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Enhancing Conceptual Understanding in Junior High School Science through the POE2WE Learning Model

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Abstract
Conceptual understanding remains a major challenge in junior high school science learning, particularly in abstract topics such as cell structure and function. This study examined the effect of the Predict-Observe-Explain-Elaboration-Write-Evaluation (POE2WE) learning model on students' conceptual understanding. A quantitative quasi-experimental design with a non-equivalent control group pretest-posttest structure was employed involving 64 eighth-grade students from a public junior high school in Indonesia. The experimental group was taught using the POE2WE model, while the control group received conventional inquiry-based instruction. Data were collected using a validated essay-based test aligned with Bloom's revised taxonomy and analyzed using descriptive statistics, normalized gain, and an independent samples t-test. The results showed that the experimental group achieved a higher posttest mean score (M = 88.84) than the control group (M = 77.94). The experimental group also obtained a higher normalized gain (N-gain = 0.69) compared with the control group (N-gain = 0.34), indicating stronger conceptual improvement. The most pronounced improvement was observed at higher cognitive levels, particularly analysis, evaluation, and creation (C4-C6). These findings suggest that POE2WE effectively enhances students' conceptual understanding by integrating prediction, observation, explanation, elaboration, reflective writing, and evaluation. This study implies that POE2WE can serve as a structured constructivist learning model for improving conceptual mastery and addressing misconceptions in secondary science classrooms.

Keywords: Conceptual understanding; Constructivist learning; Junior high school students; POE2WE learning model; Science education.

INTRODUCTION

Conceptual understanding is widely recognized as a fundamental objective of science education, particularly at the lower secondary level where students construct foundational scientific knowledge that supports advanced learning and scientific literacy. In contemporary curricula, science learning is expected to move beyond rote memorization toward deep understanding, enabling learners to explain phenomena, apply concepts across contexts, and evaluate scientific evidence critically. However, international large-scale assessments such as PISA consistently indicate that many students demonstrate limited conceptual understanding, especially in abstract scientific domains such as biology and cellular organization (OECD, 2019, 2023).

A growing body of research attributes this persistent issue to the dominance of instructional practices that prioritize procedural completion and factual recall rather than conceptual construction. Traditional and semi-inquiry-based approaches often fail to explicitly address students' prior knowledge and misconceptions, which are known to strongly influence conceptual change in science learning (Nana, 2019, 2020). As a result, students may perform adequately on surface-level tasks while retaining fragmented or scientifically inaccurate conceptions. Constructivist learning theory emphasizes that conceptual understanding is actively constructed through cognitive engagement, prediction, reflection, and the reconciliation of prior knowledge with empirical evidence. Instructional models grounded in constructivism, particularly those that incorporate prediction and explanation have demonstrated greater effectiveness in promoting conceptual change compared to conventional instruction (Hattie & Clarke, 2018; Valsecchi et al., 2024). One widely implemented constructivist framework is the Predict-Observe-Explain (POE) model, which engages students in anticipating outcomes, observing phenomena, and explaining discrepancies between predictions and observations.

Despite its strengths, recent studies have highlighted important limitations of the classical POE model. Specifically, POE-based instruction often lacks structured opportunities for elaboration, reflective writing, and systematic evaluation, which are essential for consolidating conceptual understanding and supporting higher-order cognitive processes (K.-F. Chen et al., 2025; Edres et al., 2025; Hong et al., 2021). Without these components, students may successfully resolve immediate cognitive conflicts yet fail to integrate new concepts into a coherent and transferable knowledge structure. In response to these limitations, the Predict-Observe-Explain-Elaboration-Write-Evaluation (POE2WE) learning model was developed as an extended constructivist framework. POE2WE integrates elaboration activities that contextualize concepts, reflective writing that promotes metacognitive processing, and evaluation stages that reinforce conceptual consolidation. Empirical studies conducted between 2018 and 2025 have reported positive effects of POE2WE on various learning outcomes, including critical thinking skills, mathematical connections, and student engagement (Anggraeni et al., 2024; Barkah & Pitrisia, 2025; Panggabean et al., 2023; Pitaloka et al., 2024).

Nevertheless, a critical review of the existing literature reveals several notable limitations. First, most prior studies have examined POE2WE in relation to affective variables, generic higher-order skills, or domain-general outcomes, rather than focusing explicitly on conceptual understanding as a distinct cognitive construct (Almaida et al., 2023; Mu et al., 2022; Nana et al., 2023). Second, many studies employ descriptive or literature-based methodologies, limiting causal inference regarding the effectiveness of the model. Third, empirical evidence at the junior high school level, particularly within biology-related science topics that are abstract and conceptually demanding remains limited. As such, the extent to which POE2WE systematically enhances students' conceptual understanding in lower secondary science education has not been sufficiently established. This gap is particularly evident in the context of cell biology, a foundational topic that introduces students to microscopic structures, functional relationships, and levels of biological organization. Research consistently identifies cell-related concepts as prone to misconceptions due to their abstract nature and limited direct observability (F. Chen & Chen, 2025; Diana et al., 2020; Lara-Alecio et al., 2018). Instructional approaches that fail to explicitly scaffold prediction, observation, explanation, and conceptual elaboration may therefore be insufficient to support deep understanding in this domain.

Accordingly, the present study addresses this research gap by empirically examining the effect of the POE2WE learning model on students' conceptual understanding in eighth-grade science. Using a quasi-experimental design, this study compares students taught using POE2WE with those receiving conventional inquiry-based instruction, with conceptual understanding measured across multiple cognitive levels. The study aims to provide robust evidence regarding the effectiveness of POE2WE as a structured constructivist model for enhancing conceptual understanding in junior high school science. The contribution of this study is threefold. Theoretically, it extends constructivist learning research by empirically validating the role of elaboration and reflective writing in strengthening conceptual understanding. Methodologically, it provides quasi-experimental evidence addressing limitations of prior descriptive studies. Practically, it offers science educators empirically grounded guidance for designing instruction that supports deep conceptual learning in abstract scientific topics.

METHODS

Research Design

This study employed a quantitative quasi-experimental design using a non-equivalent control group pretest–posttest framework. This design was selected to examine the causal effect of the POE2WE learning model on students' conceptual understanding while maintaining ecological validity in an authentic classroom setting. Random assignment at the individual level was not feasible due to institutional constraints; therefore, intact classes were used (Muin, 2023; Soesana & dkk, 2023).

Population and Sample

The population of this study consisted of all eighth-grade students enrolled in a public junior high school in Bandar Lampung, Indonesia, during the 2024/2025 academic year. Two intact classes were selected through cluster random sampling. One class was assigned as the experimental group (n = 32), while the other served as the control group (n = 32). Both groups were taught by the same science teacher to minimize instructor-related variability. Prior to the intervention, a pretest was administered to ensure equivalence in students' initial conceptual understanding. The results indicated no statistically significant difference between groups at baseline.

Instructional Treatment

The experimental group received instruction using the POE2WE learning model over four weeks on the science topic of cell structure and function, including cell components, differences between plant and animal cells, and basic cellular processes. Instruction followed six structured phases: prediction, observation, explanation, elaboration, writing, and evaluation. The control group was taught using the school's conventional inquiry-based approach, which emphasized observation and discussion but did not include systematic prediction, reflective writing, or structured elaboration activities. Both groups received the same instructional duration, learning objectives, and assessment schedule.

Instrumentation and Validity

Students' conceptual understanding was measured using an essay-based test developed by the researchers, aligned with Bloom's revised taxonomy (C1-C6). The instrument consisted of open-ended items designed to assess students' ability to explain concepts, analyze relationships, apply knowledge, and justify scientific reasoning. Content validity was established through expert judgment involving three specialists in science education and educational assessment. Item relevance, clarity, and alignment with learning objectives were evaluated, and revisions were made accordingly. Instrument reliability was examined through a pilot test administered to a comparable student cohort. Reliability analysis yielded a Cronbach's alpha coefficient exceeding 0.80, indicating high internal consistency and suitability for research purposes (Nurmaya et al., 2022; Syahri Ramdhani et al., 2024).

Data Collection Procedure

Data were collected through pretest-posttest administration. The pretest was conducted prior to the instructional intervention to assess initial conceptual understanding, while the posttest was administered immediately after the completion of the instructional sequence (Pahrudin et al., 2025; Raicha Oktafiani et al., 2024).

Data Analysis

Data analysis was conducted using descriptive and inferential statistical techniques. Descriptive statistics were used to summarize mean scores and standard deviations. Assumptions of normality and homogeneity of variance were tested using the Kolmogorov-Smirnov test and Levene's test, respectively (Mousavipour & Bavi, 2024; Syahri Ramdhani et al., 2024). To examine differences in posttest conceptual understanding between the experimental and control groups, an independent samples t-test was performed. Statistical significance was determined at the 0.05 level. Additionally, Cohen's d was calculated to determine the magnitude of the instructional effect. All statistical analyses were performed using standard statistical software.

RESULT AND DISCUSSION

Result

Descriptive Statistics of Students' Conceptual Understanding

Students' conceptual understanding was measured using pretest and posttest scores obtained from both the experimental and control groups. As presented in Table 1, the pretest results indicate that the two groups exhibited comparable levels of initial conceptual understanding prior to the instructional intervention. The mean pretest score of the experimental group was 62.62, while the control group achieved a mean score of 64.23, suggesting no substantial baseline difference between groups.

Following the intervention, notable differences emerged in posttest performance. The experimental group, which received instruction using the POE2WE learning model, achieved a mean posttest score of 88.84, whereas the control group obtained a mean score of 77.94. These descriptive results indicate a greater improvement in conceptual understanding among students exposed to the POE2WE model.

Table 1. Descriptive Statistics of Students' Conceptual Understanding Scores

Group	Test	N	Mean
Experimental (POE2WE)	Pretest	32	62.62
Experimental (POE2WE)	Posttest	32	88.84
Control (Conventional)	Pretest	32	64.23
Control (Conventional)	Posttest	32	77.94

Learning Gain Analysis

To further examine the magnitude of students' conceptual improvement, normalized gain (N-gain) scores were calculated for each group. As shown in Table 2, the experimental group achieved a mean N-gain score of 0.69, while the control group achieved a mean N-gain score of 0.34. Although both values fall within the medium gain category, the experimental group demonstrated a substantially higher level of conceptual improvement. These results indicate that the POE2WE learning model was associated with a greater proportional increase in students' conceptual understanding compared to conventional inquiry-based instruction.

Table 2. Normalized Gain (N-gain) of Conceptual Understanding

Group	Pretest Mean	Posttest Mean	N-gain	Category
Experimental (POE2WE)	62.62	88.84	0.69	Medium
Control (Conventional)	64.23	77.94	0.34	Medium

Conceptual Understanding Across Cognitive Levels

Students' conceptual understanding was further analyzed across cognitive levels based on Bloom's revised taxonomy (C1-C6). The percentage of mastery at each cognitive level for both groups is presented in **Table 3**. The results show that improvements occurred across all cognitive levels in both groups; however, the experimental group consistently outperformed the control group at every level in the posttest. The most pronounced differences were observed at higher-order cognitive levels, particularly C4 (analyze), C5 (evaluate), and C6 (create). These findings suggest that the instructional intervention had a stronger effect on higher-level conceptual processing than on lower-level recall and comprehension.

Table 3. Conceptual Understanding Across Cognitive Levels

Cognitive Level	Experimental Pretest (%)	Experimental Posttest (%)	Control Pretest (%)	Control Posttest (%)
C1 – Remember	59	78	63	66
C2 – Understand	51	83	60	66
C3 – Apply	50	79	55	73
C4 – Analyze	57	82	58	71
C5 – Evaluate	58	80	63	70
C6 – Create	56	80	55	63

Assumption Testing and Inferential Analysis

Prior to hypothesis testing, the assumptions of normality and homogeneity of variance were examined. The results of the Kolmogorov–Smirnov test indicated that pretest and posttest scores in both groups were normally distributed ($p > .05$). Levene's test further confirmed the homogeneity of variance between groups ($p > .05$), indicating that the data met the assumptions for parametric analysis. An independent samples t-test conducted on posttest scores revealed a statistically significant difference between the experimental and control groups ($p < .05$). This result indicates that the difference in conceptual understanding observed between groups following the intervention was statistically reliable.

Discussion

The findings of this study demonstrate that the POE2WE learning model has a substantial positive effect on students' conceptual understanding in junior high school science, particularly when compared to conventional inquiry-based instruction. This result is consistent with prior studies reporting the effectiveness of POE-oriented instructional models in facilitating conceptual change through prediction and observation mechanisms (X. Chen, 2025; Damayanti et al., 2025; Gustina et al., 2023). However, the magnitude and distribution of learning gains observed in this study extend earlier findings by showing that the inclusion of elaboration, writing, and evaluation stages significantly strengthens conceptual mastery, especially at higher cognitive levels.

Compared to traditional POE implementations that mainly focus on prediction, observation, and explanation as isolated activities, the findings of this study are theoretically grounded in the ICAP framework proposed by Gürses (2024), which emphasizes that learning activities fostering constructive and interactive engagement result in more robust conceptual understanding than activities that are merely active in nature. Although prior studies have demonstrated that POE is effective in inducing cognitive conflict, evidence regarding its ability to support sustained conceptual integration remains inconclusive, particularly in instructional designs that lack explicit reflective and metacognitive scaffolding. The superior posttest outcomes and higher N-gain values obtained in this study indicate that POE2WE effectively overcomes this limitation by integrating structured reflective writing and elaborative learning tasks, thereby facilitating deeper conceptual consolidation.

The results also corroborate findings reported by Fajriyah & Jatmiko (2021) and Anggraeni et al. (2024), who found that POE2WE positively influences higher-order thinking skills and scientific reasoning in secondary science contexts. However, unlike those studies, which focused on broader cognitive or affective outcomes, the present study isolates conceptual understanding as a standalone dependent variable. This focus allows for a more precise examination of how POE2WE influences conceptual mastery rather than general learning performance, thereby filling an important gap in the existing literature.

Furthermore, the pronounced gains observed at higher cognitive levels (C4-C6) resonate with research by Schoute et al. (2024), who emphasize that deep conceptual understanding in science is characterized by students' ability to analyze relationships, evaluate evidence, and generate coherent explanations. Conventional inquiry-based instruction, as reflected in the control group's results, appeared sufficient for lower-level cognitive outcomes but less effective in facilitating higher-order conceptual processing. This finding supports Heppt et al. (2023) argument that inquiry learning without explicit scaffolding may fail to support students' cognitive integration, particularly in abstract scientific domains such as cell biology.

From a novelty perspective, this study contributes to the international science education literature in several important ways. First, it provides quasi-experimental evidence demonstrating that POE2WE is not only effective for skills-based or affective outcomes, but also for strengthening conceptual understanding as a distinct cognitive construct. Second, the study empirically validates the added value of the elaboration and writing components within POE2WE, offering concrete evidence that these stages are not merely supplementary but central to promoting higher-order conceptual mastery. Third, by focusing on junior high school students and a biologically abstract topic, this research extends the applicability of POE2WE beyond contexts that are typically dominated by physics or mathematics-based investigations.

The implications of these findings are both theoretical and practical. Theoretically, the study reinforces constructivist and conceptual change frameworks by demonstrating that structured reflection and evaluation are critical mechanisms for deep learning, complementing prediction and experimentation. Practically, the findings suggest that science educators should move beyond minimally guided inquiry and adopt instructional models that explicitly scaffold conceptual restructuring. The POE2WE model offers a practical framework that can be readily implemented in secondary science classrooms to address persistent issues of superficial understanding and misconceptions.

Despite these contributions, several limitations should be acknowledged. The study was conducted in a single school with a relatively small sample size, which may limit the generalizability of the findings. Additionally, the intervention focused on a single science topic and a short instructional duration, preventing conclusions about long-term retention or transfer of conceptual understanding. The use of essay-based assessments, while appropriate for measuring conceptual depth, may also introduce subjectivity despite acceptable reliability. Future research should therefore examine the longitudinal effects of POE2WE across multiple scientific domains, incorporate mixed-methods approaches to capture students' cognitive processes, and explore its scalability across diverse educational contexts.

CONCLUSION

This study demonstrates that the POE2WE learning model significantly enhances students' conceptual understanding in junior high school science, particularly in the context of cell structure and function. Students exposed to POE2WE achieved higher posttest scores and greater conceptual gains than those taught through conventional inquiry-based instruction, with the most substantial improvements occurring at higher cognitive levels, indicating deeper conceptual processing. Theoretically, these findings contribute to constructivist and conceptual change perspectives by providing empirical evidence that the integration of prediction, elaboration, reflective writing, and evaluation is critical for strengthening conceptual mastery beyond procedural engagement. Practically, the results suggest that POE2WE offers a structured and pedagogically sound alternative for science educators seeking to address persistent misconceptions and superficial understanding in abstract scientific topics. Nevertheless, the study is limited by its single-school context, relatively small sample size, short intervention duration, and reliance on essay-based assessments, which may constrain the generalizability of the findings. Future research should examine the longitudinal impact of POE2WE, explore its application across diverse scientific domains and educational levels, and employ mixed-methods.

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