



Intertextual-Based Learning Strategy Development Using POE Model on Electrolysis Cell Material to Support Students' Concept Mastery and Science Process Skills

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Abstract: Intertextual-Based Learning Strategy Development Using POE Model on Electrolysis Cell Material to Support Students' Concept Mastery and Science Process Skills.

This study aims to produce an intertextual-based learning strategy using the POE model on the electrolytic cell topic to support students' conceptual mastery and science process skills (SPS). The method refers to the first five stages of Borg & Gall's R&D model: research and information gathering, planning, preliminary product development, preliminary product testing, and preliminary product revision. The research instruments consist of five suitability review sheets assessing the alignment among the learning objective trajectory (LOT), learning outcomes (LO), SPS indicators, concept descriptions, and learning activities. The learning strategy was designed by integrating the intertextual approach into the POE model syntax, systematically connecting macroscopic, submicroscopic, and symbolic levels of chemical representation through prediction, observation, and explanation. Based on review by six experts, inconsistencies were identified across several components, serving as the basis for comprehensive revision. The revised product is a four-cycle learning strategy covering the electrolysis of molten compounds using inert electrodes, electrolysis of solutions using inert electrodes, electrolysis of solutions using non-inert electrodes, and electrolysis applications in daily life and industry, each supplemented with quantitative aspects of Faraday's Law and designed with conceptually and pedagogically aligned SPS indicators, concept descriptions, and learning activities.

Keywords: intertextual-based learning strategy, POE model, electrolytic cell, conceptual understanding, science process skills.

Abstrak: Pengembangan Strategi Pembelajaran Intertekstual dengan Model POE pada Materi Sel Elektrolisis untuk Meningkatkan Penguasaan Konsep dan Keterampilan Proses Sains.

Penelitian ini bertujuan menghasilkan strategi pembelajaran intertekstual dengan model POE pada materi sel elektrolisis untuk meningkatkan penguasaan konsep dan keterampilan proses sains (KPS) murid. Metode yang digunakan mengacu pada lima tahap pertama model R&D Borg & Gall, meliputi penelitian dan pengumpulan data, perencanaan, pengembangan produk awal, uji coba produk awal, dan revisi produk awal. Instrumen penelitian terdiri atas lima lembar uji kesesuaian yang menilai keselarasan antara alur tujuan pembelajaran (ATP), capaian pembelajaran (CP), indikator KPS, deskripsi konsep, dan kegiatan pembelajaran. Strategi pembelajaran dirancang dengan mengintegrasikan pendekatan intertekstual ke dalam sintaks model POE, menghubungkan level representasi kimia makroskopik, submikroskopik, dan simbolik secara sistematis melalui tahapan prediksi, observasi, dan eksplanasi. Berdasarkan review enam orang ahli, ditemukan ketidaksesuaian pada beberapa komponen yang menjadi

dasar revisi menyeluruh. Produk hasil revisi berupa strategi pembelajaran empat siklus yang mencakup elektrolisis lelehan menggunakan elektroda inert, elektrolisis larutan menggunakan elektroda inert, elektrolisis larutan menggunakan elektroda tidak inert, dan aplikasi elektrolisis dalam kehidupan sehari-hari dan industri, yang masing-masing dilengkapi aspek kuantitatif Hukum Faraday dan dirancang dengan indikator KPS, deskripsi konsep, serta kegiatan pembelajaran yang selaras secara konseptual dan pedagogis.

Kata kunci: strategi pembelajaran intertekstual, model POE, konsep sel elektrolisis, penguasaan konsep, KPS

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▪ INTRODUCTION

Chemistry plays a crucial role in everyday life, ranging from cooking and pharmaceutical use to industrial processes, yet is frequently perceived as difficult due to its abstract concepts. Students are required to understand phenomena across three levels of chemical representation macroscopic, submicroscopic, and symbolic (Johnstone, 2000) and the inability to connect these three levels holistically has been identified as the root cause of misconceptions (Huie et al., 2022). As a branch of natural science, chemistry also trains students to think scientifically and understand natural phenomena in depth (Novita & Aini, 2022).

This capacity for scientific thinking is closely related to science process skills (SPS), which among Indonesian students remains relatively low, particularly in communicating results, designing experiments, and controlling variables (Fitriyani, 2017; Uriyah et al., 2023). This is largely attributed to theoretical instruction, underutilization of laboratories, and passive learning methods that prevent students from engaging directly with learning experiences (Fitriyani, 2017; Feyzioğlu, 2019), indicating that instructional models must actively engage students and provide hands-on learning experiences within a structured framework, as unguided inquiry alone shows limited impact on science achievement (Jerrim et al., 2022).

One of the topics most affected is the electrolytic cell, where processes cannot be directly observed and all three representation levels must be connected simultaneously. Indonesian students' conceptual understanding of electrochemistry reaches only 44% (Rahayu et al., 2010), with 84% of its concepts considered difficult within Abia state (Obomanu & Onuoha, 2012). Documented misconceptions include the reversal of redox reaction positions relative to galvanic cells (Acar & Tarhan, 2007), the assumption that all electrodes are inert (Bong & Lee, 2016), and misunderstanding of water's role in the electrolysis of molten substances (Asnawi, 2017), all exacerbated by teacher-centered instruction and poorly structured laboratory activities (Thayban et al., 2024).

The Decree of the Head of BSKAP Number 046/H/KR/2025 affirms that chemistry learning outcomes encompass both chemical understanding and process skills. Grounded in constructivism, which emphasizes active knowledge construction through meaningful experiences (Nurhasanah, 2024), an instructional strategy is needed that simultaneously develops students' ability to connect the three representation levels and their SPS.

The intertextual-based learning strategy is considered relevant in addressing this need, as it links various chemical representations to students' everyday experiences and has been shown to improve conceptual mastery at a high criterion level (Sagala et al., 2022). Complementing this, the POE model guides students to predict, observe, and

explain phenomena proven effective in enhancing SPS (Pohan et al., 2020) while simultaneously encouraging students to examine their prior understanding so that misconceptions can be identified and corrected. Both approaches thus possess complementary characteristics with strong potential for integration into a single cohesive instructional design.

Although Priantama (2024) developed an intertextual-based learning video incorporating the POE model, and Manik (2023) developed an interactive contextual e-module, both studies focused exclusively on media product development rather than on designing a systematic instructional framework. Prior studies have similarly contributed to electrolytic cell instruction through a Moodle-based interactive learning media integrating macroscopic, submicroscopic, and symbolic representation levels (Rosyidah et al., 2021), and a STEM-based problem-based learning e-module with high validity and practicality (Fauzi et al., 2022). These studies collectively reflect a growing research interest in improving electrolytic cell instruction; however, the intentional design of an integrated intertextual instructional framework that systematically structures the POE model syntax into a complete, classroom-ready learning strategy has yet to be explored. This gap underscores the need for the present study.

Based on the foregoing, this study aims to develop an intertextual-based learning strategy using the POE model on the electrolytic cell topic to improve students' conceptual mastery and SPS. The primary research question is: "How is the intertextual-based learning strategy with the POE model developed on the electrolytic cell topic to improve students' conceptual mastery and science process skills?" Specifically, the study seeks to obtain: (1) the characteristics of the initial learning strategy product; (2) expert review results; and (3) a revised product based on expert recommendations, concretely embodied in the form of a Student Worksheet (SW) as a guide for classroom learning activities.

▪ **METHOD**

This study employed a research and development (R&D) method adapted from the Borg & Gall model. The R&D method is a research approach used to produce a specific product and to test its effectiveness (Gall et al., 2003). Although the Borg & Gall model comprises ten stages, this study was limited to the first five stages, namely: (1) research and information collecting, (2) planning, (3) develop preliminary form of product, (4) preliminary field testing, and (5) main product revision. This limitation was intentional, as the study focuses on the development and expert validation of the instructional design as a foundational phase prior to broader field implementation.

The object of this study was an intertextual-based learning strategy incorporating the Predict-Observe-Explain (POE) model, developed for the electrolytic cell topic with the aim of improving students' conceptual mastery and science process skills (SPS). The developed learning strategy was subsequently validated to assess the degree of alignment among its variables.

The research instruments consisted of five suitability review sheets, namely: (1) alignment of the learning objective trajectory (LOT) with the chemistry understanding element of the learning outcomes; (2) alignment of the LOT with the science process skills element of the learning outcomes; (3) alignment of the concept descriptions with the LOT for conceptual mastery; (4) alignment of the science process skills descriptions with the SPS indicators; and (5) alignment of the learning activities with the LOT for conceptual mastery and SPS indicators.

Data were collected through reviews by six chemistry education lecturers. Three experts assessed the alignment of concept and SPS descriptions with their respective indicators, while the remaining three evaluated the alignment of LOT with learning outcomes and the alignment of learning activities with both conceptual mastery and SPS indicators.

The review results were analyzed descriptively to identify chemistry understanding indicators, concept descriptions, SPS indicators, SPS descriptions, and learning activities within the intertextual learning strategy using the POE model on electrolytic cells that have potential to enhance students' chemistry understanding and science process skills.

▪ RESULT AND DISCUSSION

The validation process in this study was conducted through expert review, generating qualitative feedback and suggestions aimed at refining each component of the learning strategy prior to implementation. The development of an intertextual learning strategy incorporating the POE model on the electrolytic cell concept was carried out through several stages: analysis of learning elements and outcomes in the Merdeka Curriculum, formulation of the learning objective trajectory (LOT) for conceptual mastery along with concept labels and descriptions, formulation of the process skills LOT and SPS indicator descriptions, analysis of multiple representations and student misconceptions, and optimization of practical experiments to be integrated into the learning strategy.

Product Collection and Planning Stage

Derivation of the Learning Objective Trajectory and Concept Descriptions for the Chemistry Understanding Element

The planning stage began with an analysis of the Chemistry Phase F learning outcomes (LO) in the Merdeka Curriculum (Decree No. 046/H/KR/2025), covering two elements: chemistry understanding and process skills. The chemistry understanding LO was derived into learning objectives (LOT) by analyzing its operational verbs analyzing and connecting. The verb analyzing targets C4-level cognition, requiring students to identify species, determine electrode reactions, and explain products systematically (Anderson & Krathwohl, 2001). The verb connecting requires students to integrate electrolysis concepts and apply them in real world contexts at C4–C5 levels. The LOT derivation and concept labels are presented in Table 1.

Table 1. Learning Objective Trajectory and Concept Labels for the Chemistry Understanding Element

Learning Outcome	Learning Objective Trajectory	Concept Label
Analyzing the relationship between atomic structure and the periodic table; comparing types of chemical bonds and their relationship to molecular geometry and intermolecular forces in predicting physical properties of matter; relating the standard enthalpy change of a chemical reaction to energy sources in the surrounding	Analyzing the electrolysis process of solutions using inert electrodes	Electrolysis of Solutions with Inert Electrodes
	Analyzing the electrolysis process of molten substances using inert electrodes	Electrolysis of Molten Substances with Inert Electrodes

Learning Outcome	Learning Objective Trajectory	Concept Label
environment; analyzing factors affecting reaction rate; analyzing chemical equilibrium and its applications; explaining electrical conductivity and colligative properties of solutions; explaining electrochemical cells in everyday life; and explaining carbon compounds and macromolecules.	Analyzing the electrolysis process of solutions using non-inert electrodes Connecting the working principles of electrolytic cells to their applications in daily life and industry	Electrolysis of Solutions with Non-Inert Electrodes Working Principles and Applications

Derivation of the Learning Objective Trajectory and Science Process Skills Descriptions

For the process skills element, the LOT was elaborated into six SPS indicators per cycle, encompassing predicting, planning and conducting investigations, observing, interpreting data, drawing conclusions, and communicating results. The process skills included in the learning outcomes along with their descriptions are presented in Table 2.

Table 2. Process Skills Specified in the Learning Outcomes

No.	Process Skill	Description
1	Observing	Observing scientific phenomena in everyday life and in the laboratory, and recording observations with attention to the details of the object observed in order to generate questions for further investigation.
2	Questioning and Predicting	Formulating scientific questions about relationships between variables and hypotheses that can be investigated scientifically.
3	Planning and Conducting Investigations	Planning and selecting appropriate methods, and controlling variables based on references to collect reliable data; selecting and using tools and materials, including appropriate digital technology, to collect and record data systematically and accurately.
4	Processing, Analyzing Data and Information	Interpreting obtained information honestly and responsibly; using various methods to analyze patterns and trends in data; describing relationships between variables and identifying inconsistencies; using data and references to draw conclusions consistent with investigation results.
5	Evaluating and Reflecting	Identifying sources of uncertainty and possible alternative explanations in order to evaluate conclusions, and describing specific ways to improve data quality; analyzing the validity of information from primary and secondary sources and evaluating the approaches used to solve problems in the investigation.
6	Communicating Results	Communicating investigation results systematically and comprehensively, supported by scientific argumentation and openness to more relevant perspectives.

To verify that the developed LOT reflects all six SPS aspects as specified in the learning outcomes, a suitability check was conducted between each LOT and the SPS aspects it encompasses. This alignment is presented in Table 6 using a checkmark system based on previously established SPS numbers.

Table 3. Results of SPS Derivation from the Learning Outcomes for Each Learning Objective Trajectory

Learning Objective Trajectory	SPS 1	SPS 2	SPS 3	SPS 4	SPS 5	SPS 6
1.1. Predicting phenomena related to the electrolysis of solutions and molten substances using inert electrodes		✓				
1.2. Planning and conducting an investigation of the electrolysis of solutions and molten substances using inert electrodes			✓			
1.3. Observing the electrolysis process of solutions and molten substances using inert electrodes	✓					
1.4. Interpreting observational data from the electrolysis experiment of solutions and molten substances using inert electrodes				✓		
1.5. Drawing conclusions from the electrolysis experiment of solutions and molten substances using inert electrodes					✓	
1.6. Communicating the results and analysis of the electrolysis of solutions and molten substances using inert electrodes						✓
2.1. Predicting phenomena related to the electrolysis of solutions using non-inert electrodes		✓				
2.2. Planning and conducting an investigation of the electrolysis of solutions using non-inert electrodes			✓			
2.3. Observing the electrolysis process of solutions using non-inert electrodes	✓					
2.4. Interpreting observational data from the electrolysis experiment of solutions using non-inert electrodes				✓		
2.5. Drawing conclusions from the electrolysis experiment of solutions using non-inert electrodes					✓	
2.6. Communicating the results and analysis of the electrolysis of solutions using non-inert electrodes						✓
3.1. Predicting differences in the mechanisms of electroplating and electrorefining based on initial observations		✓				
3.2. Planning and conducting an investigation to identify the mechanisms of electroplating and electrorefining			✓			
3.3. Observing the mechanisms of electroplating and electrorefining	✓					
3.4. Interpreting observational data on the mechanisms of electroplating and electrorefining				✓		
3.5. Drawing conclusions on the mechanisms of electroplating, electrorefining, and the working principles of electrolysis applications					✓	
3.6. Communicating the results and analysis of electrolysis applications in daily life and industry						✓

Analysis of Multiple Representations and Student Misconceptions on the Electrolytic Cell Topic

The analysis of multiple representations on the electrolytic cell concept constitutes a critical stage in designing an intertextual-based learning strategy. The intertextual approach views learning as the interconnection between students' authentic experiences, the use of chemical representations at the macroscopic, submicroscopic, and symbolic levels, and the interactions formed within classroom learning dynamics. To obtain a comprehensive understanding of the characteristics and use of chemical representations, an analysis was conducted across five widely referenced university-level general chemistry textbooks Whitten *et al.* (2014), Chang and Goldsby (2015), Brown *et al.* (2012), Zumdahl and Zumdahl (2010), and Petrucci *et al.* (2017) supplemented by relevant scientific journals. Textbooks were selected for their recognized content accuracy, while journals were used to reinforce macroscopic representations grounded in direct experimental observation. The analysis was limited to the electrolysis of molten substances using inert electrodes, electrolysis of solutions using both inert and non-inert electrodes, and applications of electrolysis in everyday life and industry.

The analysis confirmed the presence of all three representation levels, though with varying depth. At the macroscopic level, representations appeared in two forms: everyday contextual phenomena such as hydrogen fuel cell vehicles, an silverware, as well as direct experimental observations including gas formation at electrodes, electrode mass changes, and solution color changes sourced from scientific journals. At the submicroscopic level, representations described ion movement, electron transfer mechanisms, and species competition based on standard reduction potentials. At the symbolic level, representations included half-reaction equations, overall cell reactions, and the Faraday equation. Notably, submicroscopic representations varied considerably in explicitness across textbooks, particularly in explaining preferential electrode reactions a gap that the intertextual strategy specifically addresses by explicitly linking all three levels within each instructional activity through the POE model.

In addition to the representation analysis, an analysis of student misconceptions was conducted based on prior research. Dominant misconceptions include the belief that viewing electrolysis as mere ionization without electrode redox reactions (Asnawi, 2017), disregarding water's role in solution electrolysis (Asnawi, 2017; Febyanti *et al.*, 2020), overgeneralizing results across molten and solution systems (Bong & Lee, 2016), and assuming all electrodes are inert (Bong & Lee, 2016). These misconceptions reflect students' inability to holistically connect the three representation levels (Huie *et al.*, 2022), reinforcing the need for an intertextual learning strategy that explicitly bridges all three levels in every instructional activity.

Laboratory Optimization

Laboratory optimization was carried out to determine the optimal experimental conditions prior to integration into the learning strategy at the observe stage. Optimization covered four experimental conditions: electrolysis of NaCl solution using inert electrodes, electrolysis of CuSO₄ solution using non-inert electrodes with both battery and power supply current sources, and the processes of electroplating and electrorefining.

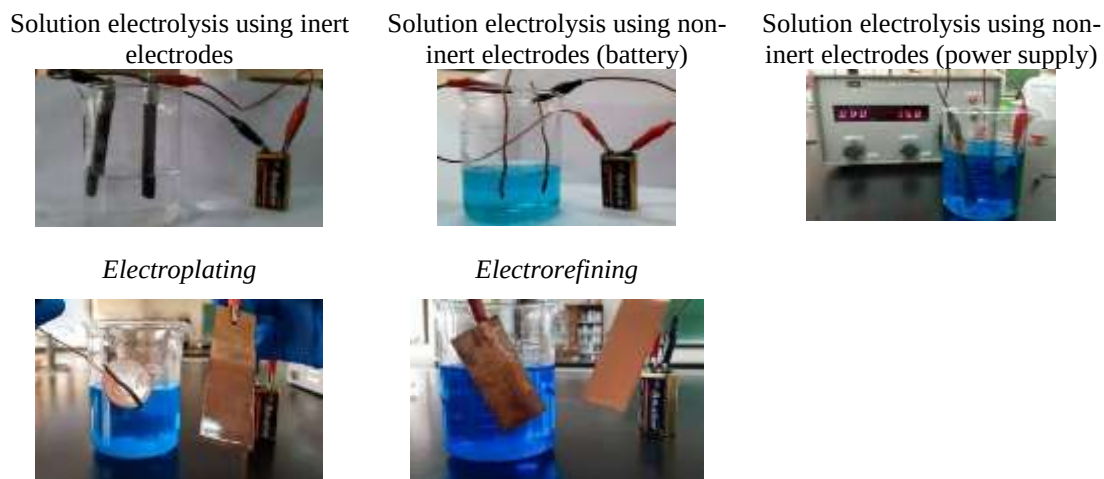


Figure 1. Laboratory Optimization Results

In the electrolysis of molten substances using non-inert electrodes, which was observed through video media, limitations in observing actual conditions resulted in suboptimal interpretation; consequently, the discussion of Faraday's Law was conducted only qualitatively due to insufficient data. In the electrolysis of solutions using both inert and non-inert electrodes, the optimization results were generally consistent with the literature; however, when using the power supply, a discrepancy was found between the mass of Cu deposited and the measured change in cathode mass, leading to the use of secondary data from the literature as a more reliable reference for Faraday's Law calculations. Furthermore, the quality of the coating in electroplating was influenced by battery voltage, plating duration, and metal surface condition, while the purification efficiency in electrorefining was affected by electrolyte composition, battery voltage, and process duration, resulting in minor residual impurities.

Initial Product Development Stage

Initial Product of the Learning Strategy

The initial product of the intertextual-based learning strategy using the POE model was designed in three learning cycles with a total allocation of eight lesson periods (360 minutes) in accordance with the Regulation of the Minister of Education, Culture, Research, and Technology Number 262/M/2022. Cycle 1 covers the electrolysis of solutions and molten substances using inert electrodes; Cycle 2 covers the electrolysis of solutions using non-inert electrodes; and Cycle 3 covers the working principles and applications of electrolysis. Each cycle consists of introductory activities (orientation, apperception, motivation, and provision of reference), core activities following the predict-observe-explain sequence, and closing activities, with students organized into heterogeneous groups and all activities supported by a Student Worksheet (SW).

Cycle 1 (Electrolysis of Solutions and Molten Substances Using Inert Electrodes)

The introductory activity begins with apperception designed to build cognitive conflict through a comparison of galvanic and electrolytic cells, followed by a trigger question about the spontaneity of redox reactions. Motivation is provided by presenting the phenomenon of gas bubbles appearing at the electrodes when current is passed through a solution, cultivating students' awareness that not all redox reactions proceed spontaneously and that external electrical energy is required.

In the predict stage, students individually predict which system NaCl solution or molten NaCl can conduct electricity and which particles are responsible, before discussing their predictions in small groups. In the observe stage, students conduct a direct experiment on the electrolysis of NaCl solution using inert electrodes, while the electrolysis of the molten substance is observed via video due to high-temperature constraints. Observations are recorded in a table combining checkboxes and short-answer fields covering color changes, precipitate formation, gas evolution, and changes at and near the electrodes. At the end of this stage, students are shown a particle movement animation presenting a submicroscopic representation of the process, enabling them to connect macroscopic observations with the particle-level picture before entering the explain stage.

In the explain stage, students analyze a standard reduction potential table and a comparison table of solution and molten systems, identifying the species reacting at each electrode, products formed, possible half-cell reactions, availability of water, and final electrolysis products bridging macroscopic, submicroscopic, and symbolic reasoning. Students answer scaffolded questions progressing from identifying differences between NaCl solution and molten NaCl phenomena, to analyzing why cathode products may differ despite identical electrolytes, how water's role alters the reaction mechanism, and why electrode potential tables cannot be applied without considering system conditions, concluding with a generalization of how to predict electrolysis products in both systems. The explain stage is followed by a class discussion facilitating scientific communication, and closing activities involving conclusions, learning outcome evaluation, and self-reflection via Google Form.

Cycle 2 (Electrolysis of Solutions Using Non-Inert Electrodes)

The introductory activity connects prior knowledge from Cycle 1 through apperception, with motivation drawn from the phenomenon of metal coating on household appliances.

In the predict stage, students observe carbon (inert) and copper (non-inert) electrodes displayed without a complete circuit, then predict whether the electrolysis process will differ when copper electrodes are used reasoning through how electrode type may influence changes in the reaction mechanism. In the observe stage, students conduct a direct experiment on the electrolysis of CuSO_4 solution using both electrode types, additionally weighing the electrodes before and after the experiment and recording observations in a time-interval-based table.

The explain stage follows the same structure as Cycle 1 using the standard reduction potential table, but the scaffolded questions are specifically directed toward: confirming macroscopic differences between both electrode systems, identifying physical changes at the electrodes as indicators of their involvement in the reaction, analyzing whether any electrode participates in the reaction and why, understanding that the inert or non-inert nature of an electrode determines whether it can serve as the oxidized species at the anode, and analyzing the role of Cu^{2+} ions in the competition for reduction at the cathode concluding with a comprehensive formulation of the difference in function between inert and non-inert electrodes.

Cycle 3 (Applications of Electrolysis in Daily Life and Industry)

The introductory activity reflects on concepts from Cycle 2, with motivation connecting electrolysis to the phenomenon of shiny cutlery and the industrial need for pure copper.

In the predict stage, students observe images of electroplating and electrorefining systems and predict the difference in purpose between the two processes based on visual observation and prior knowledge. Unlike Cycles 1 and 2, the observe stage in this cycle relies entirely on video an experimental video and a particle mechanism animation accessed via QR codes on the SW as direct experimentation is not feasible for industrial-scale processes.

The explain stage follows the same general structure, with questions specifically directed toward analyzing differences in electrode roles in electroplating and electrorefining, connecting the purpose of each process to electrode type and position selection, and relating redox principles to the practical benefits of electrolysis in industry concluding that electrode selection and system configuration are the key determinants of successful electrolysis application.

Characteristics of the Initial Learning Strategy Product

The developed learning strategy possesses four primary characteristics. First, it is grounded in an intertextual approach that connects the three levels of chemical representation macroscopic, submicroscopic, and symbolic through contextual experiences, with each cycle beginning from everyday electrolysis examples before progressing to submicroscopic and symbolic explanation.

Second, it consistently follows the POE model syntax, actively engaging students from prediction formulation through observation to data-based explanation. This integration enables connections across representation levels to be built gradually and systematically, so that emerging misconceptions can be redirected toward more meaningful conceptual reconstruction.

Third, it is designed to progressively build conceptual mastery across cycles. Cycle 1 focuses on distinguishing the species reacting in the electrolysis of molten substances and solutions at each electrode. Cycle 2 deepens understanding of non-inert electrode involvement in redox reactions, enabling students to analyze electrolysis differences based on electrode type. Cycle 3 guides students to analyze the working principles of electroplating and electrorefining from the macroscopic to the symbolic level, enabling comprehensive and contextual understanding of each electrolysis application.

Fourth, the strategy requires students to actively engage in scientific processes predicting outcomes in the predict stage, observing phenomena in the observe stage, and communicating concepts in the explain stage ensuring that students simultaneously develop both conceptual mastery and science process skills.

Preliminary Product Testing and Revision Stage

Expert Review Results on the Initial Learning Strategy Product

Expert review was conducted by six chemistry education lecturers from Universitas Pendidikan Indonesia, divided into two groups. The first three experts reviewed the alignment of the LOT with the learning outcomes for both the chemistry understanding and process skills elements, as well as the alignment of learning activities with the POE syntax and SPS indicators. The remaining three reviewed the alignment of

concept descriptions with conceptual mastery indicators and SPS descriptions with SPS indicators. Results indicate that the LOT for both elements is aligned with the learning outcomes, and that both concept and SPS descriptions are consistent with the formulated indicators; however, not all learning activities were found to align with the LOT and SPS indicators, necessitating revision. Misaligned activities were revised based on expert recommendations, while aligned activities were refined to improve clarity and effectiveness in achieving conceptual mastery and SPS development, as described in detail below.

Table 4. Expert Review Results on the Alignment of the Learning Objective Trajectory with the Learning Outcomes for the Chemistry Understanding Element

Learning Outcome	Learning Objective Trajectory	Aligned (Yes)	Aligned (No)	Suggestions
Analyzing the relationship between atomic structure and the periodic table; comparing types of chemical bonds and their relationship to molecular geometry and intermolecular forces in predicting physical properties of matter; relating the standard enthalpy change of a chemical reaction to energy sources in the surrounding environment; analyzing factors affecting reaction rate; analyzing chemical equilibrium and its applications; explaining electrical conductivity and colligative properties of solutions; explaining electrochemical cells in everyday life; and explaining carbon compounds and macromolecules.	Analyzing the electrolysis process of solutions using inert electrodes	✓		Expert 1: - Reorder begin with electrolysis of molten substances; - add a learning objective on calculating the mass of electrolysis products. Expert 2: - Replace "electrolysis with..." with "electrolysis using..." Expert 3: - Specify whether the LOT is intended for qualitative only, quantitative only, or both.
	Analyzing the electrolysis process of molten substances using inert electrodes	✓		
	Analyzing the electrolysis process of solutions using non-inert electrodes	✓		
	Connecting the working principles of electrolytic cells to their applications in daily life and industry	✓		

Based on expert recommendations, revisions were made by adding quantitative LOTs: (1) connecting the electrolysis process with Faraday's Law in Cycle 1; (2) analyzing the conditions for applying Faraday's Law in Cycle 2; and (3) applying Faraday's Law to calculate the mass of electrolyzed substances in Cycles 3 and 4, alongside a phrasing revision from "electrolysis with electrode..." to "electrolysis using electrode..." for greater conceptual precision.

Concept descriptions were also developed based on the formulated LOT and concept labels, presenting chemical representations at the macroscopic, submicroscopic, and symbolic levels derived from an analysis of five chemistry textbooks. This three-level

presentation is grounded in the Johnstone (2000) framework, which asserts that complete chemistry understanding requires integrating all three levels, as the inability to do so is the root cause of misconceptions (Huie et al., 2022). Expert review confirmed that all concept descriptions are aligned with the LOT, with recommendations limited to refinement of grammar and sentence structure, supplementing statements with underlying explanations, rewriting reaction equations in text format, and improving figures or illustrations for greater clarity and scientific accuracy.

Table 5. Expert Review Results on the Alignment of the Learning Objective Trajectory with SPS Indicators

Learning Objective Trajectory	Aligned (Yes)	Aligned (No)	Suggestions
1.1–1.6 (Cycle 1: Inert electrode LOTs)	✓		Expert 1: • Begin with electrolysis of molten substances. Expert 2: • Replace "electrolysis with..." with "electrolysis using...". Expert 3: —
2.1–2.6 (Cycle 2: Non-inert electrode LOTs)	✓		
3.1–3.6 (Cycle 3: Application LOTs)	✓		

Based on the expert review results, revisions were limited to adjusting the sequence of topics so that electrolysis of molten substances is addressed before solutions, given the relative simplicity of the former system consistent with the principle of organizing content from concrete and simple concepts toward more complex ones (Dick & Carey, as cited in Nasution, 2017). Phrasing was also revised from "electrolysis *with* electrode..." to "electrolysis *using* electrode..." for conceptual accuracy. Furthermore, the SPS descriptions developed based on these indicators were confirmed as fully aligned by all three experts without requiring revision.

A suitability review of the learning activities against the LOT and SPS indicators was subsequently conducted by three chemistry education lecturers from Universitas Pendidikan Indonesia. The review results indicate that not all learning activities were aligned, necessitating revision. A summary of the improvement recommendations and their follow-up actions is presented in Table 6.

Table 6. Expert Review Results on the Initial Learning Strategy Product

Aspect	Improvement Recommendations
Apperception	Apperception should be adjusted to exclude concepts not yet studied by students, and should be incorporated into the SW for each cycle as a bridge for activating prior knowledge.
Motivation	Motivation should be adapted to align with contextual phenomena from everyday life.
Learning Objectives	Each cycle should focus on one core concept to prevent misconceptions. In addition to qualitative aspects, quantitative aspects should be incorporated through the application of Faraday's Law and calculations of the mass of electrolysis products.
Predict Stage	Prediction questions should be revised to guide students in predicting the electrolysis mechanism, changes at the anode and cathode, and quantitative aspects of electrolysis products predictions that can be verified through the observe and explain stages. Images used should be improved and should not contain cues that may lead students toward predetermined answers.

Observe Stage	Students should be given the opportunity to design the experiment independently, rather than simply following a pre-determined step-by-step procedure. However, general guidance should still be provided to prevent procedural errors. In addition, the placement of the particle mechanism animation should be moved to the end of the explain stage, with the purpose of deepening students' understanding of the electrolysis mechanism.
Explain Stage	Questions should be structured progressively, beginning from the identification of macroscopically observed phenomena, then directed toward understanding the electrolysis mechanism at the submicroscopic level through focused guiding questions on the material being studied with the assistance of a standard reduction potential table as an analytical tool, while simultaneously being directed toward symbolic representation. It is also recommended to explicitly explain the function of the standard reduction potential table within the SW so that students understand its role as a tool for analyzing and comparing the tendency of species to react at the cathode and anode.

Based on reviewer recommendations, the primary revision involved restructuring from three to four cycles, enabling deeper conceptual understanding of each aspect before progression. Apperception was revised to exclude information preceding the material to be studied and contextualized to each cycle, while motivation was linked to everyday life phenomena to highlight contextual relevance. Prediction questions were revised to be directly confirmable through the observe stage and explainable in the explain stage, forming a coherent reasoning sequence consistent with POE principles (Pohan et al., 2020). The observe procedure was made more flexible by retaining general guidance without a step-by-step protocol, ensuring that experiment planning and execution skills remain practiced. Explain questions were progressively structured from macroscopic to submicroscopic and symbolic levels, supported by the standard reduction potential table as scaffolding for holistic conceptual construction. The resulting revised product is fully aligned across learning activities, LOT, and both conceptual mastery and SPS indicators, demonstrating potential to simultaneously and sustainably improve students' conceptual mastery and science process skills.

▪ CONCLUSION

Based on the research conducted, it can be concluded that the intertextual-based learning strategy incorporating the POE model on the electrolytic cell topic developed to connect macroscopic, submicroscopic, and symbolic phenomena through prediction, observation, and explanation activities demonstrates potential to simultaneously improve students' conceptual mastery and science process skills.

Expert validation by six reviewers identified misalignments in the predict stage, which was found to be inconsistent with the observe and explain stages and misaligned with the intended learning objective trajectory. Furthermore, the combination of two molten electrolysis LOTs within a single POE cycle was deemed likely to trigger misconceptions, given that each involves distinct reaction characteristics.

Based on these findings, revisions were carried out comprising the improvement of the predict stage, the separation of the two LOTs into two independent POE cycles, and the addition of a Faraday's Law LOT to complement the quantitative dimension of the learning objectives. The resulting revised product has been aligned across learning activities, the LOT, and both conceptual mastery and SPS indicators, yielding a learning strategy comprising four more cohesive cycles with strong potential for effective implementation in the teaching and learning of the electrolytic cell topic.

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