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Exploring the nature of scientific explanations: An interactive predict-observe-explain model-based intervention for pre-service science teachers

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ABSTRACT

This study explored the nature of scientific explanations of pre-service science teachers' using an interactive teaching and learning approach while applying the predict-observe-explain (POE) model as intervention. It adopted an action research approach and quasi-experimental design on purposively sampled intact group of 251 first year students of the Department of Integrated Science Education, University of Education, Winneba (UEW). Data collected with pre- and post-tests items were analyzed using descriptive statistics and the statistical package for social sciences version 25.0. Findings revealed that prior to the intervention; about 61.4% of the pre-service science teachers' scientific explanations were mainly descriptive and every day in nature, thus, being informal and not reflecting use of formal language of science. However, after the implementation of the model-based strategy, their scientific explanations improved, with 86.9% being formal and causal in nature, inculcating experts' language use. The study recommended the adoption of an interactive POE model-based strategy by science educators in training pre-service science teachers.

Keywords: scientific explanations, pre-service teachers, POE model, interactive teaching, nature of science

INTRODUCTION

In the science classroom, it is essential for students to construct meaningful scientific explanations in order to acquire the right scientific knowledge, comprehend scientific phenomena and develop the critical thinking skills needed to be successful in their study of the subject (Candela, 2024; Nawani et al., 2019). Being able to connect scientific explanations to conceptual understanding makes scientific explanation not only one of the goals of science education, but the very purpose of science itself (Alameh et al., 2023; McMillan et al., 2018). Hence, a call to construct a scientific explanation is a call to exhibit the ability to provide both appropriate explanation and the evidence of conceptual understanding (Darling-Hammonda et al., 2020; Habiddin et al., 2021). Thus, constructing scientific explanations tends to enable students study science beyond mere memorisation and prepares them for the scientific world. The predict-observe-explain (POE) model of engaging learners, an inquiry-based approach to teaching and learning, has been touted as an efficient teaching strategy for eliciting and promoting discussion of students' science conceptions as well as explanations (Nari & Purwanti, 2024; Yang, 2023). According to Purdhiyah et al. (2022), the application of the POE learning model has the potential to improve student learning outcomes, nature of their conceptual understanding and the acquisition of important process skills.

Involving the POE model in the classroom requires students to carry out tasks in three steps (Aisyah et al., 2024). In the first step, students are required to predict the outcome of an activity, and by so doing commit themselves to a possible reason(s) for their prediction. In the second step, they are made to observe, during which they are expected to study, interact with or engage in an activity, phenomenon or concept. The final or the third step enables them to provide reason-seeking or meaningful explanations in their efforts to reconcile identified discrepancies between their predictions and their observations. While research indicates that the POE model has been applied at the various educational levels, and with diverse groups of students (Azhari et al., 2023; Gustina et al., 2023; Hong et al., 2021; Setiyani et al., 2019), there is notable absence of research on its application with respect to pre-service science teachers at the university level. This lack of research on the application of the POE model poses a challenge, concerning the training of pre-service science teachers, leaving a gap in understanding how this particular group engages with and benefits from interacting with the POE model. Understanding the effectiveness of this model with this specific group of teachers can be crucial for curriculum development and improvement.

Training pre-service science teachers to enhance their conceptual understanding, enables them construct appropriate scientific explanations and to acquire scientific knowledge are key factors that facilitate meaningful science teaching and learning experiences for their overall education (Badmus & Jita, 2024). Pre-service teachers are expected to develop a range of theoretical and practical experiences that will enable them explain concepts, as well as develop the skills and competencies needed to effectively teach science at various levels (Boateng & Tatira, 2023). Generally, a teacher's conceptual understanding, and hence knowledge of the subject matter tends to directly affect students' achievement in the subject. However, studies have indicated that pre-service science teachers have difficulties regarding their own understanding of scientific phenomena, and so tend to be handicapped in explaining these phenomena (Ozdemir, 2023; Takaoglu, 2017; Tanak, 2020). Previous research primarily focused on investigating teaching methods that sought to enhance students' conceptual understanding and performance in science, but there is limited exploration of the effectiveness of these methods in developing students' abilities to construct explanations of the right nature (Joyce & Calhoun, 2024; Kim et al., 2018; Ryder, 2015). Resolving this limitation is essential for identifying the most impactful methods or strategies useful for developing students' scientific explanations, especially for pre-service science teachers. Furthermore, research has proven that some studies applied interactive teaching methods in the science teaching and learning process of pre-service teachers to improve their conceptual understanding of scientific concepts (Alemneh et al., 2024; Antwi, 2013; Attard et al., 2021; Jantrasee, 2022). However, these studies did not focus on exploring the nature of scientific explanations of concepts of the pre-service teachers.

BACKGROUND

Teaching Strategies

Teaching strategies or methods that involve lectures and other traditional direct approaches have been criticised for being rigid, providing little room for adjustment and restricting the use of active techniques such as dialogues, probing and case studies (Saira & Hafeez, 2021; Tularam & Machisella, 2018). As Reeder (2022) propounds, direct teaching methods such as lectures are most widely used methods of teaching in most classrooms. According to Reeder such methods are characterised by clear and systematic presentation of knowledge with the goal of helping students to develop background knowledge so that they may apply and link it to new knowledge. However, these methods stifle interactions among students and heavily dwell on memorisation of facts. Direct instructions are often performed in an authoritarian, manipulative and bureaucratic manner, and so have been derogatorily described as 'dehumanising' and 'robotic' in some cases (Saira & Hafeez, 2021; Tularam & Machisella, 2018). According to Dietrich and Evans (2022), even though the traditional lecture method is touted as beneficial to teaching and learning because it gives full play to teachers' roles as leaders and enables learners to obtain more knowledge, it can make learners lose their learning initiative and creativity at the same time. Studies about science teaching and learning at second cycle institutions in Ghana found out that traditional, didactic and teacher-directed strategies were mainly utilised. Again, these strategies emphasised on memorisation of scientific facts and replication of scientific experiments. Hence, it could be envisaged that many first year university students may have been predominantly exposed to such approaches in their pre-tertiary science education (Akon-Yamga et al., 2024; Marcourt et al., 2023).

Nature of Scientific Explanations of Concepts

Research proves that science explanations provide a window into a person's thinking, and it is a way to help students understand scientific phenomena (Cabello et al., 2021; Venkadasalam et al., 2024). Students' explanations of natural events have traditionally been used to test how well they understand topics and to plan lessons (Balukovic et al., 2015; Tran et al., 2023; White & Gunstone, 2014). Thus, the generation of scientific explanations tends to be an important learning goal in the teaching and learning of science. However, there seem to be no clear criteria for scientific explanation of natural phenomena in science education. Learners' abilities to provide the right scientific explanations to concepts at various levels of education has been an issue of concern in this discipline (Alameh et al., 2023; Brock & Kampourakis, 2023), as there has not been a single or commonly accepted definition of scientific explanations in research.

In this study, the nature of an explanation reflected how scientific explanations were constructed using formal language of science, that is, scientific explanations aligning to those provided by experts of the scientific domain (Kaartinen & Kumpulainen, 2002). The study adopted Kaartinen and Kumpulainen's (2002) scale for categorising the nature of scientific explanations. The categorisation included *formal explanation* (FE), *causal explanation* (CE), *descriptive explanation* (DE), and *everyday explanation* (EE). The authors described the category of FE as explanation reflecting formal scientific terminology and structure. Further, an explanation in this category contained language and structure that was consistent with what scientists know. In the CE category, informal language was used to describe the cause and/or effect of physical phenomena. These explanations were less formal than FEs and were not necessarily consistent with the explanations of experts. Explanations that merely explained the procedure of a physical phenomenon, without establishing firm causal connections, fell under the heading of DEs. The category of EEs illustrated the emergence of situational or practical meanings from informal contexts.

Specifically, in this study, there was the need to determine if the students could improve on their explanations to become more explanatory or detailed, reflecting cause-effect reasoning and formal reasoning, rather than using only their everyday understanding of the phenomena. Due to their peculiar status as pre-service science teachers, the students' possible transition from informal to FEs and from descriptive and/or every day to causal reasoning was especially important to investigate. This is because science teaching entails communicating scientific knowledge to students, whether scientists or non-scientists, using formal explanations (Agustina et al., 2024; Özer & Sarıbaş, 2023).

The Predict-Observe-Explain Model Strategy

The POE model-based strategy of teaching and learning adopts an instructional procedure whereby students are engaged in making predictions for an event, then observing, that is, interacting or studying or demonstrating an activity, and are required to compare what they observed to what they predicted, in order to monitor or evaluate their own learning with the ultimate expectation of enhancing their conceptual understanding of scientific knowledge (Nalkiran & Karamustafaoglu, 2020).

Research reveals that applying the POE model enables students' prior knowledge or conceptions about phenomena to be identified; their misconceptions addressed, and ideas well communicated and justified (Erdem Özcan & Uyanık, 2022; Nalkiran & Karamustafaoglu, 2020; Phanphech & Tanitteerapan, 2017; Yang, 2023). As propounded by the authors, inculcating the POE model in lessons provide students with opportunities to incorporate concrete learning experiences, and acquire conceptual understanding of science phenomena. In this study, due to the participants' peculiar nature as pre-service science teachers, their abilities to link prior or existing ideas and understanding about scientific concepts to the actual ideas, meanings or imports of those concepts are paramount. Hence, it is important to engage them in strategies that stimulate their pre-existing knowledge, leave dispute resolution to them, and emphasise thorough implementation of techniques or procedures without skipping phases. The POE strategy has been explored by many studies (Erdem Özcan & Uyanık, 2022; Fauziah et al., 2023; Okur & Seyhan, 2021; Rini et al., 2019), and found to influence students' exploration of concepts, as well as probe investigation into their thinking in various disciplines. Engaging students in experiential teaching and learning models such as the POE model has been touted as effective for developing meaningful scientific explanations, as well as enhancing their conceptual understanding in science (Azhari et al., 2023; Nari & Purwanti, 2024).

Prior studies have not investigated the combined effect of interactive teaching while applying the POE model on the nature of scientific explanations of students to concepts. Therefore, this study sought to fill this gap by exploring the effect of an interactive POE model-based teaching and learning strategy on the nature of scientific explanations of first-year pre-service science teachers. The study was guided by the following research questions:

1. What is the nature of pre-service science teachers' explanations to concepts in science before engagement in interactive teaching and learning using the POE model?
2. What is the nature of pre-service science teachers' explanations to concepts in science after engagement in interactive teaching and learning using the POE model?

MATERIALS AND METHODS

Research Design

The study employed an action research with a quasi-experimental design, which included a pre-intervention phase (pre-test), intervention phase (observation), and a post-intervention phase (post-test). These were appropriate to enable the determination of the nature of scientific explanations of the pre-service science students' before and after the intervention (Jhangiani et al., 2019).

Population and Sampling

The target population was all students of Department of Integrated Science Education, UEW. However, the study focused on only level 100 students of the Department, with a total enrollment of 251. They were purposely selected because these students were first year students at the university. This group of students had gone through the pre-tertiary level of education and had been exposed to different methods of science teaching and learning. They were therefore in a good position to impact the interactive POE model-based strategy better than students in other levels. The sample was also among the group of students taught by the author and was therefore easily accessible for the purposes of the study.

Research Instruments

The research instruments used to collect data for the study were pre- and post-tests items. The test items used in the study were adopted from the revision questions of their recommended textbook, Conceptual Physics, 12th edition (Hewitt, 2015). All items were selected from the aspects of the questions named think and rank (analysis), think and explain (synthesis), and think and discuss (evaluation). The pre-tests were used to diagnose nature of the scientific explanations of the students to concepts before their engagements in interactive POE model-based teaching and learning strategy (the intervention); while the post-tests helped to determine nature of the students' explanations to the concepts after the intervention. There were five pre-tests each made up of three open-ended questions and based on given pre-reading assignments from the textbook. However, the five post-tests were in the form of two-tier questions each made up of three multiple-choice questions, followed by an open-ended question. The first tier of each item consisted of a multiple-choice question with answer options from which participants were expected to choose their own correct answer, while the second tier elicited explanations or justifications for the chosen option made in the first part. Scores from both pre- and post-tests were collected with the aid of the *nature of scientific explanation evaluation form* developed by the researcher, outlined in **Table 1**.

In this study, explanations that were considered acceptable included FEs and CEs. These categories reflected a higher level of conceptual understanding and proficiency in the use of formal language of science, with FEs being the most desirable. But explanations in the categories of DEs and EEs were rated low and unacceptable. These explanations reflected informal understanding of concepts, and the use of situational, context-specific meanings without use of formal language of science.

Table 1. Nature of explanation evaluation form

Student ID	Nature of explanation	Pre-/post-test 1	Pre-/post-test 2	Pre-/post-test 3	Pre-/post-test 4	Pre-/post-test 5

Validity and Reliability

To ensure good face validity of the instruments, a team comprising the researcher, and two other science education researchers evaluated the items in the research instruments to ensure good face and content validity. The instruments were checked for clarity of instructions and items, relevance of the items, appropriateness of the items, and absence of obvious errors such as spelling or grammatical errors, as well as inconsistencies in the wording of items. The items used for both pre- and post-tests were selected from the revision question items of the recommended textbook, Conceptual Physics, 12th edition (Hewitt, 2015) used for the course of the study, and hence were considered reliable.

Data Collection Procedure

The study involved seven concepts selected from the course content of heat and thermodynamics, studied during a semester by level 100 students in the department. They included heat and temperature, thermal expansion, quantity of heat, specific heat capacity, thermal conduction, thermal convection, and thermal radiation. Three phases; pre-intervention, intervention and post-intervention phases were involved, and were tailored along the steps of the interactive POE model of teaching and learning.

The pre-intervention phase also deemed the prediction stage of the POE model was the first step of the interactive engagements and was carried out as a pre-test. This was conducted during the first 30 minutes of the interactive engagements. At this phase, students would commit themselves to a prediction for a particular outcome or phenomenon by providing answers to the pre-tests in the form of giving explanations to concepts. These exercises were based on prior knowledge gained from the given pre-reading assignments on the concepts. After this, they were engaged in interactive activities (observation).

The intervention phase became the second (observation) phase of the study, where students were actively engaged in activities to discover concepts by themselves. It involved the use of various interactive materials such as pictures, illustrations, texts, simulations, and videos from the recommended textbook used for the course. PowerPoint presentations, videos, simulations, and group presentations were employed to explain the concepts. The students were divided into 73 small mixed-gender groups to promote cooperative learning and active verbal discourses. They engaged in discussions, debates, and other forms of interactions to explore scientific principles underlying phenomena in order to arrive at conclusions. After the interactions, each group provided feedback by explaining any discrepancies between their predictions and observations. This led to the third and final phase of the engagements. In the post-intervention phase, the students reconciled their earlier predictions made in the pre-tests with their observations by answering post-test questions. The post-test items were questions similar to that of the pre-tests, but on the same concept studied during the interactions. The post-tests assessed the students' progression from the use of informal to FEs after the interactive engagements. After each engagement session, scores from both the pre- and post-tests were collected to be analysed.

Data from both pre- and post-tests were analysed using descriptive analysis to measure the trends in the nature of scientific explanations of the students' before and after the interactive POE engagements. This was done with the statistical package for social sciences software version 25.0.

RESULTS

The findings of the descriptive analyses conducted on the students' responses to both pre- and post-test items are summarised in **Tables 2** and **3**.

In **Table 2**, the results on the nature of the students' explanations to concepts in all five pre-tests are presented. In pre-test 1, thirteen participants representing 17.8% gave their explanations to the concepts using EEs. More than half of the participants, 41 (56.2%) also gave DEs, with 18 (24.7%) of them offering CE. One participant (1.4%) was able to give FE to those concepts in pre-test 1. Thus, over 75% of total answers were in the everyday and DEs, leaving just about a quarter of answers in the causal and FEs.

A similar trend was observed in pre-test 2 concepts where majority of the students continued to provide answers largely falling in the everyday and DEs than in the causal and FEs. Fourteen participants representing 19.2% and 28 (38.4%) presented their answers in the form of everyday and DEs, respectively, while 23 (31.5%) and 8 (11.0%) gave causal and FEs to the concepts, respectively. Again, for the concepts in pre-test 2, majority of the responses were in the DE category. Concepts in pre-test 3 had the highest number of responses in the form of EEs among all the five tests with 21 (28.8%) responses. Thirty-one explanations representing 42.5% were found to be descriptive in nature, with 18 (24.7%) and 3 (4.1%) explanations being causal and formal in nature, respectively.

The trend of responses from the participants slightly changed in the pre-test 4. CEs recorded the highest number of responses with 35 (47.9%) falling into the category. Twenty-one explanations being 28.8% were descriptive in nature, while 11 (15.1%) responses were categorised as EEs. FE recorded the least number of responses in pre-test 4 with only 6 (8.2%) answers. In pre-test 5, there were 12 (16.4%) responses in the everyday category, 32 (43.8%) in the descriptive category, 24 (32.9%) in the causal category, and only 5 responses being 6.8% recorded in the formal category.

For a more visual representation of the results in **Table 2**, the responses from all five pre-tests were plotted in a graph, as shown in **Figure 1**.

Figure 1 revealed that during the pre-tests, the category of explanations with the highest average number of responses was DE with 30.6 responses (41.9%). This was followed by CE

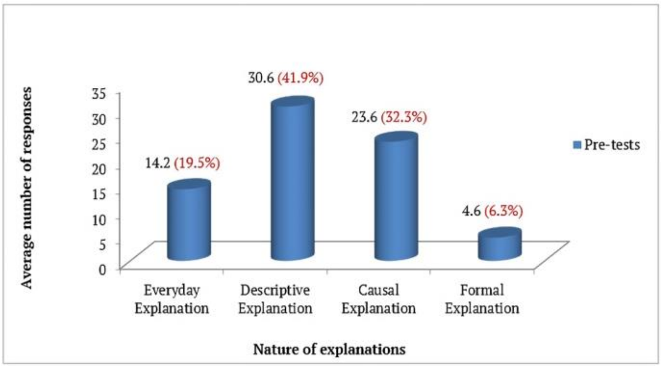


Figure 1. Distribution of average number of responses for nature of explanations in the pre-tests (Source: Author's own elaboration)

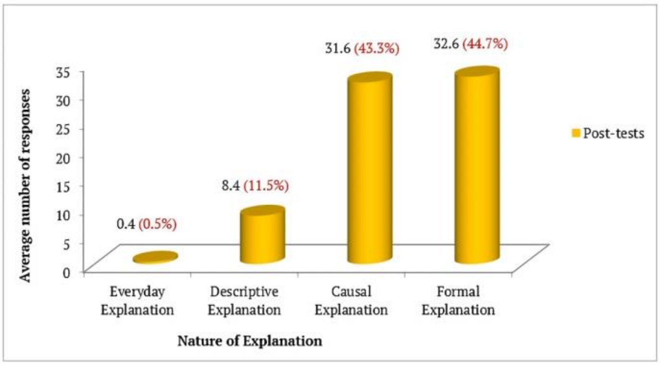


Figure 2. Distribution of average number of responses for nature of explanations in the post-tests (Source: Author's own elaboration)

Table 2. Distribution of nature of participants' explanations to concepts in the pre-tests

Nature of explanation	Pre-test 1 n (%)	Pre-test 2 n (%)	Pre-test 3 n (%)	Pre-test 4 n (%)	Pre-test 5 n (%)
Everyday explanation	13 (17.8)	14(19.2)	21 (28.8)	11 (15.1)	12 (16.4)
Descriptive explanation	41 (56.2)	28 (38.4)	31 (42.5)	21 (28.8)	32 (43.8)
Causal explanation	18 (24.7)	23 (31.5)	18 (24.7)	35 (47.9)	24 (32.9)
Formal explanation	1 (1.4)	8 (11.0)	3 (4.1)	6 (8.2)	5 (6.8)
Total	73 (100)	73 (100)	73 (100)	73 (100)	73 (100)

Table 3. Distribution of nature of participants' explanations to concepts in the post-tests

Nature of explanation	Post-test 1 n (%)	Post-test 2 n (%)	Post-test 3 n (%)	Post-test 4 n (%)	Post-test 5 n (%)
Everyday explanation	1 (1.4)	1 (1.4)	0 (0.0)	0 (0.0)	0 (0.0)
Descriptive explanation	19 (26.0)	16 (21.9)	3 (4.1)	4 (5.5)	0 (0.0)
Causal explanation	40 (54.8)	35 (47.9)	34 (46.6)	23 (31.5)	26 (35.6)
Formal explanation	13 (17.8)	21 (28.8)	36 (49.3)	46 (63.0)	47 (64.4)
Total	73 (100)	73 (100)	73 (100)	73 (100)	73 (100)

indicating an average of 23.6 (32.3%) and EE with 14.2 (19.5%). The category of FE had the lowest number 4.6 average responses indicating 6.3%.

Table 3 presents the students' results with regard to the nature of the students' explanations to concepts in the post-tests. For post-test 1, majority of the responses, 40 (54.8%) gave CE to concepts and only 1 (1.4%) responded using EE. There were 19 (26.0%) participants who answered using DE and 13 participants representing 17.8% explained concepts using FE.

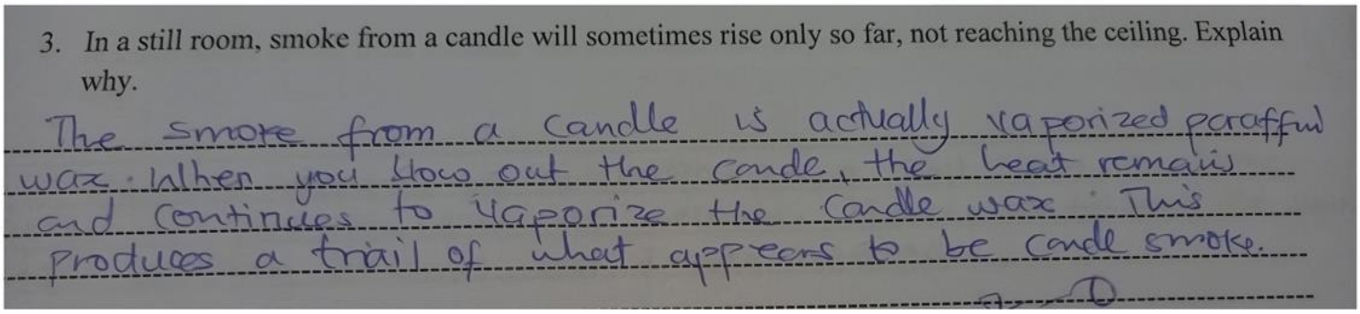
In post-test 2, only 1 participant representing 1.4% of the respondents used EE to give meaning to concepts, just as in post-test 1. Responses that were of CE came from 35 (47.9%) of participants, while FEs increased to 21 (28.8%) from the 13 recorded in post-test 1. Sixteen explanations indicating 21.9% of the participants explained concepts using DEs. Data from post-test 3 showed that none of the participants responded using EE and quite a few (3) representing 4.1% gave DEs to concepts. Almost half of the responses from the participants (49.3%) fell in the category of FE and 46.6% of them gave their answers using CE. The results from post-test 4 clearly show that there was no answer given using EE and only 4 (5.5%) explanations were in the descriptive category. A chunk of the participants 46 (63.0%) used FE to give meaning to concepts. Again, 21 participants, making 31.5% explained concepts by applying CE. In the last post-test there were only two categories of explanations given by the participants, and they were 26 (35.6%) and 47 (64.4%) for causal and FEs, respectively. None of the explanations from the students fell into the categories of everyday and descriptive.

To further provide details on the nature of the participants' explanations to concepts in the post-tests, the average value for each category of explanation as well as its corresponding percentage was determined using data from **Table 3**. The result of the analysis is shown in **Figure 2**.

In **Figure 2**, the average number of responses for all the categories of nature of explanation for the five post-tests was displayed. The category of FE had the highest number of 32.6 responses indicating 44.7%. This was followed by CE with 31.6 (43.3%) responses and DEs with 8.4 (11.5%) responses. The average responses for EE were the least with 0.4 responses indicating 0.5%.

DISCUSSIONS

Findings from **Table 2** and **Figure 1** revealed that the pre-service science teachers' explanations were mainly descriptive and ordinary or every day in nature before the intervention. That is, about 61.4% of the pre-service science teachers approached the learning of the science concepts largely on the basis of their everyday understanding of the phenomena. Majority could not use appropriate scientific language or formal language to explain the concepts. For instance, in pre-test 5 which was on the concept of heat transfer, sample question 1 was asked.



3. In a still room, smoke from a candle will sometimes rise only so far, not reaching the ceiling. Explain why.

The smoke from a candle is actually vaporized paraffin wax. When you blow out the candle, the heat remains and continues to vaporize the candle wax. This produces a trail of what appears to be candle smoke.

Figure 3. Example 1: Sample response to sample pre-test question (Source: Field study)

> Sample question 1. In a still small room, smoke from a candle will sometimes rise only so far, not reaching the ceiling. Explain why.

Excerpt of a response to the question is presented in example 1 in **Figure 3**.

Example 1 in **Figure 3** depicts the trend of the use of only suggestive practical knowledge of phenomena of the concept of convection currents. The question tested students' abilities to explain how convection currents are set up due to temperature differences in a system, as well as how thermal equilibrium in the same system causes the convection currents to cease. However, a greater percentage of the responses (60.2%) were given using every day and descriptive language of science.

Similarly, in pre-test 4, on the concept of heat transfer (conduction), a question posed and excerpts of responses from students are indicated below.

> Sample question 2. If you hold one end of a piece of metal against a piece of ice, the end in your hand soon becomes cold. Does this mean that cold flows from the ice to your hand? Explain your answer.

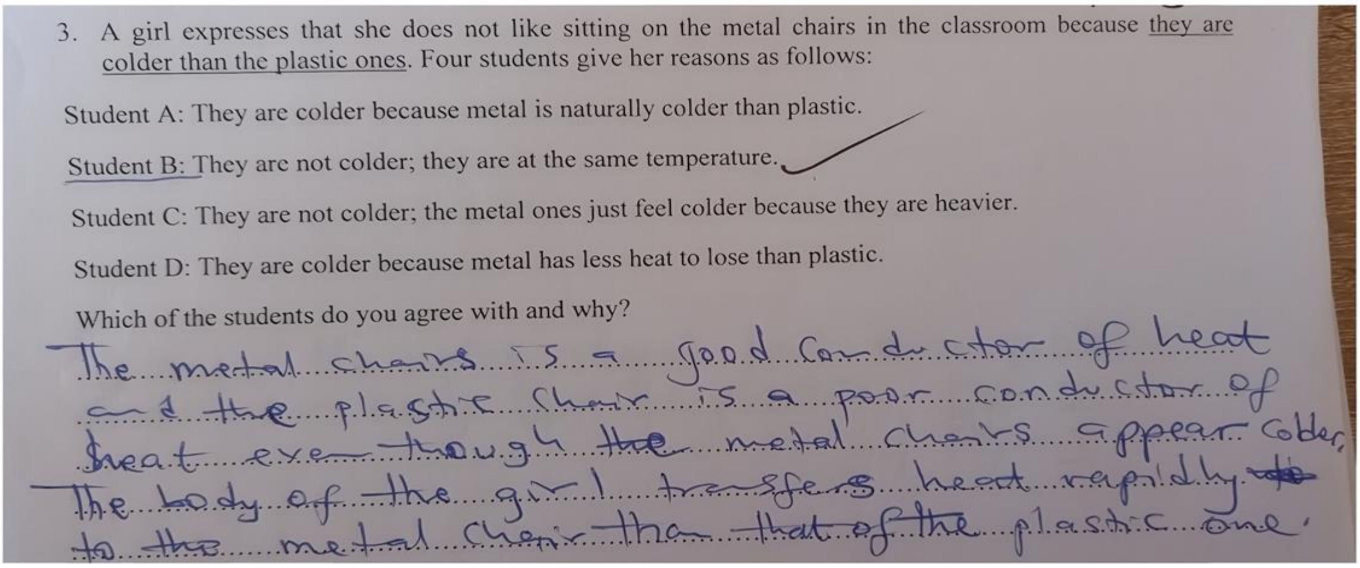
> Sample response 1. No, because heat transfer from the hot metal to the ice, because it takes a long time for heat to get to the end of the hand.

> Sample response 2. If we hold one end of the metal nail against a piece of ice the end in your hand will soon become cold.

The concept centered around metals being good conductors of heat and being able to transfer heat from bodies of higher temperature to bodies of colder temperature easily. Hence, students were expected to establish the fact that the high thermal conducting ability of the metal was the reason for the conduction of heat away from the warm hand causing the hand to lose thermal energy, and as a result feel cold. However, in the sample response 1 and response 2 above, and in most responses recorded, the pre-service teachers could not use the formal language of science to describe the phenomenon. Majority (71.3%) used descriptive and everyday languages to explain the concepts.

An observation of majority of responses revealed how the pre-service teachers responded to the questions using only everyday practical language instead of formal or expert-like language incorporating the right scientific words. Many of the responses did not express any scientific ideas and lacked the formal nature in which scientific concepts are to be explained. A striking feature that was observed in all the pre-tests was the proportion of participants that provided FEs, which remained consistently low throughout all the study. This could have been due to the fact that EEs are often rooted in informal language and contexts that individuals encounter in their daily lives. Participants might have been more comfortable and familiar with using everyday language to explain scientific phenomena, as it reflected their personal experiences and observations.

Hence, this study found out and concluded that prior to the use of the POE model-based teaching strategy; the pre-service science students' explanations to concepts were mainly descriptive and every day in nature, expressed using situational, common-context and informal practical language. This could be explained by the fact that although the concepts on heat and thermodynamics were quite familiar to them, because they might have encountered them in their pre-tertiary studies, they could have been engaged in the teaching and learning of these concepts through teaching strategies other than the POE model-based teaching and learning strategy. These findings were congruent with those by Akon-Yamga et al. (2024) and Marcourt et al. (2023) who found in their studies that the common approach to teaching at the various pre-tertiary institutions in Ghana emphasised memorisation of scientific facts and the replication of scientific experiments. These tend to stifle students' abilities to provide scientific explanations using formal language or terminologies as expected. Thus, instead of using the knowledge gained from the recommended textbook and from observation (the intervention) to explain the concepts, which could have enabled them to acquire and use formal texts, the students fell on the use of their own everyday experiences associated with the concepts. Perhaps, if the students had been engaged in more interactive teaching and learning methods aside the common traditional methods mostly employed at pre-tertiary levels, they would have elaborated more on their use of scientific language. These findings are also in agreement with a studies by Saira and Hafeez (2021) as well as Tularam and Machisella (2018) in which the authors described the direct mode of teaching and learning as being very rigid and providing little room for adjustment. Furthermore, the authors revealed how such teaching strategies tended to restrict the use of active problem-solving learning strategies such as workshops, dialogues, and collaborative studies.


3. A girl expresses that she does not like sitting on the metal chairs in the classroom because they are colder than the plastic ones. Four students give her reasons as follows:

Student A: They are colder because metal is naturally colder than plastic.

Student B: They are not colder; they are at the same temperature.

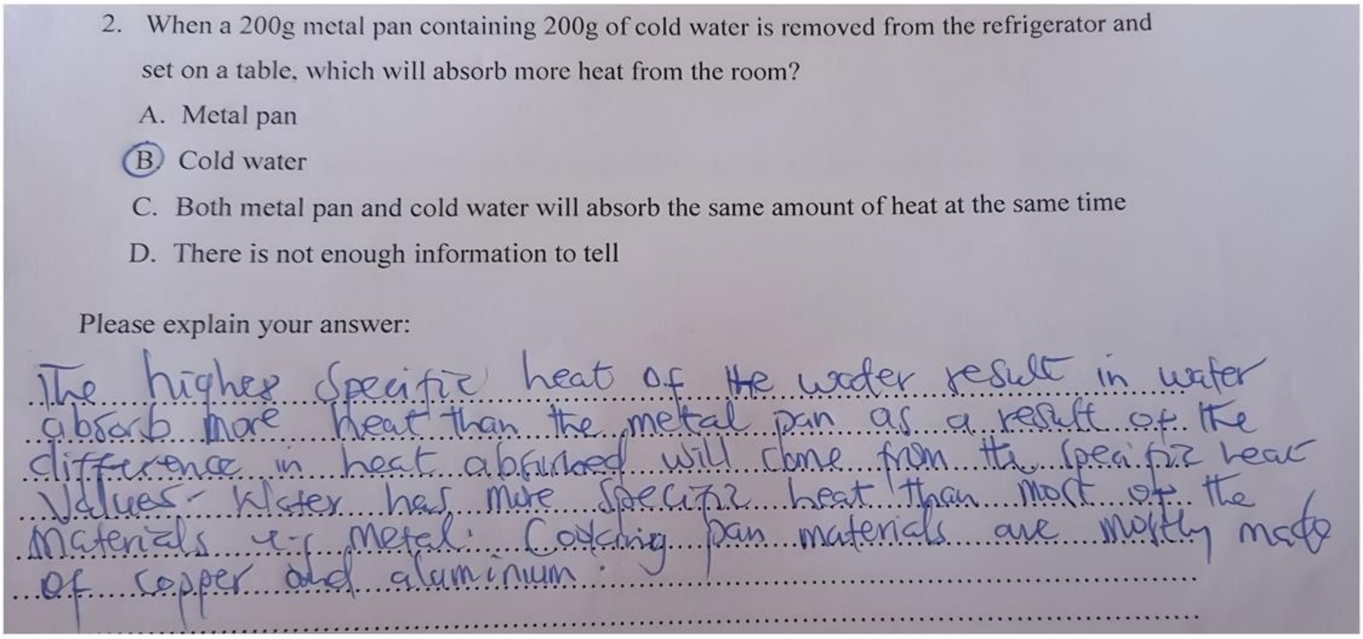
Student C: They are not colder; the metal ones just feel colder because they are heavier.

Student D: They are colder because metal has less heat to lose than plastic.

Which of the students do you agree with and why?

The metal chairs is a good conductor of heat and the plastic chair is a poor conductor of heat even though the metal chairs appear colder. The body of the girl transfers heat rapidly to the metal chair than that of the plastic one.

Figure 4. Example 2: Sample response 1 to sample post-test question (Source: Field study)


2. When a 200g metal pan containing 200g of cold water is removed from the refrigerator and set on a table, which will absorb more heat from the room?

A. Metal pan

B. Cold water

C. Both metal pan and cold water will absorb the same amount of heat at the same time

D. There is not enough information to tell

Please explain your answer:

The higher specific heat of the water result in water absorb more heat than the metal pan as a result of the difference in heat absorbed will come from the specific heat values. Water has more specific heat than most of the materials e.g. metal. Cooking pan materials are mostly made of copper and aluminium.

Figure 5. Example 3: Sample response 2 to sample post-test question (Source: Field study)

Dietrich and Evans (2022) also supported the findings of this study by indicating that even though traditional teaching methods such as the lecture teaching method had been touted as beneficial to teaching and learning; because it gave full play to teachers' roles as leaders, and enabled learners to obtain more knowledge, it had the tendency to make learners lose their learning initiative and creativity. Again, the findings also confirm Reeder's (2022) claim that in lectures, active interaction with learners is limited, with less emphasis on practice, and dwelling on recitation. Therefore, inferring from literature that the students' previous engagements in science teaching and learning might have been mainly through direct and other traditional teaching methods, the study concluded that these seem to have inhibited their abilities to provide explanations to science concepts using the formal language of science.

After the intervention, samples of students' responses to the post-tests as shown in example 2 in **Figure 4** and example 3 in **Figure 5** revealed the nature of scientific explanations of the pre-service science teachers.

A careful examination of the responses to all the post-test questions revealed that they were in sharp contrast to most of the responses they gave for the pre-test questions. This is an indication that the pre-service science teachers had made improved transitions from giving mainly informal (EEs which lacked the correct scientific language used in explaining concepts) to FEs. This suggests that through the use of the interactive POE model-based teaching strategy, about 86.9% of the pre-service science teachers were able to elaborate and expand on their conceptual understanding of the science concepts; and thus, were able to extend their explanations from simple every day to detailed formal ones.

The study therefore concluded that the use of the interactive POE model-based strategy afforded the pre-service teachers the opportunity to observe phenomena, interact with peers to arrive at conclusions and helped eliminate wrong conceptions on the concepts studied. The study observed that even though the students were expected to answer the pre-tests based on their knowledge gained from the pre-reading assignments in the textbook, majority approached the questions based on their own ideas about these concepts, and so used every day practical situations to explain the concepts. However, after the intervention, due to the interactive nature of the lessons, majority acquired the formal scientific language needed to provide the explanations to the concepts. This agrees with the study by Nari and Purwanti (2024) as well as Purdhiyah et al. (2022) in which the authors concluded that using interactive strategies along with the application of the POE model had a positive impact on the nature of science teachers' explanations to concepts. That is, the strategies elaborated the pre-service teachers' explanations, and reflected cause-effect reasoning and formal reasoning. The study also tends to agree with research by Yang (2023) who also found the POE as a helpful strategy in promoting student discussions in the learning process, thereby increasing their conceptual understanding and reduce their wrong use of terminologies. Moreover, the study confirmed findings from previous studies such as those of Erdem Özcan and Uyanık (2022) as well as Rini et al. (2019), in which they found that the distinct stages of the POE strategy provided a rich discussion or learning environment for students, and gave them an advantage in exploring, generating or probing ideas or concepts. These are further reiterated by Phanphech and Tanitteerapan (2017) who asserted in their study that active engagements in the interactive POE model-based processes enabled students to express their understanding by explanations which were written down in the form of tests. Thus, the interactive engagements coupled with the POE strategy was found to have increased probing among the students and led them to express ideas or concepts effortlessly. By extension, justifying and articulating ideas increased the acquisition of formal reasoning and use of formal language in science among the pre-service science teachers. In this study, due to the intervention of the interactive POE model-based teaching strategy, the pre-service science students had to convince each other in their various groups before presenting ideas to the whole class. In so doing, they were able to go beyond using situational meanings based on descriptive everyday reasoning to generating well-articulated, formal, conceptual explanations of the phenomena being investigated.

CONCLUSIONS

This study explored the nature of scientific explanations of pre-service science teachers using an interactive POE strategy as an intervention in their study of heat and thermodynamics concepts. The findings suggested that, before the intervention, the students relied on everyday language and informal practical knowledge in their scientific explanations. However, after the intervention there was a notable shift, leading to an improvement in the nature of explanations towards formal use of scientific language. Thus, reflecting the transformative impact of interactive and collaborative teaching and learning strategies in enhancing students' conceptual understanding and language use. The findings of the study tend to emphasise the importance of the POE model-based strategy in fostering conceptual understanding and encouraging the use of formal scientific language. Hence, it aligns with the growing recognition of the limitations of traditional teaching methods, emphasising on the need for more engaging teaching and learning approaches in science education.

The study's observed transition of students' explanations from informal everyday ones to formal ones supports existing theories that favour the idea that active engagement, collaboration and hands-on experiences play pivotal roles in students' conceptual understanding, other than rote memorisation and traditional lectures. Therefore, the study prompts a re-examination of existing theories related to science teaching and learning to incorporate the significance of interactive strategies like the POE model in bridging the gap between every day and formal use of scientific language.

Based on the findings and conclusions, the study recommends the followings:

1. Science teacher educators, especially in the Department of Integrated Science Education of the University of Education, Winneba where this study was conducted should adopt and integrate the POE model-based teaching and learning strategy in their teaching of pre-service science teachers.
2. Teacher training institutions such as teacher training universities and colleges of education may adopt more interactive learning strategies like the POE model-based strategy, to promote a deeper understanding of scientific concepts and improve the nature of scientific explanations given by pre-service science teachers.

Further research may consider the following areas of study:

1. Investigate further the effectiveness of the POE model-based teaching and learning strategy on the conceptual understanding and, nature of scientific explanations of students in other science concepts apart from heat and thermodynamics.
2. Conduct similar studies with a larger sample size and different demographic groups to investigate the generalisability of the findings.
3. Further studies should investigate factors that could affect the implementation and effectiveness of the POE model-based teaching and learning strategy in science education; such as the availability of resources, teacher and student factors, and institutional factors.

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REFERENCES

Agustina, T. W., Handayani, W., & Millah, R. L. (2024). Scientific explanation skills of prospective biology teachers. In *Proceedings of the International Conference on Mathematics and Science Education* (pp. 64-73). https://doi.org/10.18502/kss.v9i13.15908

Aisyah, S., Yuliani, Y., & Raharjo, R. (2024). The students' critical thinking skills with the implementation of sustainability learning to energy conservation and transformation material based on the POE (predict-observe-explain) model. *IJORER: International Journal of Recent Educational Research, 5*(1), 193-203. https://doi.org/10.46245/ijorer.v5i1.538

Akon-Yamga, G., Funkor, G., Tsey, K., Kingsford-Adaboh, R., Quaye, W., & Ntewusu, D. A. (2024). Perspectives from students and teachers about the challenges of teaching and learning STEM subjects in Ghana. *Frontiers in Education, 9*. https://doi.org/10.3389/feduc.2024.1288413

Alameh, S., Abd-El-Khalick, F., & Brown, D. (2023). The nature of scientific explanation: Examining the perceptions of the nature, quality, and "goodness" of explanation among college students, science teachers, and scientists. *Journal of Research in Science Teaching, 60*(1), 100-135. https://doi.org/10.1002/tea.21792

Alemneh, E. D., Kidanmariam, D. A., Mengistie, S. M., & Beyene, B. B. (2024). Effect of computer simulation and animation-integrated instruction on pre-service science teacher trainees conceptual understanding and retention of acid-base chemistry and stoichiometry. *JOTSE: Journal of Technology and Science Education, 14*(2), 453-472. https://doi.org/10.3926/jotse.2435

Antwi, V. (2013). *Interactive teaching of mechanics in a Ghanaian university context*. Utrecht. Freudenthal Institute for Science and Mathematics Education. Faculty of Science, Utrecht University.

Attard, C., Berger, N., & Mackenzie, E. (2021). The positive influence of inquiry-based learning teacher professional learning and industry partnerships on student engagement with STEM. *Frontiers in Education, 6*, Article 693221. https://doi.org/10.3389/feduc.2021.693221

Azhari, S., Purwati, N., Mahsul, A., Azmi, B. S. M., & Lestari, J. (2023). POE (predict-observe-explain) learning model for critical thinking skills of Miftahul Khair Middle School students NW Central Lombok Regency. *Otus Education: Jurnal Biologi dan Pendidikan Biologi, 1*(2), 103-112. https://doi.org/10.62588/tysxn849

Badmus, O. T., & Jita, L. C. (2024). Preservice teachers' level of knowledge on elements and rationale for nature of science: Towards advancing quality instruction. *International Journal of Cognitive Research in Science, Engineering and Education, 12*(1), 77-87. https://doi.org/10.23947/2334-8496-2024-12-1-77-87

Balukovic, J., Slisko, J., & Cruz, A. C. (2015). Electrostatic demonstration of free-fall weightlessness. *Physics Education, 50*(3), Article 288. https://doi.org/10.1088/0031-9120/50/3/288

Boateng, S., & Tatira, B. (2023). Voices from the field: Pre-service teachers' first time experiences of teaching physical sciences during school-based experience. *International Journal of Learning, Teaching and Educational Research, 22*(6), 59-77. https://doi.org/10.26803/ijlter.22.6.4

Brock, R., & Kampourakis, K. (2023). A justification of legitimate teleological explanations in physics education: An argument from necessary constraints. *Science & Education, 32*(4), 927-945. https://doi.org/10.1007/s11191-022-00358-8

Cabello, V. M., Moreira, P. M., & Griñó Morales, P. (2021). Elementary students' reasoning in drawn explanations based on a scientific theory. *Education Sciences, 11*(10), Article 581. https://doi.org/10.3390/educsci11100581

Candela, A. (2024). Discursive interaction and construction of science in the classroom. In M. R. Quintanilla Gatica, & A. Adúriz-Bravo (Eds.), *Science teaching and a new teacher culture: Sociocultural explorations of science education* (pp. 29-40). Springer. https://doi.org/10.1007/978-3-031-50004-6_2

Darling-Hammonda, L., Flooka, L., Cook-Harveya, C., Barronb, B., & Osher, D. (2020). Implications for educational practice of the science of learning and development. *Applied Developmental Science, 24*(2), 97-140. https://doi.org/10.1080/10888691.2018.1537791

Dietrich, H., & Evans, T. (2022). Traditional lectures versus active learning--A false dichotomy? *STEM Education, 2*(4), 275-292. https://doi.org/10.3934/steme.2022017

Erdem Özcan, G., & Uyanık, G. (2022). The effects of the "predict-observe-explain (POE)" strategy on academic achievement, attitude and retention in science learning. *Journal of Pedagogical Research, 6*(3), 103-111. https://doi.org/10.33902/JPR.202215535

Fauziah, F. M., Sudiatmika, A. A. I. A. R., & Suja, I. W. (2023). Modified POE learning model: Its effect on students' science learning motivation and critical thinking skills. *Jurnal Penelitian Pendidikan IPA, 9*(11), 9224-9230. https://doi.org/10.29303/jppipa.v9i11.4841

Gustina, R., Hastuti, I. D., Nizaar, M., & Syaharuddin, S. (2023). Predict observe explain learning model: Implementation and its influence on students' critical thinking ability and learning outcomes (a meta-analysis study). *Jurnal Kependidikan, 9*(2), 706-718. https://doi.org/10.33394/jk.v9i2.7388

Habiddin, H., Atikah, A., Husniah, I., Haetami, A., & Maysara, M. (2021). Building scientific explanation: A study of acid-base properties of salt solution. *AIP Conference Proceedings, 2330*, Article 020047. https://doi.org/10.1063/5.0043215

Hewitt, P. G. (2015). *Conceptual physics* (12th ed.). Pearson.

Hong, J.-C., Hsiao, H.-S., Chen, P.-H., Lu, C.-C., Tai, K.-H., & Tsai, C.-R. (2021). Critical attitude and ability associated with students' self-confidence and attitude toward "predict-observe-explain" online science inquiry learning. *Computers & Education, 166*, Article 104172. https://doi.org/10.1016/j.compedu.2021.104172

Jantrasee, R. (2022). A comparison of the effects of the integration sequence of interactive simulation on pre-service science teachers' scientific explanation of buffer solutions. *Journal of Turkish Science Education, 19*(4), 1155-1170. https://doi.org/10.36681/tused.2022.167

Jhangiani, R. S., Chiang, I. A., Cuttler, C., & Leighton, D. C. (2019). *Research methods in psychology*. KPU Pressbooks.

Joyce, B., & Calhoun, E. (2024). *Models of teaching*. Taylor & Francis. https://doi.org/10.4324/9781003455370

Kaartinen, S., & Kumpulainen, K. (2002). Collaborative inquiry and the construction of explanations in the learning of science. *Learning and Instruction, 12*, 189-213. https://doi.org/10.1016/S0959-4752(01)00004-4

Kim, N. J., Belland, B. R., & Walker, A. E. (2018). Effectiveness of computer-based scaffolding in the context of problem-based learning for STEM education: Bayesian meta-analysis. *Educational Psychology Review, 30,* 397-429. https://doi.org/10.1007/s10648-017-9419-1

Marcourt, S. R., Aboagye, E., Armoh, E. K., Dougblor, V. V., & Ossei-Anto, T. A. (2023). Teaching method as a critical issue in science education in Ghana. *Social Education Research, 4*(1) 82-90. https://doi.org/10.37256/ser.4120232058

McMillan, C., Loads, D., & McQueen, H. A. (2018). From students to scientists: The impact of interactive engagement in lectures. *New Directions in the Teaching of Physical Sciences, 13*. https://doi.org/10.29311/ndtps.v0i13.2425

Nalkiran, T., & Karamustafaoglu, S. (2020). Prediction-observation-explanation (POE) method and its efficiency in teaching "work, energy, power" concepts. *International Journal of Assessment Tools in Education, 7*(3), 497-521. https://doi.org/10.21449/ijate.727399

Nari, H., & Purwanti, K. Y. (2024). Influence of assisted POE (predict, observe, explain) model diorama on students' understanding of science concepts at SD Negeri Pringapus 01. *Jurnal Pendidikan Dasar Nusantara, 9*(2), 300-308. https://doi.org/10.29407/jpdn.v9i2.22100

Nawani, J., von Kotzebue, L., Spangler, M., & Neuhaus, B. J. (2019). Engaging students in constructing scientific explanations in biology classrooms: A lesson-design model. *Journal of Biological Education, 53*(4), 378-389. https://doi.org/10.1080/00219266.2018.1472131

Okur, M. & Seyhan, H.G. (2021). Determination of pre-service science teachers' conceptual understandings about the "Solutions: Dissolving-melting" with predict-observe-explain technique. *International Journal of Progressive Education, 17*(3), 381-396. https://doi.org/10.29329/ijpe.2021.346.24

Ozdemir, O. A. (2023). Turkish pre-service teachers' understanding of daily life phenomena related to chemistry and compatibility with the current chemistry curriculum. *Science Insights Education Frontiers, 16*(2), 2477-2503. https://doi.org/10.15354/sief.23.or311

Özer, F., & Sarıbaş, D. (2023). Exploring pre-service science teachers' understanding of scientific inquiry and scientific practices through a laboratory course. *Science & Education, 32*(3), 787-820. https://doi.org/10.1007/s11191-022-00325-3

Phanphech, P., & Tanitteerapan, T. (2017). Using predict-do-observe-explain strategy to enhance conceptual understanding of electric circuits for vocational learners. In *Proceedings of the Asian Conference on Technology in the Classroom 2017*.

Purdhiyah, P., Wulandari, S., Wulandari, M., & Annovasho, J. (2022). Studi literatur: Penerapan model pembelajaran prediction, observation, and explanation (POE) pada pembelajaran fisika [Literature study: Application of the prediction, observation, and explanation (POE) learning model in physics learning]. *Jurnal Pendidikan Fisika, 3*(2), 87-95. https://doi.org/10.53682/charmsains.v3i2.190

Reeder, E. (2022). *What are the different types of teaching models?* https://www.languagehumanities.org/what-are-the-different-types-of-teaching-models.

Rini, A. P., Suryani, N., & Fadhilah, S. S. (2019). Development of predict observe explain (POE)-based thematic teaching materials. *Al-Ta Lim Journal, 25*(3), 206-215. https://doi.org/10.24331/ijere.458067

Ryder, J. (2015). Being professional: Accountability and authority in teachers' responses to science curriculum reform. *Studies in Science Education, 51*(1), 87-120. https://doi.org/10.1080/03057267.2014.1001629

Saira, N. Z., & Hafeez, M. (2021). A critical review on discussion and traditional teaching methods. *Psychology and Education Journal, 58*(1), 1871-1886. https://doi.org/10.17762/PAE.V58I1.1042

Setiyani, T. W., Churiyah, M., & Arief, M. (2019). Enhancing the students' critical thinking ability and learning outcome through POE learning model. *Jurnal Pemikiran Ilmiah Dan Pendidikan Administrasi Perkantoran, 6*(1), 61-72. https://doi.org/10.26858/JA.V6I1.9700

Takaoglu, Z. B. (2017). Challenges faced by pre-service science teachers during the teaching and learning process in Turkey. *Journal of Education and Training Studies, 5*(2), 100-110. https://doi.org/10.11114/jets.v5i2.2132

Tanak, A. (2020). Developing preservice science teachers' teaching practices with an emphasis on higher order thinking. *Science Education International, 31*(3), 237-246. https://doi.org/10.33828/sei.v31.i3.2

Tran, T. N. A., Hoang, T. T. D., Pham, T. M. H., & Tran, T. T. T. (2023). Application of 5E model in natural science teaching to develop students' nature-understanding competence in junior high school. *Dong Thap University Journal of Science, 12*(3), 72-80. https://doi.org/10.52714/dthu.12.3.2023.1048

Tularam, G. A., & Machisella, P. (2018). Traditional vs non-traditional teaching and learning strategies-the case of e-learning. *International Journal for Mathematics Teaching and Learning, 19*(1), 129-158. https://doi.org/10.4256/ijmtl.v19i1.21

Venkadasalam, V. P., Larsen, N. E., & Ganea, P. A. (2024). Promoting scientific understanding and conceptual change in young children using explanations and guidance. *Developmental Psychology, 60*(4), 729-746. https://doi.org/10.1037/dev0001672

White, R., & Gunstone, R. (2014). *Probing understanding*. Routledge. https://doi.org/10.4324/9780203761342

Yang, X. (2023). Discussion on POE teaching strategies applied to science concept transformation teaching. *International Journal of Education and Humanities, 9*(2), 92-94. https://doi.org/10.54097/ijeh.v9i2.9718