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The Effectiveness of the POE Learning Model on Acid-Base Material Based on Multiple Chemical Representations to Improve Higher-Order Thinking Skills

Dea Nisa Amelia [1*], Ila Rosilawati [2], Bayu Saputra [3], Chansyanah Diawati[4]

[1, 2, 3, 4] University of Lampung, Indonesia

* nisaameliadea@gmail.com

Abstract

The urgency of this study lies in addressing students' difficulties in connecting multiple chemical representations and developing higher-order thinking skills when learning acid–base concepts. This research is motivated by the low level of higher-order thinking skills of Indonesian students due to learning that does not involve students actively. This study describes the effectiveness of the Predict, Observe, Explain (POE) learning model on acid-base material based on multiple chemical representations to improve higher-order thinking skills. This study is a quasi-experimental study with a non-equivalent pretest-posttest control group research design. The population in this study were all students of grade XI MAN 1 Bandar Lampung in the 2025/2026 academic year from grades XI F1.1 to XI F1.7. The sampling of this study used a purposive sampling technique. The instruments used were a high-order thinking skills test, an observation sheet for the implementation of the learning model, and an observation sheet for student activities. The research data were analyzed by testing the difference between two means using the Independent Sample t-Test. The results of the Independent Sample t-Test showed that the average *n-Gain* of students' higher-order thinking skills in the experimental class was 0.73, while the average *n-Gain* of students' higher-order thinking skills in the control class was 0.57. Based on this, it can be concluded that the POE learning model on acid-base material based on multiple chemical representations is effective in improving higher-order thinking skills.

Kata Kunci: *Acid-Base, Hots, Multiple Chemical Representations, Poe Learning Model.*

Introduction

Learning in the 21st century is expected to provide opportunities for students to develop thinking skills so they can compete in the era of the industrial revolution 4.0 (Mahrunnisya, 2023). Thinking skills are grouped into two: lower-order thinking skills (LOTs) and higher-order thinking skills (HOTs) (Putri et al., 2024; Larsen et al., 2022). One of the skills needed to successfully face the increasingly complex challenges of life, compete globally, and pursue a career is HOTS (Januariawan et al., 2020). HOTS involves a process in which students are required to process information and ideas to acquire new knowledge. This allows them to actively seek, analyze, process information, and utilize their knowledge optimally. Based on Anderson and Krathwohl's revised Bloom's taxonomy, students are expected to be able to analyze (C4), evaluate (C5), and create (C6). These skills require students to not only understand information but also be able to process, connect, and use that information to solve problems critically and creatively (Setiawati, 2019).

HOTs can help students have a good foundation of knowledge and understanding, so that students will be able to analyze complex conditions and dare to provide fundamental ideas to be able to compete in the modern era (Firdiana et al., 2023). Indonesian students' HOTS skills

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are still under-developed. The 2022 international assessment by the Programme for International Student Assessment (PISA) showed that the global average standard for scientific literacy was 485, while Indonesia's average score ranked 68th out of 81 countries, in the low-performing category (OECD, 2023). Research by previous studied explains that PISA questions, particularly those on scientific literacy, are among those that demand HOTS skills because they are at a high cognitive level (Ariastanti etal., 2026; Ramadhani et al., 2024). These questions require students to analyze problems, evaluate scientific data and arguments, and use scientific evidence to formulate decisions and problem-solving strategies. Research by previous studied also indicates that Indonesian students' HOTS skills are still relatively low (Rahmasary et al., 2024; Rizki et al., 2024).

The above facts are reinforced by interviews and observations with a chemistry teacher at MAN 1 Bandar Lampung, who found that the school has implemented the Independent Curriculum. The classroom learning process utilizes several learning methods, including lectures, Q&A discussions, presentations, and practical exercises. However, the practical activities are not optimal and are not applied to all materials due to limited tools and materials. Student activity varies widely, with some actively asking questions, while others tend to be passive and require teacher guidance. Furthermore, the use of Student Worksheets (LKPD) is not implemented for all materials, and the LKPDs used only contain material summaries and practice questions. This situation results in students not having sufficient opportunities to practice HOTS, especially in analyzing a problem and evaluating information based on evidence.

Chemistry learning outcomes (CP) in the Independent Curriculum phase F include elements of knowledge and elements of process skills. One element of knowledge is using the concept of acids and bases in everyday life. The acid-base sub-material includes the Arrhenius acid-base concept, the concept of pH, and the strength of acids and bases. Meanwhile, the process skills elements include observing, questioning and predicting, planning and implementing, selecting appropriate methods based on references to collect reliable data, considering risks and ethical issues in using these methods, processing, analyzing data and information, interpreting the information obtained honestly and responsibly, evaluating and reflecting, and communicating the results (Kemendikbud, 2022). To achieve this CP, a learning process is needed that is able to encourage students to be active in building HOTs. Students are given a phenomenon and make predictions about the problems presented based on the initial knowledge they already have. Then these predictions are then tested. Based on the data obtained, students relate and explain the relationship between the data obtained. This process is in accordance with the steps in the predict-observe-explain (POE) learning model. The POE learning model is a learning model that involves students in predicting or predicting a phenomenon, making observations through demonstrations or experiments and explaining the suitability of predictions with the results of experimental activities that have been carried out (Alfiyanti, 2020).

Expected Learning Outcomes in the Independent Curriculum When compared to the facts on the ground, the learning implemented has not fully provided opportunities for students to develop higher-order thinking skills (HOTS), such as analyzing problems, processing data, evaluating results based on evidence, and constructing logical arguments. Therefore, learning experiences are needed that actively involve students in building their knowledge. One learning model that can facilitate this learning experience is the Predict–Observe–Explain (POE) model. However, in acid-base material, the application of the POE model needs to be supported by multiple chemical representations so that students are able to connect observed phenomena (macroscopic) with processes at the particle level (submicroscopic) and symbolic representations, so that higher-order thinking skills can develop optimally.

The use of the POE learning model in acid-base learning based on multiple chemical representations can improve students' HOTS (Sushanti & Mintohari, 2026), thereby helping students analyze observed phenomena, connect particle representations with chemical symbols, and evaluate observation results during the learning process. Through the stages of predicting, observing, and explaining, students are encouraged to think at a higher level, solve problems, and draw conclusions based on the concepts learned. Thus, the application of the POE model based on multiple chemical representations in acid-base material is expected to train students' HOTS skills.

Several studies have shown that learning using the POE model has been proven to increase students' HOTS. The application of the POE model combined with blended learning effectively increased students' HOTS in physics (Amelia et al., 2021). The POE model was effective in increasing students' HOTS in plantae material (Ula et al., 2022). Revealed that the POE learning model with a metaphorical thinking approach was proven to increase students' HOTS (Rahmawati et al., 2022). Although several studies have shown that the POE model is effective in improving students' HOTS, research that applies the POE model based on multiple chemical representations to improve students' HOTS is still relatively limited. Particularly in acid-base material, there are not many studies that specifically examine the application of this model in training students' HOTS. Based on the description above, the problem in this study is how effective the POE model is on acid-base material based on multiple chemical representations to improve higher-order thinking skills.

The novelty of this study lies in the effectiveness of combining the POE learning model—based on multiple chemical representations with the development of Higher-Order Thinking Skills (HOTS) in chemistry instruction, specifically regarding the topic of acids and bases. While previous research on the POE model has extensively examined improvements in learning outcomes, critical thinking skills, and HOTS, the use of multiple representations has primarily focused on strengthening the understanding of chemical concepts. This study integrates both approaches, specifically targeting the enhancement of students' HOTS within the context of acid-base chemistry. Consequently, the study contributes by implementing a learning model that emphasizes student engagement in the learning process through the use of diverse representations and higher-order thinking skills.

Method

This study is a quasi-experimental study with a non-equivalent (pretest and posttest) control group design. The following research design is presented in the Table 1.

***Table** 1. Research Design (Creswell & Creswell, 2023)*

Eksperiment Class	O	X	O
Control Class	O	C	O

Description:
O = Pretest and posttest given to both research classes.
X = Experimental class treatment in the form of learning using the POE model based on multiple representations.
C = Control class treatment in the form of conventional learning. In general, this section describes how the study was conducted.

The population in this study was all students of class XI MAN 1 Bandar Lampung in the 2025/2026 academic year, consisting of seven classes that received chemistry subjects, namely XI F1.1 to XI F1.7. Of the seven classes, two classes were selected as research samples. The

sampling technique used was purposive sampling, namely a technique for determining samples based on certain considerations determined by the researcher in accordance with previously known population characteristics. The sample selection was carried out by considering information regarding the cognitive abilities of students obtained from the chemical equilibrium material test scores of the two classes. In class F1.1 the average value was 76.25 while class F1.2 was 75.50.

Based on the information obtained, two classes were used as samples, namely class XI F1.1 as an experimental class that will implement learning using the POE model on acid-base material based on multiple chemical representations with a total of 33 students and XI F1.2 as a control class that will implement conventional learning with a total of 31 students. The two types of data used in this study are primary data and supporting data. Primary data consists of HOTs pretest and posttest results. Supporting data consists of student activity and learning implementation data. The data sources for this study came from all students in the experimental and control classes.

The data collection techniques used in this study included: a) Pretest and posttest data collection techniques using written tests. The pretest was given to students before the learning process using the POE model based on multiple chemical representations to determine students' initial HOTS abilities. The posttest was given after all learning activities were completed to determine students' final HOTS abilities. The pretest and posttest data were then used to determine students' HOTS improvement after participating in the learning process. b) Learning implementation data was collected using observation techniques using a learning implementation observation sheet. Observations were conducted during the learning process and conducted by the chemistry subject teacher. The observation data were used to determine the level of implementation of each stage of the POE model based on multiple chemical representations during the learning process. c). Student activity data was collected using observation techniques using a student activity observation sheet. Observations were conducted throughout the learning process by one observer. The observation data were used to determine students' activities during the learning process using the POE model based on multiple chemical representations at each meeting.

The research instruments used in this study were as follows: a) Pretest and posttest questions consisting of six descriptive questions to measure HOTS, along with a grid and a scoring rubric. The scoring rubric ranged from 3 to 0. A score of 3 was awarded for a correct and complete answer, a score of 2 for a correct answer with one error, a score of 1 for an inaccurate answer, and a score of 0 for no correct answer or the student's failure to answer. The HOTS indicators measured were analysis and evaluation, with a maximum pretest-posttest score of 18. b) Observation sheet for the implementation of the POE model based on multiple chemical representations. The aspects observed included introductory activities, core activities according to the existing learning stages using the POE model based on multiple chemical representations, and closing activities. The observation sheet for the implementation of the POE model based on multiple chemical representations was completed by placing a checkmark (✓) on the yes/no options. The assessment was conducted by giving a score of 0 for the no option and a score of 1 for the yes option. c) Student activity observation sheet, which consists of four observation aspects related to student activities during the learning process. The aspects observed are asking questions, working together, providing opinions, and responding to other groups' presentations. Filling out the student activity observation sheet is done by placing a checkmark (✓) next to the activity carried out. Validation of learning tools and assessment

instruments is carried out through judgment. In this case, the researcher involves the research supervisor as an expert to provide the assessment. Testing is carried out by reviewing the grid and checking the alignment between skill indicators and learning objectives and test items.

The data analysis technique used in this study was the pretest and posttest scores of students' higher-order thinking skills in the experimental and control classes. After obtaining the *n-Gain* value for each student in the experimental and control classes. The results of the *n-Gain* calculations obtained were then interpreted into three categories using the previous studied criteria, which are presented in Table 2 (Hake, 1998).

Table 2. *n-Gain Criteria*

***n-Gain* Criteria**	**Criteria**
n-Gain ≥ 0,7	High
0,3 ≤ *n-Gain* < 0,7	Medium
n-Gain < 0,3	Low

A normality test was conducted to determine whether the sample data was normally distributed, using the Kolmogorov-Smirnov test with the help of SPSS 26.0. The hypothesis states that H_0 is accepted if the data is normally distributed and H_1 is accepted if the data is not normally distributed. The normality test criteria are to accept H_0 if the Sig. value is > 0.05 and reject H_0 if the Sig. value is < 0.05. The homogeneity test was conducted to determine whether the two sample groups came from populations that had homogeneous variances or not, using the Levene statistics test with the help of SPSS 26.0. The hypothesis states that accept H_0 if the sample population is homogeneous and accept H_1 if the sample population is not homogeneous. with the homogeneity test criteria, namely accept H_0 if the significance value is > 0.05 and reject H_0 if the significance value is < 0.05.

The test of the difference between the two average research samples was conducted to determine the effect of sample treatment by looking at the average *n-Gain* score of the experimental class and the control class using the Independent Sample T-test. with the hypothesis of accepting H0 if the average *n-Gain* HOTs of students in the experimental class is lower or equal to the average *n-Gain* HOTs of students in the control class and accepting H1 if the average *n-Gain* HOTs of students in the experimental class is higher than the average *n-Gain* HOTs of students in the control class. with the test criteria of accepting H0 if the Sig. (2-tailed) value > 0.05 and rejecting H0 if the Sig. (2-tailed) value < 0.05. Supporting data regarding the implementation of instruction were obtained through observation during the learning process, using an observation sheet completed by an observer. These data were then analyzed descriptively using percentages and interpreted based on the criteria presented in Table 3.

Table 3*. Learning Implementation Criteria*

Percentage (%)	Criteria
80,1 – 100	Very high
60,1– 80,0	High
40,1 – 60,0	medium
20,1 – 40,0	Low
0 – 20,0	Very low

Furthermore, supporting data regarding student activity were obtained through observation during the learning process using an observation sheet completed by an observer; the aspects observed included asking questions, offering opinions, collaborating, and responding to other groups' presentations. These data were then analyzed descriptively using percentages and interpreted based on the criteria presented in Table 4.

Table 4. *Student Activity Criteria*

Percentage (%)	Criteria
75 – 100	Very high
50– 74,99	High
25 – 49,55	medium
0,0 – 24,99	Low

Table 4 presents the criteria used to categorize student activity based on the percentage of activity observed during the learning process. A percentage ranging from 75% to 100% is categorized as very high, indicating that students demonstrated a high level of active participation in the learning activities. A percentage of 50% to 74.99% is categorized as high, showing that students actively participated in most learning activities. A percentage of 25% to 49.55% is categorized as medium, indicating that student participation was present but still needed improvement. Meanwhile, a percentage of 0.0% to 24.99% is categorized as low, indicating that student participation in the learning activities was still limited. These criteria provide a basis for interpreting the level of student activity during the implementation of the learning process.

Result

The effectiveness of the POE learning model on acid-base material based on multiple chemical representations in improving high-level thinking skills was determined through analysis of *n-Gain* HOTs scores and hypothesis testing, as presented in the Table 5.

Table 5*. Average pretest and posttest scores of HOTs*

Average Pretest Postest Score HOTs		
Research Class	Pretest	Postest
Experiment	5	14,57
Control	4,45	12,25

Based on Table 5. it can be seen that the maximum score for the pretest and posttest is 18. The average HOTs pretest score in the experimental class and the control class is relatively the same, namely in the control class of 4.45 and in the experimental class of 5 which means that both classes have the same initial ability. After treatment, the average posttest score in the two research classes has a difference, where the average posttest score of the experimental class using the multiple representation-based POE model is higher than the average posttest score of the control class using conventional learning, namely in the control class of 12.25 and in the experimental class of 14.57.

n-Gain HOTs Scores

The *n-Gain* calculation shows an increase in students' higher-order thinking skills after participating in the learning process. The average *n-Gain* obtained from the experimental class and the control class is as shown in Table 6.

Table 6. *Average n-Gain HOTs*

Research Class	Average n-Gain HOTs
Experiment	0,73
Control	0,57

Table 6. shows a comparison of the average *n-Gain* of students' higher-order thinking skills (HOTS) in the experimental class and the control class. The average *n-Gain* of the experimental class was 0.73, which is included in the high category based on criteria (Hake, 1998). Meanwhile, the average *n-Gain* of the control class was 0.57, which is in the medium category. These results indicate that the increase in students' HOTS in the experimental class was higher than in the control class. This difference in *n-Gain* categories indicates that the application of the Predict–Observe–Explain (POE) learning model based on multiple chemical representations is more effective in improving students' higher-order thinking skills than the learning applied to the control class.

n-Gain per HOTs Indicators

The improvement in higher-order thinking skills for each indicator can be seen through the average *n-Gain* for each HOTs indicator. The higher-order thinking skills studied were analysis and evaluation. The average *n-Gain* HOTs for each indicator can be seen in Table 7.

Table 7. *Average n-Gain of each HOTs Indicator*

Research Class	HOTs Indicators	
	Analyzing	Evaluating
Experiment	0,76	0,7
Control	0,6	0,53

Table 7. shows the average *n-Gain* of higher-order thinking skills (HOTS) for each indicator, namely analyzing and evaluating, for the experimental and control classes. For the analyzing indicator, the average *n-Gain* for the experimental class was 0.76, which is included in the high category, while the control class was 0.60, which is included in the medium category based on criteria (Hake, 1998).. Meanwhile, for the evaluating indicator, the average *n-Gain* for the experimental class was 0.70, which is included in the high category, while the control class obtained an average *n-Gain* of 0.53, which is included in the medium category. These results indicate that both HOTS indicators in the experimental class experienced a higher increase compared to the control class. In addition, the analyzing indicator obtained a slightly higher average *n-Gain* than the evaluating indicator in both classes.

Hypothesis Testing

Hypothesis testing using the two-mean difference test was conducted to determine whether the average *n-Gain* was statistically significantly different or not with the help of SPSS 26.0. The results of the normality test using the Kolmogorov-Smirnov test are presented in Table 8.

Table 8. *Normality Test Result*

Skills	Class	Normality Test (Kolmogorov-Smirrnov)	
		Sig. Value	Test Criteria
HOTs	Eksperiment	0,200	If Sig. > 0,05 accept H_0
	Control	0,065	

Based on Table 8. the results of the *n-Gain* normality test for high-order thinking skills (HOTS) in the experimental and control classes using the Kolmogorov–Smirnov test. The significance value in the experimental class was 0.200, while in the control class it was 0.065. Both significance values are greater than 0.05 (Sig. > 0.05), so the *n-Gain* data in both classes meet the assumption of normality or are normally distributed.

Table 9. *Homogeneity Test Result*

Skills	Class	Homogeneity Test (Levene Statistic)	
		Sig. Value	Test Criteria

HOTs	Eksperiment Control	0,155	If Sig. > 0,05 accept H_0

Table 9. shows the results of the homogeneity test of the *n-Gain* data for high-order thinking skills (HOTS) using the Levene Statistic test. The test results show a significance value of 0.155, which is greater than 0.05 (Sig. > 0.05). Thus, the variance of the *n-Gain* data in the experimental and control classes is homogeneous, thus fulfilling the homogeneity assumption. Therefore, the data is worthy of further analysis using a parametric test, namely the Independent Sample t-Test.

Table 10. *Test of difference of two means result*

Skills	Class	Independent Sample t-Test	
		Sig. (*2-tailed*)	Test Criteria
HOTs	Eksperiment Control	0,000	If Sig. (*2-tailed*) < 0,05 accept H_0

Table 10. shows the results of the Independent Sample t-Test on the *n-Gain* data of students' higher-order thinking skills (HOTS). The test results obtained a significance value (Sig. 2-tailed) of 0.000, which is smaller than 0.05 (Sig. < 0.05). These results indicate that there is a significant difference in the increase in HOTS between the experimental class and the control class. Thus, H_0 is rejected and H_1 is accepted, so it can be concluded that the application of the Predict–Observe–Explain (POE) learning model based on multiple chemical representations provides a better increase in HOTS compared to learning in the control class. The average percentage of implementation of the stages of the POE Learning model at each stage is presented in Table 11.

Table 11*. Data on the implementation of the POE model stages*

POE model Syntax	Average Percentage of POE Model Implementation at Each Stage (%)
Predict	100
Observe	100
Explain	100

Table 11. shows that the overall average percentage of implementation of the POE model stages from predict, observe, to explain has quite high criteria so that it can be said that the implementation of the POE Model is running optimally. The increase in the average *n-Gain* HOTs of the experimental class was also supported by student activity data. Student activity in learning activities was measured using a student activity observation sheet with four observation activities. Student activity data is presented in Figure 5.

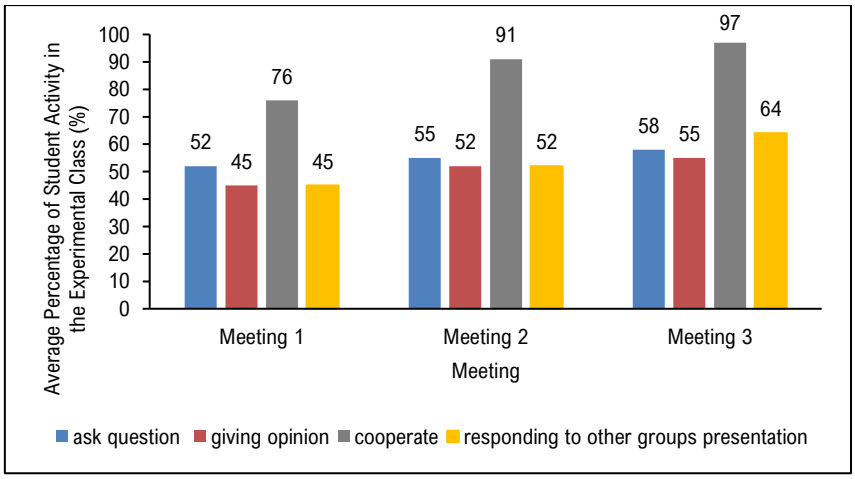


Figure 1. *Average percentage of student activity in the experimental class at each meeting*

Based on Figure 1. it can be seen that student activity from the first to the third meeting tended to increase. The highest increase occurred in the categories of collaborating and asking questions. Furthermore, student involvement in various activities tended to be more evenly distributed, indicating that the POE model stages were able to actively involve all students in the learning process. The following also shows the average percentage of student activity for each indicator presented in Figure 6.

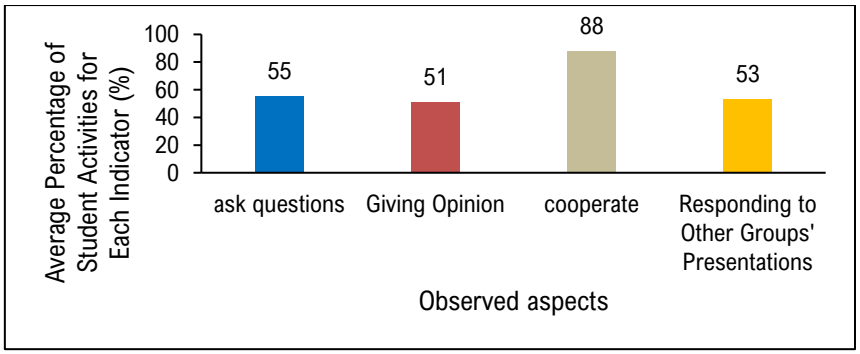


Figure 2*. Average percentage of student activity on each indicator*

Based on Figure 2. it can be seen that the average percentage of student activity in the aspects of asking questions, giving opinions, and responding to other groups' presentations is at the high criteria, while in the aspect of working together it is at the very high criteria. This can be concluded that the stages of the POE model are successful in increasing student activity during the learning process.

Discussion

Based on the research results, the application of the Predict–Observe–Explain (POE) model based on multiple chemical representations has a better effect on improving students' higher-order thinking skills (HOTS) on acid-base material compared to conventional learning. This is indicated by the relatively similar average pretest scores of both classes, namely 5 in the experimental class and 4.45 in the control class, thus indicating that the initial HOTS abilities of students in both classes are not significantly different. After being given treatment, the average posttest score of the experimental class increased to 14.57, while the control class only reached 12.25. These results indicate that learning using the POE model based on multiple chemical representations is able to improve students' mastery of questions that measure higher-order

thinking skills. This is consistent with research conducted by previous studied, which stated that the POE learning model can increase students' HOTs (Nurfadilah et al., 2021). This improvement is supported by the results of the *n-Gain* analysis which shows that the experimental class obtained an average *n-Gain* of 0.73 with a high category, while the control class obtained an average *n-Gain* of 0.57 with a medium category. These results indicate that the increase in HOTS of students who learned using the POE model based on multiple chemical representations was higher than students who received conventional learning. These results indicate that the learning process that actively involves students through predicting, observing, and explaining activities is able to provide a more meaningful learning experience so that students do not only passively acquire concepts, but build their own understanding based on the results of the investigations carried out.

The improvement of HOTS in the experimental class is inseparable from the characteristics of the POE model, which is based on constructivism theory. In the prediction stage, students are given an acid-base phenomenon in everyday life and then asked to make a prediction based on their prior knowledge. This activity encourages students to activate prior knowledge, connect concepts they have learned with the presented phenomenon, and provide reasons for their predictions. This activity trains students' ability to analyze problems before obtaining proof through experimental activities. HOTS-oriented learning needs to provide opportunities for students to construct knowledge through thinking activities, not just receiving information from the teacher (Widiasworo, 2023).

Next, in the observation stage, students conduct a practicum using acid-base indicators to verify their predictions. Students observe the indicator's color changes, record their observations, and then compare them with their initial predictions. At this stage, students not only observe directly visible phenomena (macroscopic representation), but are also guided to understand the solution ionization process at the particle level (submicroscopic representation) and relate it to ionization equations and chemical symbols (symbolic representation). Through this process, students are trained to analyze the relationship between observation results, processes occurring at the particle level, and symbolic representations, thereby enhancing their understanding of acid-base concepts. This is in line with the previous studied, who stated that chemistry learning that integrates multiple representations helps students connect macroscopic, submicroscopic, and symbolic representations, thus making chemical concepts easier to understand (Permatasari et al., 2022).

In the explain stage, students explain the results of the practicum based on the data obtained. Students discuss the correspondence between initial predictions and observational results, then provide scientific explanations based on the acid-base concepts they have learned. At this stage, students not only analyze the relationship between the practicum data and the concepts learned but also evaluate the accuracy of the predictions and the underlying reasons. Thus, the explain stage plays a role in training evaluation skills (C5), because students are required to provide an assessment of the results obtained based on scientific evidence. These results are in line with research by previous studied, which shows that the POE model can improve critical thinking skills because students are encouraged to compare predictions with observational results and provide explanations based on the evidence obtained (Alfiyanti et al., 2020). The increase in students' HOTS was also seen in each measured indicator. The analyzing indicator obtained an average *n-Gain* of 0.76 in the experimental class, categorized as high, while the control class obtained an average *n-Gain* of 0.60, categorized as medium. Meanwhile, the evaluating indicator obtained an average *n-Gain* of 0.70 in the experimental class and 0.53 in the control class, categorized as medium. These results indicate that both HOTS indicators

experienced a higher increase in the experimental class compared to the control class. In addition, the analyzing indicator obtained a slightly higher increase than the evaluating indicator.

The significant increase in the analysis indicator is due to the fact that at each stage of the POE model, students are constantly involved in activities that require analytical skills. In the predict stage, students analyze acid-base phenomena to formulate predictions; in the observe stage, students analyze observation results and connect them to submicroscopic and symbolic representations; and in the explain stage, students analyze the relationship between experimental results and the scientific concepts being studied. Thus, analytical skills are continuously practiced throughout the learning process, resulting in higher improvements. Meanwhile, the evaluation indicator improved because students were given the opportunity to reassess their predictions based on lab data. Students evaluated whether their initial predictions were consistent with their observations and then provided scientific justification supported by acid-base concepts and data obtained during the lab. This activity helped students develop their ability to evaluate arguments based on evidence, resulting in more logical and scientific decisions.

The effectiveness of the POE model based on multiple chemical representations is also strengthened by the results of statistical tests. The results of the normality test show that the *n-Gain* data in both classes are normally distributed, while the results of the homogeneity test show that both classes have homogeneous variances. Furthermore, the results of the Independent Sample t-Test obtained a significance value (Sig. 2-tailed) of 0.000 (<0.05), so there is a significant difference in HOTS improvement between the experimental class and the control class. Thus, the application of the POE model based on multiple chemical representations has been proven to have a significant effect on improving students' HOTS on acid-base material.

Learning success was also supported by the implementation of the POE model, which achieved 100% success at each stage: predict, observe, and explain. This demonstrates that the entire learning syntax was implemented according to the learning plan, optimally achieving the objectives at each stage. Furthermore, student activity during the learning process showed an increasing trend at each meeting. The greatest improvement was seen in the aspects of collaborating and asking questions, while the aspects of providing opinions and responding to other groups' presentations also increased. The high level of student activity indicates that the POE model based on multiple chemical representations is able to create student-centered learning. Through activities such as predicting, conducting experiments, discussing observation results, and explaining phenomena based on three levels of chemical representation, students became more active in building knowledge, discussing, and conveying scientific arguments. This condition also supports the development of students' higher-order thinking skills because they gain learning experiences that enable them to analyze, evaluate, and solve problems independently.

Overall, the results of the study indicate that the Predict–Observe–Explain (POE) model based on multiple chemical representations is effective in improving students' higher-order thinking skills in acid-base material. This success is not only demonstrated by improved learning outcomes and HOTS, but is also supported by optimal learning implementation and increased student activity during the learning process. The integration of the POE model with multiple chemical representations provides a learning experience that allows students to connect macroscopic phenomena, processes at the particle level, and symbolic representations, so that students are able to build a more meaningful understanding of concepts while developing analytical and evaluation skills in solving chemical problems. The results of this study are in line

with who showed that the application of the POE model has an effect on improving student learning outcomes in acid-base material. Furthermore, research by the previous studied, stated that teaching materials oriented towards multiple representations can help and facilitate students in connecting the three levels of representation (Helsy & Andriyani, 2017).

Conclusion

Based on the results of data analysis and discussion in this study, it can be concluded that the use of the POE learning model based on multiple chemical representations is effective in increasing students' HOTs in acid-base material. This can be seen from the average *n-Gain* HOTs of students in the experimental class which is significantly different from the control class. This means that the average *n-Gain* HOTs of students in the experimental class is higher than the *n-Gain* HOTs of students in the control class. Based on the research findings, it is recommended that the implementation of the POE learning model should consider effective time allocation to ensure optimal learning. Adequate equipment and materials should also be available. If laboratory facilities are limited, demonstrations or supporting media can be used to ensure optimal learning outcomes.

This study has a limitation that warrants attention, the implementation of POE-based instruction utilizing multiple chemical representations involves practical activities and the use of diverse learning resources, thereby requiring adequate time, equipment, materials, and facilities. This factor is significant because the availability of facilities can influence the smooth execution of the instruction. Future research could also develop instruments capable of capturing students' thought processes in greater depth. Furthermore, there is a need to develop instructional materials and alternative practical activities adaptable to varying school facilities, allowing for more flexible implementation of POE-based instruction utilizing multiple chemical representations and providing a more comprehensive assessment of its effectiveness.

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Reference

Alfiyanti, I. F., Jatmiko, B., & Wasis. (2020). The effectiveness of the Predict–Observe–Explain (POE) model with PhET to improve critical thinking skills of senior high school students. *Studies in Learning and Teaching, 1*(2), 76–85. https://doi.org/10.46627/silet.v1i2.34

Amelia, R., Husniyah, R., Hidayatullah, S., & Permaisuri, L. (2021). The implementation of the POE model based on blended learning to improve higher-order thinking skills of Grade XI senior high school students. *Jurnal Penelitian dan Pembelajaran Fisika, 7*(2), 121–127. https://doi.org/10.24036/jppf.v7i2.113335

Ariastanti, N., Indana, S., Sudibyo, E., Satriawan, M., & Rosdiana, L. (2026). Measuring science competencies on the theme of carbon emissions based on the PISA 2025 science framework. *JagoMIPA: Jurnal Pendidikan Matematika dan IPA, 6*(2), 761–772. https://doi.org/10.53299/jagomipa.v6i2.4276

Creswell, J. W., & Creswell, J. D. (2023). *Research design: Qualitative, quantitative, and mixed methods approaches*. SAGE Publications.

Firdiana, I. R., Supeno, & Rusdianto. (2023). The effect of the 5E learning cycle model assisted by multirepresentation-based e-LKPD in science learning on junior high school students' higher-order thinking skills. *PENDIPA Journal of Science Education, 7*(3), 355–361. https://doi.org/10.33369/pendipa.7.3.355-361

Hake, R. R. (1998). Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. *American Journal of Physics, 66*(1), 64–74. https://doi.org/10.1119/1.18809

Helsy, I., & Andriyani, L. (2017). Development of teaching materials on chemical equilibrium oriented toward multiple chemical representations. *Jurnal Tadris Kimiya, 2*(1), 104–108. http://dx.doi.org/10.15575/jta.v2i1.1365

Januariawan, I. W., Wijaya, I. K. W. B., Supadmini, N. K., & Dewi, D. N. (2020). Development of higher-order thinking skills through an open-ended approach. *Cetta: Jurnal Ilmu Pendidikan, 3*(2), 125–137. http://dx.doi.org/10.37329/cetta.v3i2.444

Kemdikbudristek. (2022). *Regulation of the Minister of Education, Culture, Research, and Technology of the Republic of Indonesia Number 21 of 2022 concerning educational assessment standards*.

Larsen, T. M., Endo, B. H., & Yee, A. T. (2022). Probing internal assumptions of the Revised Bloom's Taxonomy. *CBE—Life Sciences Education, 21*(4), ar66. https://doi.org/10.1187/cbe.20-08-0170

Mahrunnisya, D. (2023). Learner skills in the 21st century. *JUPENJI: Jurnal Pendidikan Jompa Indonesia, 2*(1), 101–109. https://doi.org/10.57218/jupenji.Vol2.Iss1.598

Nurfadilah, N., Asra, R., & Syaiful, S. (2021). The effect of the Predict–Observe–Explain learning model and motivation on students' higher-order thinking skills. *BIODIK, 7*(2), 143–152. https://doi.org/10.22437/bio.v7i2.12065

Nurkamaliah, Siahaan, J., & Haris, M. (2025). The effect of the POE (Predict, Observe, Explain) learning model on chemistry learning outcomes on acid–base material among Grade XI students at SMAN 1 Langgudu. *Chemistry Education Practice, 8*(2), 402–406. https://doi.org/10.29303/cep.v8i2.10146

OECD. (2023). *PISA 2022 results*. OECD Publishing.

Permatasari, M. B., Rahayu, S., & Dasna, I. W. (2022). Chemistry learning using multiple representations: A systematic literature review. *Journal of Science Learning, 5*(2), 334–341. https://doi.org/10.17509/jsl.v5i2.42656

Putri, A. K., Fahrunisa, A. H., Evriliani, A. S., Volosa, E., & Nahadi, N. (2024). Transforming chemistry learning through the development of higher-order thinking based on Revised Bloom's Taxonomy: A systematic review. *Hydrogen: Jurnal Kependidikan Kimia, 12*(3), 589–605. https://doi.org/10.33394/hjkk.v12i3.12452

Rahmasary, D. F., Rustina, R., & Heryani, Y. (2024). Computational thinking in solving HOTS problems based on self-confidence. *ELIPS: Jurnal Pendidikan Matematika, 5*(2), 145–151. https://doi.org/10.47650/elips.v5i2.1287

Rahmawati, I., Setiani, A., & Lukman, H. S. (2022). Experimentation with the POE learning model using a metaphorical thinking approach to students' higher-order thinking skills. *Prisma, 11*(2), 320–328. https://doi.org/10.35194/jp.v11i2.2342

Ramdhani, S. S., Susanti, R., & Meilinda, M. (2024). Cognitive level of Program for International Student Assessment (PISA) questions based on the Revised Bloom's Taxonomy. *European Journal of Education and Pedagogy, 5*(2), 164–169. https://doi.org/10.24018/ejedu.2024.5.2.785

Rizki, D., Almay, F. A. P., & Ramadani, S. D. (2024). Development of a higher-order thinking skills (HOTS) assessment instrument on ecology material in senior high school. *Biodik: Jurnal Ilmiah Pendidikan Biologi, 10*(4), 691–702. https://doi.org/10.22437/biodik.v10i4.36741

Sushanti, S. I. N., & Mintohari, M. (2026). Development of an interactive adventure-based smart box on the digestive system to improve higher-order thinking skills in science learning. *Jurnal Pelita: Jurnal Pembelajaran IPA Terpadu, 6*(1), 384–397. https://doi.org/10.54065/pelita.6.1.2026.1387

Ula, F. K., Khoiri, N., & Akmalia, H. A. (2022). The effect of Predict–Observe–Explain on students' higher-order thinking skills on Plantae material. *Bioeduin: Jurnal Program Studi Pendidikan Biologi, 12*(2), 92–102. https://doi.org/10.15575/bioeduin.v12i2.20121

Widiasworo, E. (2023). *Integrative HOTS learning: Based on the spirit of independent learning*. Araska Publisher.