This study aims to examine the effect of applying the Prediction, Observation, Explanation, Elaboration, Write, and Evaluation (POE2WE) learning model based on Ethno-STEM on scientific communication skills in electrochemistry. This study used a quasi-experimental method with a nonequivalent control group design involving 62 students from Suwawa 1 Public High School who were divided into an experimental group and a control group. The research instruments consisted of a test in the form of seven essay questions and non-test instruments to assess scientific communication skills during the learning process. The Mann-Whitney test results showed an Asymp. Sig. (2-tailed) value < 0.001, indicating a significant effect of the application of the Ethno-STEM-based POE2WE learning model on students' scientific communication skills. Based on the N-Gain calculation results, the scientific writing indicator was in the high category, while the information representation indicator was in the moderate category in the experimental group. In addition, the non-test assessment results showed an increase in students' scientific communication skills in three of the four indicators observed in each learning meeting.

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1. INTRODUCTION

Electrochemistry is a branch of chemistry that studies the transfer of electrons in conductive systems, including electrolyte solutions, redox reactions, electrochemical cells, electrode potentials, and their various applications in everyday life (Yuliani et al., 2022). This subject is often considered difficult because it requires a deep understanding at the macroscopic, microscopic, and symbolic levels simultaneously, making it prone to misconceptions (Pebriani et al., 2024; Sari, 2021). This difficulty is exacerbated by learning that tends to emphasize the symbolic aspect without the support of particle visualization, limited laboratory activities, and a lack of representations that facilitate translation between levels (Turner et al., 2024). Consequently, electrochemistry remains one of the most conceptually demanding topics in chemistry learning, posing persistent challenges for student.

Weak conceptual understanding of electrochemistry material not only impacts cognitive achievement but also students' scientific communication skills. Without a thorough understanding of electron flow and redox processes, they find it difficult to construct evidence-based claims, interpret experimental data, and reason logically about their observations (Nazmutdinov et al., 2023). In fact, scientific communication is an essential 21st-century competency that requires students to be able to present data systematically and connect experimental results with theory (Jensen et al., 2023).

This situation is also reflected in actual classroom settings. Initial observations at Suwawa 1 Public High School and interviews with chemistry teachers indicate that scientific communication skills have

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not previously been specifically assessed in classroom instruction. Furthermore, classroom observations show that students still struggle to articulate ideas clearly, explain experimental results, and present information systematically. These findings confirm that students' scientific communication skills remain relatively low and highlight the urgency of implementing targeted learning strategies to address this issue.

Various studies show that learning models such as problem-based learning and inquiry-based learning are effective in improving conceptual understanding and problem-solving skills (Khoviriza et al., 2024; Sari, 2021). Active learning strategies in STEM education have also been shown to support the development of inquiry skills and learning engagement (Ješková et al., 2022). However, improved conceptual understanding does not necessarily automatically lead to improved scientific communication skills. Without explicit stages that train students to systematically write, explain, and evaluate their thoughts, scientific communication competencies tend to develop only to a limited extent.

The prediction, observation, explanation, elaboration, writing, and evaluation (POE2WE) model offers a learning structure that integrates the processes of prediction, empirical observation, conceptual explanation, elaboration, reflective writing, and evaluation. Previous research shows that the POE2WE model has a positive effect on scientific communication skills, particularly on indicators of scientific writing and scientific argumentation (Alatas et al., 2024). Scientific writing activities have also been proven to strengthen students' scientific literacy and argumentative coherence (Sari et al., 2023). The existence of the "Write" and "Evaluation" stages in POE2WE is a key differentiator from conventional inquiry models because it directly instills scientific communication practices in the learning cycle.

In addition to pedagogical structure, the relevance of the learning context also plays an important role in building meaningful understanding. The Ethno-STEM approach integrates local cultural phenomena into science learning so that abstract concepts become more contextual and relevant to the experiences of students (Hiqmah et al., 2023). STEM-based learning that is integrated with real-world contexts has been proven to improve science literacy and scientific information representation skills (Kusasi et al., 2021; Sulistina et al., 2024). By linking electrochemical concepts to local cultural practices, students have the potential to develop a deeper understanding while enriching the quality of their scientific explanations.

This integration is achieved through local cultural practices in Gorontalo, such as incense burning, Mo Polihu Lo Limu (a traditional lemon-bath ritual), and the metal plating process used in sunthi jewelry. The acidic nature of lemons reflects the concept of electrolytes in science, while the use of electroplating tools represents technology, and the application and modification of these processes demonstrate simple engineering principles in everyday life.

Although a number of studies have developed POE2WE-based learning tools for various subjects, such as hydrocarbons (Novalentia & Erna, 2025), thermochemistry (Oktania et al., 2024), reaction rates (Syahlina & Futra, 2024) and colligative properties of solution (Ningsih et al., 2022), Previous studies have focused more on developing tools or improving conceptual understanding, without explicitly assessing their impact on scientific communication skills. Thus, based on the overall background described above, this study aims to analyze whether the application of this model has a significant impact on scientific communication skills and to identify the indicators that show the most dominant improvement. The results are expected to contribute theoretically to the development of chemistry learning models and practically to the application of contextual STEM oriented towards scientific communication.

2. METHOD

This study was conducted at Suwawa 1 Public High School in the odd semester of the 2025-2026 academic year. The research method used in this study was a quasi-experimental design. The research design was a nonquivalent control group design involving two groups, namely the experimental group and the control group. The nonquivalent control group design can be illustrated in Table 1. as follows.

Table 1. Research design

Group	*Pretest*	Treatment	*Posttest*
Experimental	O_1	X_1	O_3
Control	O_2	X_2	O_4

Source: (Creswell, 2014)

Before applying the treatment to the two sample classes, both were given a pretest for the experimental

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class (O_1) and the control group (O_2). Then the treatment was given during three meetings, with the POE2WE based on ethno-STEM in the experimental class (X_1) and a scientific approach in the control group (X_2). After that, a posttest was given to the experimental class (O_3) and the control group (O_4).

The population in this study consisted of 12th-grade students at Suwawa 1 Public High School. Sample determination was conducted using a cluster random sampling technique, with XII D serving as the control group and XII E as the experimental group. In class XII E, there were 14 male students and 17 female students, while class XII D consisted of 13 male students and 18 female students.

Data collection techniques were carried out using test and non-test instruments conducted with observation sheets during learning. The scientific communication instrument used in this study have undergone a validation process by experts in the field and demonstrated a high level of validity. Data analysis techniques were carried out through normality tests (*Shapiro-Wilk*) and homogeneity tests (*Levene*). These preliminary tests were essential to determine the appropriate statistical approach and to ensure that the data met the assumptions required for further analysis. Because some of the data were not normally distributed, hypothesis testing used nonparametric statistics, namely *the Mann-Whitney U test* to compare the two classes and the *Wilcoxon Signed Ranks test* to see the differences between the pretest and posttest in each class, with a significance level of 0.05. The improvement in learning outcomes was analyzed using N-Gain calculated using SPSS version 31, with categories of high (≥ 0.70), medium (0.30-0.69), and low (< 0.30). Then, the hypothesis in this study was as follows:

H_0: *Sig.* (2 *tailed*) > $\boldsymbol{\alpha}$

H_1: *Sig.* (2 *tailed*) < $\boldsymbol{\alpha}$

This study used a significance level of 0.05 with the following description: H_0 states that the Ethno-STEM-based POE2WE model has no effect on students' scientific communication skills in electrochemistry, and H_1 states that the Ethno-STEM-based POE2WE model has an effect on students' scientific communication skills in electrochemistry. The hypothesis of this study is that there is a significant effect of the application of the POE2WE model based on Ethno-STEM on students' scientific communication skills in electrochemistry.

3. RESULT AND DISCUSSION

3.1. Result

Validity and Reliability Tes

The validity test results using Pearson Product-Moment correlation showed that all seven items had an $r_{calculated\ value} > r_{table}$ (0.355) at a significance level of 5%, so all items were declared valid.

The reliability test using the Cronbach's Alpha method produced a coefficient of 0.635, which is in the moderate category. Thus, the test instrumen is in the moderate category. Thus, the test instrumen is declared reliable for measuring students' scientific communication skills.

Analysis of Pretest dan Posttest Data

Based on statistical calulations, the concentration and dispersion scores were obtained from the pretest and posttest average scores for scientific communication skills for the control and experimental classes in Figure 1. as follows.

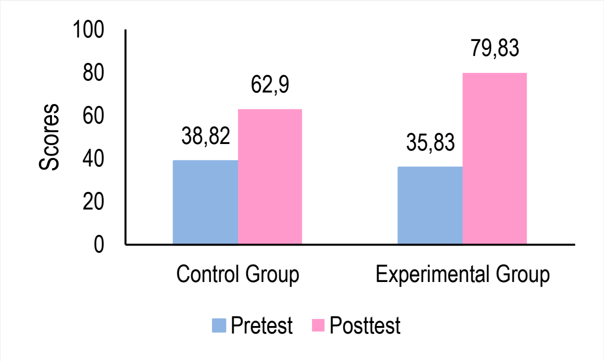

Figure 1. Average pretest and posttest scores for the control group and experimental group

Normality Test Results

The normality test of data as a prerequisite test was conducted for both classes, namely the control and experimental group. The test results can be seen in Table 2 below.

Table 2. Normality test results

Group	Shapiro-Wilk		
	Statistic	df	Sig.
Control Pre-test	0,945	31	0,115
Control Post-test	0,917	31	0,019
Experiment Pre-test	0,919	31	0,022
Experiment Post-test	0,961	31	0,304

Normality test results, the values in the Shapiro-Wilk test indicate that the pretest data for the experimental group (Sig. = 0.022) and the posttest data for the control group (Sig. = 0.019) is not normally distributed because the significance value is < 0.05. Meanwhile, the control group pretest (Sig. = 0.115) and the experimental group posttest (Sig. = 0.304) are normally distributed.

Because some of the data did not meet the normality assumption, hypothesis analysis was continued using nonparametric tests.

Homogenity Test

Both the pretest and posttest data were tested using SPSS 31, as shown in Table 3 below.

Table 3. Results of the homogeneity test

Levene Statisctic	**Pretest**	**Posttest**
Significance	0,008	0,763
α	0,05	0,05
Decision	Not Homogeneous	Homogeneous

Hypothesis Test Results

Because the prerequisite of data normality was not met, hypothesis testing in this study was conducted using nonparametric tests. The testing criterion was a Sig. value > 0.05, so Howas accepted. The results of the independent samples test using the Mann–Whitney Test on the pretest and posttest data, which was considered appropriate given the distribution of the data, can be seen in Table 4 below.

Table 4. Mann-Whitney U test results

Data	**Z**	**Sig.**	**Description**
Pretest	-0,731	0.465	H_0 accepted
Posttest	-5,110	<0,001	H_0 rejected

Data measuring the effect of the Ethno-STEM-based POE2WE learning model on scientific communication skills in the experimental group and scientific inquiry skills in the control group in electrochemistry instruction were analyzed using the Wilcoxon Signed-Rank test with SPSS Statistics 31. The test results for the experimental group and control group are shown in Table 5 below.

Table 5. Wilcoxon signed rank test results

Data	**Z**	**Sig.**	**Description**
Pretest-Posttest control class	-4,868	<0,001	H_0 ditolak
Pretest-Posttest experimental class	-4,870	<0,001	H_0 ditolak

The Wilcoxon Signed Ranks test results show that both the experimental class and the control group experienced a significant increase from the pretest to the posttest (Sig. < 0.001). However, the increase in the experimental class was higher than that in the control group, indicating a stronger improvement in students' performance compared to the control group.

N-Gain Test Results

The N-Gain results were measured in 7 items of the scientific communication skills test consisting of 2 indicators, namely scientific writing and information representations. In the test indicators, the highest increase in the experimental class occurred in the scientific writing, while the information representation indicators is in the moderate category, as shown in Figure 2.

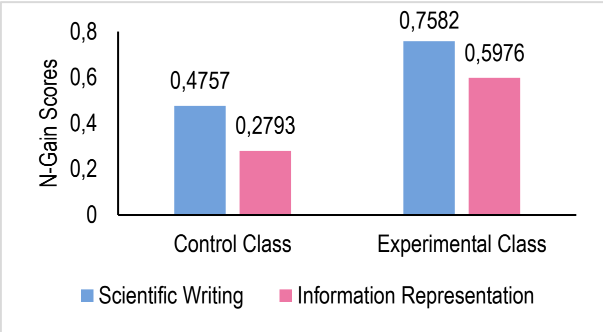

Figure 2. N-Gain test instruments for the control class and experimental class

Results of the Non-Test Instrument for Scientific Communication Skills

The observation results show an increase in scientific communication skills in the experimental class in three of the four indicators. The observations were conducted by observers consisting of chemistry education students in collaboration with chemistry teachers in the classroom, using a standardized rubric to ensure the objectivity and consistency of the assessment.

Table 6. Results of the non-test instrument

Scientific Communication Skill Indicators Scientific Communication	**Group**	**%**	**Classification**
Information retrieval and Scientific reading	Control	47	Less Skilled
	Experiment	60	Less Skilled
Listening and observing	Control	63	Moderately Skilled
	Experiment	79	Skilled
Scientific writing	Control	45	Less Skilled
	Experiment	61	Moderately Skilled
Knowledge presentation	Control	62	Moderately Skilled
	Experiment	75	Skilled

3.2. Discussion

The results of the study indicate that the application of the Ethno-STEM-based POE2WE learning model has a significant impact on students' scientific communication skills in the field of electrochemistry.. The significant difference in posttest scores between the experimental group and the control group, as shown by the Mann-Whitney test (Sig.<0.001), indicates that an integrated learning structure between conceptual stages and scientific communication practices can produce more optimal improvements compared to the scientific approach, demonstrating the clear impact of the model in fostering deeper engagement with electrochemical concepts.

Theoretically, these findings can be explained by the POE2WE pedagogical mechanism, which places students in a scientific thinking cycle. The prediction and observation stages encourage the activation of prior knowledge and direct involvement in electrochemical phenomena. These activities strengthen the cognitive process of connecting macroscopic, microscopic, and symbolic representations (Pebriani et al., 2024; Sari, 2021). In this study, the Ethno-STEM aspect was used as a real context for each stage, such as incense burning as an example of a redox reaction, *Mo Polihu Lo Limu* (a traditional lemon bath ritual in Gorontalo) as a natural electrolyte source, and the electrolysis process in Gorontalo *sunthi* jewelry. These contexts are formalized in learning that is adapted to the POE2WE stages, such as students making predictions on how to prevent sunthi from rusting easily using the concept of electrochemistry (prediction), students conducting electroplating experiments (observation), explaining findings by linking evidence and concepts (explanation), expanding analysis through experimental variants (elaboration), drawing conclusions (writing), and reflecting on and revising findings through discussion and peer assessment (evaluation). In particular, the elaboration and writing stages help students transition from verbal responses to more structured written explanations, as they are required to compare their experimental findings with electrochemical concepts and justify their answers using evidence from the lab experiment.

The important implications of this learning cycle are evident in the scientific writing indicators, which are in the high category. The writing stage plays a significant role in training students' ability to express concepts in writing. This is in line with the findings of Pikoli et al., (2023), which confirm the close relationship between scientific literacy and the ability to present information in writing. Structured scientific writing activities enable students to construct evidence-based arguments and explain the relationships between concepts in a more coherent manner. The consistent improvement in this indicator is also supported by research by Alatas et al., (2024) and Nana (2019), which states that POE2WE explicitly develops scientific communication through the integration of reflection and evaluation. Additionally Sari et al., (2023), emphasize that scientific writing tasks contribute to strengthening the coherence of students' arguments. Thus, the application Ethno-STEM-based POE2WE model can improve students' scientific communication skills in depth and structured manner.

Meanwhile, the information representation indicator showed improvement in the moderate category. This indicates that although students have made progress in representing electrochemical concepts through graphs, diagrams, or symbols, the process of translating between levels of representation remains a complex cognitive challenge. Turner et al., (2024), explain that learning electrochemistry requires consistent visualization support so that students can deeply understand particle dynamics. Thus, although the Ethno-STEM-based POE2WE Model makes a positive contribution, strengthening the aspect of visual representation still needs to be developed further.

Improvements in students' scientific communication skills are also greatly supported by the ethno-STEM approach, which makes an important contribution. The local cultural context presented in learning makes the concept of electrochemistry more relevant and meaningful to students. Alatas et al., (2024) and Hiqmah et al., (2023), state that culture-based learning can increase engagement and critical thinking skills. When scientific concepts are linked to real-world practices in the students' social environment, the process of elaboration and explanation becomes richer both conceptually and communicatively. This is reflected in the improvement of the knowledge presentation and listening and observing indicators in the experimental group. Classroom observations also show that students become more active in discussions because the local cultural context feels relevant to their daily lives, and they gain a better understanding of how to properly cite sources and select accurate references.

The results of the observation also show that the indicators of information retrieval and scientific reading are still in the less skilled category. These findings indicate that students' information literacy skills have not developed optimally, especially in evaluating and synthesizing scientific sources. Studies by Hamdani & Abid (2025) and Samaduri & Matoneng (2025), confirm that information literacy challenges among secondary school students remain a significant issue. Thus, although the Ethno-STEM-based POE2WE model is effective in improving oral and written communication aspects, strengthening information literacy requires addtional pedagogical intervation.

Instrumen Non-test instruments also measure listening and observing indicators, in which case the experimental group was categorized as skilled. This improvement was influenced by the prediction and observation stages in the POE2WE model, which directly involved students in observation and scientific discussion activities. Meanwhile, in the scientific writing indicator measured through non-test instruments, the experimental group was categorized as fairly skilled. This achievement was influenced by the students' limited ability to compile an accurate literature review in their resumes, as well as their suboptimal ability to connect concepts in a complete, relevant, and coherent manner in their discussions. This is supported by the findings of Hamdani and Abid (2025), who stated that students' writing often consists of a series of sentences or paragraphs that are not connected to each other, so that they do not form a systematic scientific line of thinking from the introduction of the topic to the conclusion.

Overall, the higher N-Gain value of the experimental group test instrument (0.6954) compared to the control group (0.3955) shows that structured and contextual learning has a more substantial impact. Ješková et al., (2022), confirm that active learning strategies in STEM tend to result in greater competency gains than traditional methods. The findings of this study reinforce this argument by showing that the integration of epistemic structure (POE2WE) and cultural context (Ethno-STEM) can optimize the development of scientific communication skills.

However, this study has limitations in terms of its relatively small sample size and treatment duration, which only lasted for three meetings. A longer duration would likely have a more significant impact on information representation and literacy indicators. Therefore, further research with a larger sample size and longer treatment duration is needed to strengthen the validity of the findings and provide a more comprehensive picture.

Thus, the results of this study indicate that the integration of the Ethno-STEM-based POE2WE model not only strengthens conceptual understanding of electrochemistry but also significantly contributes to the development of students' scientific communcation skills.

4. CONCLUSION

the Ethno-STEM-based POE2WE model has a significant impact on students' scientific communication skills in electrochemistry. The average posttest score of the experimental group increased to 79.83 compared to the control group 62.90, with Mann-Whitney and Wilcoxon tests showing significance < 0.001. N-Gain analysis confirmed that the scientific writing indicator was higher in the experimental group at 0.7582 (high category), as well as the information representation indicator at 0.5976 (medium) on the test instrument. Meanwhile, on the non-test instrument, there was an increase in 3 out of 4 scientific communication skill indicators. These findings indicate that the integration of POE2WE based on Etno-STEM has a significant effect on students' scientific communication skills.

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