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Implementation of the POE2WE (Prediction, Observation, Explanation, Elaboration, Write, and Evaluation) Learning Model to Improve Understanding of Chemical Concepts Regarding Buffer Solutions among Grade XI Students at SMAN 2 Siak Hulu

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Abstract

Students' limited conceptual understanding of buffer solutions presents a substantial learning challenge because the topic integrates acid–base concepts, chemical equilibrium, and pH calculations. This study examined the effectiveness of the Prediction, Observation, Explanation, Elaboration, Write, and Evaluation (POE2WE) learning model in improving Grade XI students' conceptual understanding of buffer solutions at SMAN 2 Siak Hulu. A quasi-experimental method with a nonequivalent control-group pretest–posttest design was employed. Class XI.4 served as the experimental group, while Class XI.5 served as the control group; both classes were selected through purposive sampling. Data were collected using an essay-based conceptual-understanding test and analyzed through normality and homogeneity tests, a t test, and normalized gain analysis. The findings demonstrated a significant difference in the improvement of conceptual understanding between the two groups, with the calculated t value (2.34) exceeding the critical value (1.998) at the 5% significance level. The experimental group achieved a normalized gain of 0.72, categorized as high, whereas the control group obtained a normalized gain of 0.56, categorized as moderate. Improvements across all indicators of conceptual understanding were also greater in the experimental group. These findings demonstrate that the POE2WE learning model effectively improves students' conceptual understanding of buffer solutions. The model therefore offers an alternative instructional approach that actively engages students in constructing, explaining, applying, and evaluating their understanding of chemistry concepts.

Keywords: Buffer Solutions; Chemistry Education; Conceptual Understanding; POE2WE Learning Model; Quasi-Experimental Research

INTRODUCTION

Education plays a strategic role in enhancing the quality of human resources. In the 21st century, advancements in science and technology require education to produce a generation that is competent, adaptive, and competitive (Nurfarkhan & Farabi, 2024). High-quality education is essential to meet these demands, partly through the optimization of the learning process in schools. The learning process is pivotal to educational success, as the effectiveness of learning is reflected in students' ability to achieve expected competencies. Such competency achievement demonstrates a student's capacity to master and comprehend the concepts within the learning material (Siahaan *et al.*, 2022).

Chemistry is a branch of natural science that studies the structure, properties, and changes of matter as well as the energy accompanying these changes and is closely linked to everyday phenomena (Sanova, 2021). Consequently, chemistry instruction requires students not merely to memorize concepts but to understand them deeply, enabling them to connect and apply the knowledge gained to real-life contexts. Conceptual understanding serves as a key indicator of success in chemistry learning, as it demonstrates that students can explain and utilize concepts rather than simply recalling formulas or definitions ((Nur Aini, 2024).

Buffer solutions represent a chemistry topic that demands deep conceptual understanding; the subject involves abstract and complex concepts that require a gradual learning process and are often perceived as difficult by students (Sanjiwani *et al.,* 2018). These difficulties arise because the concept of buffer solutions requires students to grasp the interrelationships between multiple concepts simultaneously such as acids and bases, equilibrium, and stoichiometry as well as to reason through changes in solution components when subjected to disturbances (Firdaus *et al.*, 2022). Various research findings indicate that the topic of buffer solutions is prone to generating misconceptions and conceptual difficulties. Diagnostic research involving high school students reported a 47% prevalence of misconceptions regarding buffer solutions, with the highest rate of misconception observed in the indicator concerning pH calculations when small amounts of acid or base are added (averaging 64.08%) (Nurhidayatullah & Prodjosantoso, 2018).

Beyond misconceptions, students often face difficulties because learning about buffer solutions requires active engagement to ensure concepts are truly understood rather than merely memorized (Setiawan *et al.,* 2019). The topic of buffer solutions also has real-world relevance, such as in biological systems and industrial applications (Alighiri & Drastisianti, 2018). Difficulties with this topic are also influenced by a student's mastery of prerequisite concepts and their reasoning abilities. Sariati *et al.* (2020) suggest that learning difficulties are driven by internal factors specifically a poor understanding of buffer solution concepts and the supporting prerequisite concepts which is reflected in low learning outcomes. Consequently, instruction on buffer solutions requires a learning model capable of presenting concepts concretely and systematically, while engaging students in observing phenomena, analyzing conceptual connections, and drawing logical conclusions.

Pre-research interviews with a chemistry teacher at SMAN 2 Siak Hulu revealed that the instructional process remains dominated by teacher explanations, assignments, and practice problems. Scientific activities tend to be procedural in nature, failing to provide sufficient opportunity for students to explore, test ideas, and independently construct their conceptual understanding. Many students still rely on rote memorization of formulas without grasping the underlying concepts; this leaves them unable to explain buffer solution concepts in their own words and struggling with problems that require conceptual reasoning and the ability to link concepts to real-world phenomena. This situation is corroborated by student learning outcome data: approximately 40% of students achieved the Minimum Mastery Criterion (KKTP) of 85, while about 60% failed to meet the criterion for the buffer solution topic. These findings highlight the need for instructional approaches that better facilitate students in building a conceptual understanding that is gradual, in-depth, and meaningful.

Based on a review of prior research and preliminary school-based findings, the primary issue regarding the topic of buffer solutions stems from a weak grasp of concepts specifically concerning the explanation of buffer system mechanisms and the ability to reason through pH changes upon the addition of small amounts of acid or base. Consequently, this study selects conceptual understanding as the dependent variable; it serves as a key indicator of successful chemistry learning that emphasizes the mastery of meaning, plays a role in preventing and rectifying misconceptions, and forms the foundation for students' ability to transfer knowledge to various types of problems and real-life contexts. Students are required to comprehend the concepts of buffer solutions, their working principles, pH calculations, and the role of buffers in everyday life (Genes *et al.,* 2021).

To address these issues, this study employs the POE2WE learning model (Prediction, Observation, Explanation, Elaboration, Write, and Evaluation). The POE2WE model positions students as active subjects through stages involving prediction, verification via observation or experimentation, explanation of results, elaboration on concept application, written articulation of thought processes, and evaluation of understanding (Apiati & Muslim, 2024). Unlike discovery learning, which emphasizes a problem statement as the foundation for subsequent learning steps, POE2WE explicitly begins with the Prediction stage, allowing students to articulate their initial ideas from the outset. Comparative research findings indicate that the POE model is more effective than discovery learning in enhancing conceptual understanding; consequently, learning strategies that commence with prediction and verification are considered more robust in fostering the construction of conceptual understanding (Sukarjita & Fakhruddin, 2021).

The POE2WE stages are also well-suited to the characteristics of the topic of buffer solutions, a subject area prone to misconceptions. Predictions are verified during the Observation stage through observation or experimentation, after which students revise their understanding during the Explanation stage. The Elaboration stage reinforces conceptual meaning through application in real-world contexts; the Write stage assists students in constructing concepts in a written and reflective manner; and the Evaluation stage ensures the consolidation of understanding at the conclusion of the lesson (Haryanti & Parwis, 2025). These stages are systematically designed to help students build conceptual understanding incrementally, enabling them to engage directly in exploration and observation, construct their own knowledge, and communicate ideas through discussions that foster critical and reflective thinking (Fajri & Chusni, 2024).

Previous research demonstrates that POE2WE has been effectively implemented across various learning contexts. Marfungah *et al.* (2024) showed that the use of the POE2WE model is effective in improving students' conceptual understanding. Similarly, Nana *et al.*, (2023) demonstrated that the POE2WE model serves as a viable alternative instructional approach for enhancing learners' conceptual understanding. Handayani et al., (2026) demonstrated a difference in critical thinking skills between classes implementing POE2WE and those using conventional instruction. Aritisna et al., (2026) showed that POE2WE enhances students' cognitive abilities, while Herdayana et al., (2026) found that implementing POE2WE assisted by PhET simulations was more effective in improving conceptual understanding of chemical equilibrium. Furthermore, research by Fauziah et al., (2026) indicated that the implementation of POE2WE, through systematic learning stages, helps students build a deeper understanding of concepts.

Although these studies demonstrate the effectiveness of POE2WE, research specifically examining the application of the POE2WE model to improve students' conceptual understanding of buffer solutions at the high school level remains limited. Therefore, this study focuses on implementing the POE2WE (Prediction, Observation, Explanation, Elaboration, Write, and Evaluation) learning model to enhance the conceptual understanding of chemistry regarding buffer solutions among Grade XI students at SMAN 2 Siak Hulu. The study aims to determine the improvement in students' conceptual understanding of buffer solutions comparing experimental and control classes and to identify the category of improvement in conceptual understanding following the implementation of the POE2WE model, as measured by N-gain scores.

METHODS

This study employs a quantitative approach using a quasi-experimental method. Quasi-experimental research involves both experimental and control groups, though group assignment is not achieved through full randomization of subjects. The study was conducted with Grade XI students at SMAN 2 Siak Hulu during the even semester of the 2025/2026 academic year specifically, from April to May 2026. A Non-equivalent Control Group Pretest-Posttest Design was utilized. The study involved two groups: an experimental class and a control class. Both groups underwent a pretest prior to instruction and a posttest afterward. The experimental class received instruction using the POE2WE learning model integrated with a deep learning approach, whereas the control class received instruction without the POE2WE model. Pretests and posttests were used to assess changes in students' conceptual understanding before and after the intervention.

The study population consisted of Grade XI MIPA (Mathematics and Natural Sciences) students at SMAN 2 Siak Hulu during the 2025/2026 academic year, specifically those in classes XI MIPA 4, XI MIPA 5, and XI MIPA 6. A purposive sampling technique was employed based on specific criteria. These criteria included being taught by the same teacher, sharing the same schedule and instructional time allocation, possessing relatively equal prior knowledge (based on daily test scores regarding salt hydrolysis), and having yet to achieve mastery in the prerequisite topic of buffer solutions. The daily test scores of the three classes were first analyzed using tests for normality, homogeneity, and equality of means. Based on these criteria, class XI-4 was selected as the experimental class and XI-5 as the control class, as they exhibited the most similar mean scores and relatively equivalent prior knowledge.

Data collection instruments consisted of a conceptual understanding test comprising essay questions administered as both a pretest and a posttest. The test was designed based on indicators of conceptual understanding regarding buffer solutions and featured equivalent levels of difficulty. In addition to the test, daily test scores on the topic of salt hydrolysis served as baseline data for the prerequisite analysis used in sample selection. A pretest was administered prior to instruction on the topic of buffer solutions and the experimental treatment, while a posttest was administered after the entire instructional process and treatment were concluded. Student responses were evaluated using a scoring rubric based on indicators of conceptual understanding.

Data analysis involved prerequisite testing and hypothesis testing. Prerequisite tests included tests for normality and homogeneity. Normality of the pretest data was assessed using the Lilliefors test at a significance level of 0.05, while homogeneity testing was used to determine the equality of variances between the experimental and control groups. Subsequently, the difference in conceptual understanding between the two groups was analyzed using an Independent Samples T-test with the aid of SPSS software. The N-gain test was employed to determine the magnitude of the improvement in conceptual understanding following instruction. N-gain categories were classified as high ($N > 0.70$), medium ($0.30 < N < 0.70$), and low ($N < 0.30$).

The research procedure comprised preparation, implementation, and data collection stages. During the preparation stage, the researcher selected the buffer solution topic; developed instructional materials including a Detailed Lesson Plan (RPM), Student Worksheets (LKM), and evaluation instruments; prepared pretest and posttest questions; and gathered data on daily test scores from the previous topic to serve as a basis for prerequisite testing and sample selection. In the implementation stage, the experimental class received instruction using the POE2WE model, whereas the control class received instruction without the POE2WE model. Subsequently, both classes took a posttest to obtain final data on conceptual understanding. The study was conducted at SMAN 2 Siak Hulu during April and May 2026.

RESULTS

The study was conducted at SMAN 2 Siak Hulu during April–May 2026, focusing on the topic of buffer solutions for Grade XI students. The research involved Class XI MIPA 4 (32 students) as the experimental group and Class XI MIPA 5 (33 students) as the control group. Following the selection of classes, both groups took a pre-test before instruction and a post-test after the learning process. The experimental group received instruction using the Prediction, Observation, Explanation, Elaboration, Write, and Evaluation (POE2WE) model, while the control group was taught using a deep learning approach without the POE2WE model. The pretest, post-test, and N-gain results for conceptual understanding are presented in Table 1 below :

Table 1. Pretest, Posttest, and N-gain Results for Conceptual Understanding

Class	N	Pretest	Posttest	N-gain	Category
Experimental	32	43.21	83.77	0.72	High
Control	32	38.88	73.20	0.56	Medium

Source: Research data

The findings presented in Table 1. Pretest, Posttest, and N-gain Results for Conceptual Understanding indicate an improvement in students' conceptual understanding in both classes following instruction, with a greater increase observed in the experimental group. The experimental group's mean score rose from 43.21 on the pre-test to 83.77 on the post-test, while the control group's mean increased from 38.88 to 73.20. Based on N-gain calculations, the experimental group achieved a score of 0.72 (high category), whereas the control group achieved a score of 0.56 (medium category). These results demonstrate that the improvement in conceptual understanding was greater in the class taught using the POE2WE model compared to the control group.

Table 2. Hypothesis Test Results

Group	N	Mean Difference	t-calculated	t-table	Decision
Experimental	32	40.56	2.34	1.998	Hypothesis accepted
Control	32	34.32			

Source: Research data

The hypothesis test results presented in Table 2, reinforce the study's main findings. An analysis of the difference between post-test and pre-test scores for both classes was conducted using a right-tailed t-test. The test yielded a calculated t-value of 2.34 and a critical t-value (t-table) of 1.998, with 62 degrees of freedom and a significance level of 5%. Since the calculated t-value exceeds the critical t-value, the research hypothesis is accepted. Thus, there is a difference in the improvement of conceptual understanding between students receiving POE2WE-based instruction and those receiving instruction without the POE2WE model.

Supporting findings indicate that the research data meet the requirements for parametric statistical analysis. Normality test results show that the pretest and posttest data for both the experimental and control classes are normally distributed. The data regarding the pretest-posttest difference for both classes are also normally distributed. Furthermore, test score data on the topic of salt hydrolysis used for sample selection indicate that the three population classes possess homogeneous variances. A test of mean equality reveals that classes XI MIPA 4 and XI MIPA 5 have relatively equivalent initial proficiency levels, whereas other class pairings show differences in initial proficiency. Based on these results, XI MIPA 4 and XI MIPA 5 were selected as the research samples. Table 3 presents the N-gain for each indicator of conceptual understanding.

Table 3. N-gain for Each Indicator of Conceptual Understanding

Indicator	Experimental	Category	Control	Category
Restating a concept	0.80	High	0.38	Medium
Classifying objects according to a concept	0.60	Medium	0.59	Medium
Providing examples and non-examples	0.72	High	0.53	Medium
Presenting a concept in various representations	0.72	High	0.69	Medium
Developing necessary/sufficient conditions	0.56	Medium	0.10	Low
Using and selecting procedures/operations	0.82	High	0.63	Medium
Applying concepts/problem-solving algorithms	0.73	High	0.64	Medium

Source: Research data.

Based on Table 3. (N-gain for Each Conceptual Understanding Indicator, it is evident that the improvement observed in the experimental class across all seven indicators of conceptual understanding was greater than that in the control class. In the experimental class, five indicators fell into the high category: restating a concept (0.80); providing examples and non-examples of a concept (0.72); presenting a concept in various mathematical representations (0.72); using, utilizing, and selecting specific procedures or operations (0.82); and applying concepts or problem-solving algorithms (0.73). The remaining two indicators fell into the medium category: classifying objects based on specific properties or in accordance with a concept (0.60), and developing necessary or sufficient conditions for a concept (0.56).

A significant finding regarding the lower-performing areas is that the indicator for developing necessary or sufficient conditions for a concept showed the smallest improvement in the experimental class compared to the other indicators, with an N-gain value of 0.56 although this figure still falls within the medium category. In the control class, this same indicator yielded an N-gain value of 0.10, making it the only indicator to fall into the low category. Conversely, the greatest improvement in the experimental class was observed in the indicator for using, utilizing, and selecting specific procedures or operations, which reached an N-gain value of 0.82. Thus, while there was variation in the level of improvement across indicators, the experimental class overall demonstrated greater improvement across all indicators of conceptual understanding.

DISCUSSION

The research results indicate that implementing the Prediction, Observation, Explanation, Elaboration, Write, and Evaluation (POE2WE) learning model leads to a greater improvement in students' conceptual understanding of buffer solutions compared to instruction that does not utilize the POE2WE model. This difference is evident in the improvement of students' abilities following instruction and in hypothesis test results showing a significant difference in the gain of conceptual understanding between the two classes. These findings suggest that student engagement in each stage of the POE2WE model facilitates the development of a deeper and more meaningful conceptual understanding. Conceptual understanding is a crucial aspect of chemistry education, as it enables students to grasp the interrelationships between concepts and apply them to problem-solving

(Khaerudin et al., 2017). Thus, the study demonstrates that instruction providing opportunities for students to construct and communicate their knowledge better supports the development of conceptual understanding than instruction lacking the POE2WE stages.

These findings can be explained by the characteristics of the POE2WE model, which positions students as active participants in the learning process. The prediction stage allows students to formulate hypotheses based on prior knowledge; the observation stage enables them to verify these hypotheses through observation or experimentation; and the explanation stage provides a space to articulate and clarify the results obtained. Furthermore, the elaboration stage helps students connect concepts to everyday life; the writing stage assists in organizing and restating their understanding; and the evaluation stage is used to assess understanding after the completion of the learning process. This sequence aligns with the constructivist theory underpinning POE2WE, which posits that students construct knowledge through active learning experiences Nurnazarudin *et al.* 2021). The prediction stage allows students to propose hypotheses based on prior knowledge, thereby supporting concept formation (Nana & Surahman 2020), while the experimental activities in the observation stage help students discover and verify concepts through direct experience (Rahmawati *et al.*, 2024).

These results are consistent with various previous studies demonstrating the effectiveness of the POE2WE model in enhancing conceptual understanding. Mawaddah dan Maryanti (2016) demonstrated that the implementation of POE2WE enhances conceptual understanding through students' active engagement in the learning process. Fatimatuzzohrah *et al.* (2020) explained that the stages of prediction, observation, explanation, elaboration, writing, and evaluation provide students with opportunities to construct their own knowledge. These research findings are also consistent with those of Kharismayanda et al., (2025), which showed that linking concepts to everyday phenomena and problems helps students grasp concepts more deeply. The alignment of these findings reinforces the suitability of POE2WE for learning environments that require active engagement and conceptual understanding.

Regarding indicators of conceptual understanding, the experimental class showed greater improvement across all indicators compared to the control class, although the magnitude of improvement varied by indicator. The ability to restate concepts showed a significant increase. This outcome is attributed to the prediction, explanation, and writing stages, which allow students to articulate initial ideas, explain observations, and rephrase conclusions based on their own understanding. The ability to restate concepts is a crucial component of understanding, as students who truly grasp a concept do not merely recall information but are also able to explain and reinterpret it. These findings align with Pasha & Aini, (2022), who stated that the prediction, explanation, and writing stages enable students to construct and communicate the knowledge acquired during the learning process.

Improvements were also observed in the ability to classify objects, provide examples and non-examples, present concepts through various forms of representation, select specific procedures or operations, and apply concepts to problem-solving. Regarding the indicator of classifying objects, the improvement in both classes was relatively similar, suggesting that this skill develops not only through the POE2WE model but also through instruction in the control class. Meanwhile, the abilities to provide examples and non-examples and to present concepts in various forms of representation showed greater improvement in the experimental class. The activities of observation, explanation, elaboration, and writing provided students with opportunities to observe the characteristics of solutions, discuss their findings, connect concepts to everyday life, and communicate their understanding. This process supported students' ability to recognize conceptual characteristics and present them in different forms.

Thus, this study implies that the POE2WE model can be considered an alternative chemistry teaching strategy that prioritizes conceptual understanding and active student engagement. Despite yielding positive results, the study faced limitations regarding the management of instructional time. The POE2WE model comprises six sequential stages; the prediction, observation, and explanation stages, in particular, require significant time due to the inclusion of observation, discussion, experimentation, and presentation activities. Consequently, effective time management is essential to ensure all stages are completed in alignment with learning objectives. To address this limitation, the researcher managed time allocation for each stage and provided clear instructions to the students. This limitation warrants attention in future research or classroom applications of POE2WE specifically regarding time allocation to ensure that all procedural steps are executed optimally without compromising the depth of student learning activities.

CONCLUSION

Based on the research findings, it can be concluded that the implementation of the Prediction, Observation, Explanation, Elaboration, Write, and Evaluation (POE2WE) learning model improves students' conceptual understanding of the buffer solution topic in Grade XI at SMAN 2 Siak Hulu. The improvement in conceptual understanding among students taught using the POE2WE model was superior to that of students taught without it. Thus, the research objective to determine the improvement in students' chemical conceptual understanding through the POE2WE model has been achieved.

This study contributes to chemistry education by demonstrating that the POE2WE model serves as a viable alternative for instruction focused on strengthening conceptual understanding and fostering active student engagement, particularly regarding the topic of buffer solutions. The implementation of the prediction, observation, explanation, elaboration, writing, and evaluation stages provides a learning experience that helps students construct and develop their conceptual understanding in a more meaningful way.

For future instructional practice, the POE2WE model may be considered as an alternative approach to teaching chemistry, especially for topics that are conceptual in nature and require active student engagement. Future research could apply the POE2WE model to other chemistry topics with similar characteristics and examine additional learning variables, such as learning outcomes, critical thinking skills, or active student participation.

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