Enhancing Students' Conceptual Understanding of Elemental Compounds through Predict-Observe-Explain (POE) Strategy

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Abstract: Knowledge of elemental compounds is a crucial aspect of the high school chemistry curriculum. However, students frequently encounter challenges when studying elemental compounds, including struggles with understanding chemical concepts, as well as a lack of interest in learning. The aim of this research is to investigate the impact of the predict-observe-explain (POE) strategy on enhancing the conceptual understanding of high school students in relation to elemental compounds. The research employed a pre-test and post-test design with an experimental and a control group. A total of 60 students participated in the study, with the experimental and control groups being randomly assigned. The experimental group received instruction on elemental compounds using the POE strategy, while the control group received instruction using a traditional approach. The intervention period for the experimental group lasted 8 weeks, comprising a total of 12 lessons. Data collection involved a two-tier concept test and semi-structured interviews. The results indicated that students taught using the POE strategy achieved significantly higher scores compared to those taught using the traditional approach; Interviews with students in the experimental group revealed a highly positive attitude towards the POE strategy. Thus, the POE strategy is an effective approach that can be implemented in chemistry courses to enhance students' understanding of elemental compounds concepts.

Keywords: Elemental Compounds; POE Strategy; Conceptual Understanding

Introduction

Chemistry, as a scientific discipline, is rooted in experimentation and focuses on investigating the composition, structure, properties, and laws of changes of substances at the molecular and atomic levels. Elemental compounds are fundamental for students' conceptual construction and the development of core subject abilities, which can be considered a significant theme in high school chemistry curriculum[1] . The content related to elemental compounds not only involves the specific application of concepts like substance classification, ionic reactions, and redox reactions, but also serves as a foundation for the study of the periodic table of elements in later stages. It fully reflects the discipline's requirements for the development of students' higher-order thinking and the integration of thinking, making it a topic of great research value. However, students often spend a significant amount of time studying elemental compounds, lacking understanding and systematic cognition of chemical concepts. This lack of successful experiences diminishes their motivation and interest in learning chemistry[2]. Acquiring abstract chemical concepts cannot be achieved through mere mechanical memorization, while it requires engaging in thinking activities that delve into the material's structure and changes, moving beyond surface understanding.

Constructivist teaching methods enable students to achieve meaningful learning outcomes and enhance their conceptual understanding of scientific ideas[3][4]. The predict-observe-explain (POE) strategy is considered an effective teaching strategy for concept learning in constructivist learning theory[5][6]. At the beginning, predictions are made about an experiment or subject, followed by observations and explanations[7]. The prediction stage allows students to make predictions and provide reasons for their predictions, activating their prior knowledge and prompting them to explore their ideas about a concept[8]. In the observation stage, students have the opportunity to observe the experimental activity and record the observed phenomena or results. In the explanation stage, students are challenged to provide reasonable explanations for their predictions and observations (White & Gunstone, 1992). Several studies have explored the use of the POE strategy in science education and have documented its effectiveness in improving student conceptual understanding and reducing misconceptions based on student cognitive development [9][10][11]. The POE strategy also helps develop students' critical thinking and understanding of chemical concepts (Alfiyanti & Jatmiko, 2020) and enhances students' confidence as they complete learning tasks, actively seek answers, and express their opinions[12][13].

However, there is currently a dearth of research on the application of the POE strategy to enhance students' conceptual understanding of elemental compounds. This study aims to address this research gap by investigating the following research questions:

(1) To what extent does the utilization of the POE strategy in teaching elemental compounds affect students' levels of conceptual understanding?

(2) How does the implementation of the POE strategy influence students' conceptual understanding?

Methods and Procedures

Participants

This study was conducted in a public high school in Shandong Province during the fall semester of 2023-2024. A random selection method was used to choose one experimental group and one control group from two classes in the first grade, both of which were taught by the same chemistry teacher. A total of 30 students were randomly selected for the experimental group, and another 30 students were selected for the control group as study subjects. Furthermore, 12 students from the experimental group were chosen for semi-structured interviews.

Research Design

This study utilized a quasi-experimental design to investigate the effects of different teaching approaches on students' learning outcomes. Prior to the study, students had already covered topics such as substances classification, electrolytes, ionization reactions, and redox reactions, and had completed a midterm exam. Based on the analysis of the midterm exam scores, students with similar levels of achievement in chemistry were selected as the research subjects for both the experimental and control groups. The scores from the midterm exam were used as pre-tests to ensure that the students' learning levels were similiar across both groups. In the experimental group, the teaching content on elemental compounds was delivered using a POE strategy, while the control group received traditional instruction. The intervention period for the experimental group lasted 8 weeks and included a total of 12 lessons, with nine POE activities incorporated. To assess the students' learning outcomes, a test consisting of 30 multiple-choice questions, with a maximum score of 100, was collectively designed. The test employed a two-tiered assessment method, where each multiple-choice question had two parts: the choice of the answer and the reasoning behind the chosen answer.

This study employed the SOLO taxonomy method (Biggs & Collis, 1982), categorizing students' learning outcomes into five levels and assessing their thinking levels. According to Holmes (2005), the multiple-choice questions in the study were evaluated based on the five levels of the SOLO taxonomy criteria[15]. Each question was assigned a score corresponding to its level of cognitive understanding: 'Prestructural' (1 point), 'Unistructural' (2 points), 'Multistructural' (3 points), 'Relational' (4 points), and 'Extended Abstract' (5 points). A higher score indicated a higher level of understanding. Post-tests were conducted after 12 lessons for both groups of students. An independent sample t-test was performed using SPSS (version 26) software.

Design 9 activities based on real-life scenarios and experiments. A few examples of the POE activities are provided in Figure 1.

Interview

In a semi-structured interview, a total of 12 students from experimental group were selected, with 4 students chosen from the top, middle, and bottom of each class. The main objective of the interview was to assess the students' comprehension of elemental compounds and their attitudes towards learning about them. These interviews were conducted after the post-test and each interview session lasted approximately 16 minutes. The interview questions are as follows.

1.How do you perceive the application of the POE strategy in the classroom?

2.How do you resolve cognitive conflicts when your predictions and observations do not align?

3.Do you prefer POE courses or traditional courses?

4.What is your impression of the topic 'reasonable use of iron fertilizer'?

Activity 2: Why can't NaClO be mixed with toilet cleaner (containing HCl)?

P: The mixing of NaClO and toilet cleaner containing HCl should be avoided due to their potential reaction. This reaction can reduce the effectiveness of the components present in the toilet cleaner.

O: NaClO reacts with HCl, resulting in the release of yellow gas.

E: This reaction between NaClO and HCl is classified as an oxidation-reduction reaction, which produces a significant amount of Cl_2.

Activity 5: How can we make rational use of iron fertilizer?

P: Reducing agents can be added to the iron fertilizer solution to convert Fe^{3+} to Fe^{2+}; Iron fertilizer is not suitable for calcareous and alkaline soils, as it may reduce the effectiveness of iron fertilizer.

O: Adding iron powder to deteriorated iron fertilizer causes the solution to change from yellow to light green; Adding NaOH solution dropwise to non-deteriorated iron fertilizer solution produces a white precipitate that quickly turns into gray-green, eventually transforming into reddish-brown precipitate; Adding NaOH solution dropwise to deteriorated iron fertilizer results in the formation of reddish-brown precipitate.

E: Iron powder has reducing properties, converting Fe^{3+} to Fe^{2+}, therefore adding a reducing agent to the iron fertilizer can slow down its deterioration; Adding NaOH forms precipitates of $Fe(OH)_2$ and $Fe(OH)_3$, thus iron fertilizer application should be avoided in alkaline soils.

Activity 7: When chlorine gas and sulfur dioxide are simultaneously passed into the fuchsin solution, will the bleaching effect be stronger?

P: an enhanced bleaching effect; no recovery of color after heating; no bleaching effect at all.

O: When chlorine gas and sulfur dioxide are simultaneously passed into the fuchsin solution, no noticeable bleaching phenomenon occurs. (Teacher reminds students to consider from the perspective of oxidation-reduction reactions)

E: Chlorine gas reacts with sulfur dioxide when dissolved in water, forming H_2SO_4 and HCl, losing bleaching properties.

Fig. 1. A summary of part examples of students' responses to the 9 POE activities.

Results and Discussion

Data Analysis

An independent sample t-test was conducted to compare the pre-test means of students' scores between the experimental and control groups using SPSS (version 26) software. The results showed that the average scores for the experimental group (M=82.12, SD=3.31) and the control group (M=81.94, SD=3.67, $P>0.05$) were not significantly different. This indicates that the learning levels of the two groups of students, in terms of material classification, ion reactions, and redox reactions, were similar.

Table 1. Comparison of post-test scores on the SOLO taxonomy level between the control group and experimental group students.

SOLO Taxonomy Level	Score	Mean value (Average score ± Standard deviation)		P
		Experimental group (n=30)	Control group (n=30)	
Unistructural level	21	20.45±0.87	20.01±0.91	0.902
Multistructural level	39	33.42±1.47	32.54±2.05	0.046
Relational level	27	21.67±2.82	20.23±1.87	0.023
Extended Abstract level	13	8.98±0.95	7.32±1.09	0.034
Total score	100	84.52±6.23	80.10+5.92	0.038

According to Table 1, the average scores of the experimental group and the control group in the post-test are similar at the unistructural level, with a p-value of 0.902>0.05. This suggests that there is no significant difference in thinking level between the two classes at this level. Therefore, the POE strategy has a minimal impact on the unistructural thinking level of students. However, at the multistructural level, relational level, and abstract extended level, the average scores of the experimental group are higher than those of the control group, with p-values (0.046, 0.023, 0.034)<0.05, indicating significant differences in thinking level between the experimental and control groups at these three levels. The result of the experimental group (M=84.52, SD=6.23) and control group (M=80.10, SD=5.92), p<0.05. This indicates that the test scores of the experimental group students were significantly higher than those of the control group students, demonstrating a significant difference in the learning levels between the two groups.

Hence, this suggests that the POE strategy promotes the development of metacognitive conceptual understanding from a lower to a higher level. Additionally, both the experimental and control groups had the lowest frequency of reaching the extended abstract level, indicating that students currently face challenges in knowledge transfer and complex reasoning, which require enhanced training in the subsequent teaching.

Student Interviews

1.How do you perceive the application of the POE strategy in the classroom?

The students express a positive attitude towards the implementation of the POE strategy in the classroom. They find this approach to be more engaging and interesting, as it encourages active participation in critical thinking and observation, ultimately boosting their confidence in learning chemistry. Here are some students' responses:

- 'I thoroughly enjoy engaging in POE activities where I am required to carefully analyze problems and observe experimental phenomena before presenting my own ideas.'

- 'I have noticed a significant improvement in my confidence through participating in POE activities. I am now able to confidently express my thoughts, and both my teacher and classmates value and consider my viewpoints. As a result, my interest in chemistry has grown.'

2.How do you resolve cognitive conflicts when your predictions and observations do not align?

The students employ different strategies to resolve cognitive conflicts between predictions and observations. Some students engage in reflection upon these conflicts, while others rely on additional explanations provided by the teacher to correct their views. Here are a few examples of students' responses:

- 'I begin by reflecting on the disparities between my predictions and observations, and then analyze the underlying reasons using the knowledge I have acquired. I often make notes in my notebook to solidify my understanding, and find that reviewing these notes helps me recall the learned knowledge more effectively.'

- 'When confronted with unfamiliar knowledge, I find it challenging to provide a reasonable explanation as it surpasses my cognitive capacity. Only after receiving the teacher's explanation am I able to comprehend the true reason behind it.'

3.Do you prefer POE courses or traditional courses?

The students expressed a preference for the POE curriculum over traditional classes due to the opportunities it provides for active exploration and the chance to correct misconceptions. Here are some students' responses:

-'I prefer POE courses over traditional ones because they allow me to actively explore knowledge. After going through the stages of predicting, observing, and explaining, I have a comprehensive understanding of specific chemistry concepts and reactions.'

- 'In contrast, I find that I benefit more from POE courses. Even if I give the wrong answer, the observation stage encourages my thinking, and I can correct my response during the explanation stage. This process motivates me to actively participate in answering questions and ultimately boosts my confidence level.'

4.What is your impression of the topic 'reasonable use of iron fertilizer'?

The students mentioned that the theme of 'reasonable use of iron fertilizer' left a deep impression on them because it not only taught them chemistry knowledge but also helped them appreciate the value of the subject. Here are some students' responses:

- 'The theme of this activity was highly enjoyable as it kept me fully engaged in class without any distractions. Moreover, this class has significantly transformed my understanding of iron salts, enabling me to analyze practical problems from a theoretical knowledge perspective.'

- ‘It has sparked my interest in pursuing a chemistry major in college. I also find this class very valuable as it provides me with useful knowledge to enhance the health of the plants I enjoy taking care of.’

Based on the interview results, it is evident that students have a positive attitude towards the POE curriculum. The POE activities allow students to actively explore knowledge, think independently, and express their own perspectives. This process enhances students’ thinking abilities, boosts their confidence, and increases their interest in chemistry learning. The POE curriculum allows students to propose incorrect ideas during the prediction phase and discover the correct answers during the observation and explanation phases. This process encourages students to actively resolve cognitive conflicts, construct new knowledge, and develop their critical thinking skills. However, it is important for teachers to have an understanding of students’ cognitive levels beforehand, manage the pace and difficulty of the curriculum, and provide appropriate support and guidance in the classroom to facilitate the development of students’ understanding of elemental compounds.

Conclusion

This study focuses on investigating the impact of the Predict-Observe-Explain (POE) strategy on high school students’ conceptual understanding of elemental compounds. By comparing the test scores of the two groups of students, it can be observed that before using the POE strategy, there was almost no difference in the learning levels between the two groups. However, after using the POE strategy, the experimental group showed significantly higher test scores compared to the control group. The students in the experimental group exhibited better performance in terms of multistructural level, relational level, and extended abstract level. They were able to independently analyze unfamiliar problems and engage in complex reasoning. Therefore, the POE strategy facilitated the development of conceptual understanding ability among the students in the experimental group. Based on the analysis of interview results from the experimental group, students exhibited a positive attitude towards the POE strategy. They actively engaged in exploration and knowledge acquisition, which promoted critical thinking and enhanced their interest and self-confidence in learning chemistry. Furthermore, students were able to recognize the practical applications of chemistry in real life and appreciate its charm and unique value. Therefore, the POE strategy is considered to be a highly effective approach for enhancing students’ understanding of element compounds. Based on the findings of this study, it is recommended to apply the POE strategy in the instruction of ‘elemental compounds’ in high school chemistry courses. Future research can further investigate the effectiveness of the POE strategy in different units of chemistry courses.

Declaration of interest: No conflict of interest is declared by authors.

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