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Research Article

Conceptual Understanding and Perceptions of Pre-Service Science Teachers in the Predict–Observe–Explain (POE) Model: Evidence from a Mixed-Methods Study

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ABSTRACT

Purpose of the study: This study examined pre-service science teachers' conceptual understanding and perceptions of the Predict–Observe–Explain (POE) model-based teaching and learning strategy. Specifically, it aimed to determine how the POE strategy enhances conceptual learning of science concepts while gauging the participants' views towards the use of the approach.

Methodology: A convergent parallel mixed-methods design was employed, involving seventy-three first-year pre-service Integrated Science teachers purposively sampled from a teacher education university. Data were collected during a twelve-week intervention using pre- and post-tests and the Cognitive Perceptions of the POE Model-Based Teaching and Learning (CPPOE) questionnaire. Quantitative data were analysed using descriptive statistics and normalised gain analysis, while qualitative data were thematically analysed to capture participants' perceptions.

Main Findings: Findings revealed that the POE model enhanced participants' conceptual understanding of selected science concepts, with an average normalised gain ⟨g⟩ of 0.44 indicating moderate conceptual improvement. Qualitative results also demonstrated positive perceptions with participants revealing that the strategy deepened their understanding, reduced confusion, encouraged curiosity, and helped them relate scientific ideas to everyday experiences.

Novelty/Originality of this study: This study contributes original mixed-methods evidence of the POE strategy from a Sub-Saharan African context, demonstrating its dual impact on pre-service science teachers' conceptual learning and their perceptions. These findings underscore the potential of integrating POE into science teacher education curricula to advance inquiry-driven, evidence-based scientific reasoning and student-centred instruction. The findings are limited to a single cohort of first-year pre-service science teachers within one institution.

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1. INTRODUCTION

The Predict-Observe-Explain (POE) strategy, originally known as the Demonstrate-Observe-Explain (DOE) was first used by [1] to assess the thinking skills of first year physics students at the University of

Pittsburg in 1979. The DOE dealt with real-world situations or experiences, and involved the processes of formulating a question for predicting the results of a situation or an experience, observing the effect of changes to the situation or experience and explaining the results obtained. The DOE strategy was found to have helped in reducing the quantity of verbal descriptions and allowed the use of more open-ended questions, which provided enough data to help make inferences about learners' conceptual understanding. However, White and Gunstone [2] redesigned the DOE strategy into the Predict-Observe-Explain (POE) strategy.

In the POE model-based strategy, learners must first predict the outcome of an event, interact with or study an activity, and then reconcile contradictions between what they predicted and what they observed [3]-[6]. The POE strategy may thus be considered as one of the teaching and learning strategies that teachers employ to enable learning to occur permanently in the minds of their students. It has the potential of linking learners' prior or existing ideas and understanding about scientific concepts to the actual ideas, meanings or imports of these concepts [7]. However, research shows that pre-service science teachers often enter training programmes with inconsistent conceptions, fragmented and/or limited understanding of scientific concepts. They also tend to have varied, and most often negative perceptions towards the learning of science [8]-[11]. These inadequacies, if unaddressed, are likely to persist into their professional practice, and bring about a reduction in the quality of science instruction they later provide. Examining pre-service science teachers' perceptions towards science teaching and learning is therefore crucial for identifying how pedagogical approaches such as the POE strategy influence both understanding, perceptions and attitudes towards learning. Targeted interventions and exposure to effective teaching practices could positively influence pre-service teachers' conceptual learning [12]-[15]. Furthermore, pre-service science teachers' beliefs about teaching and learning science are interconnected with their conceptual understanding, self-efficacy and interests, thus, highlighting the need for effective teaching strategies [10]. Yet, science teacher education in many contexts still fails to integrate such active learning models effectively, creating a critical gap between curriculum expectations and actual classroom practice.

In the Ghanaian education system, students of second cycle institutions commonly referred to as Senior High Schools (SHS) are generally 12 to 19 year olds, who pursue a three-year programme that follows nine years of basic education. The SHS programme consists of three core tracks: Science, Arts and Business, and typically, students select a track based on their career aspirations. Successful graduates of these second cycle institutions generally move on to the tertiary institutions such as the universities and colleges to pursue further courses, normally, in their chosen tracks. Science instruction at the secondary level remains largely teacher-centred, content-heavy, and focused on recall of facts rather than inquiry or application [16]–[19]. This situation limits learners' engagement and suppresses opportunities for meaningful conceptual change. As a result, pre-service teachers entering universities often carry forward these passive learning experiences, which may hinder their own ability to implement interactive teaching approaches later in their careers. This creates an urgent need for research-based, learner-centred interventions such as the POE model, which can actively involve pre-service teachers in constructing and reconstructing scientific concepts through the cycle of prediction, observation, and explanation.

Although extensive research [20]–[23] supports the effectiveness of the POE strategy across multiple levels of education, empirical evidence from African teacher education settings remains scarce. Particularly, little is known about how pre-service science teachers in Ghana conceptually learn through and perceive the POE strategy during their training. Addressing this gap is essential for reorienting science teacher education toward inquiry, evidence-based reasoning and learning, as well as improving conceptual teaching competence. Therefore, this study aims to examine pre-service science teachers' conceptual understanding and perceptions of the POE model-based teaching and learning strategy, specifically, to explore how their participation in POE-based instruction influences conceptual gains and students' views towards its use in science learning. This Research Objectives are: 1. To determine the effect of the POE model-based strategy on pre-service science teachers' conceptual understanding of selected science concepts; 2. To examine pre-service science teachers' perceptions of the POE model-based teaching and learning strategy.

2. LITERATURE REVIEW

Theoretical underpinnings of the POE model-based Strategy

The POE model-based teaching strategy is underpinned by several theoretical frameworks, including Jerome Bruner's Discovery Learning theory Bruner [24] and Jean Piaget's Cognitive Development theory Piaget [25]. These theories provide the foundation for the implementation of the POE model-based strategy, which aims to reiterate active engagement, critical thinking and collaborative learning among learners. Bruner's Discovery Learning theory emphasises the importance of intellectual development through active exploration and problem-solving skills [24]. The POE model, in line with the tenets of the theory, encourages students to actively engage with scientific concepts by predicting, observing, and explaining phenomena, thus, emphasising the active process of learning by discovery [26]-[28]. Furthermore, the POE model recognises the significance of students' prior knowledge and encourages learners to build on their existing understanding [29]-[31]. Consequently, students are prompted to make predictions based on their existing knowledge and actively seek explanations based on their observations and predictions.

Piaget's theory highlights the processes of assimilation (integrating new information into existing mental structures), accommodation (modifying mental structures to fit new information), and equilibration (making a balance between assimilation and accommodation). The POE model's stages of prediction, observation, and explanation encourage students to assimilate new information into their existing knowledge, accommodate it by re-evaluating their ideas, and reconciling their predictions and observations in the final stage, thereby achieving equilibration.

Impact of Teaching Strategies on Science Learning

Various teaching strategies significantly impact student learning in science. For instance, Hake [32] reveals the importance of interactive engagement strategies, such as active learning, in enhancing student understanding and performance in science courses. Comparative studies have indicated that student-centred approaches that promote active interaction among learners, like the inquiry-based learning, positively affect student achievement and retention of science concepts compared to traditional lecture-based methods [33]-[39]. These findings underscore the need for innovative teaching strategies like the POE model that encourage active participation and critical thinking, ultimately enhancing student learning outcomes in science. These outcomes align with the POE model-based strategy, allowing students to actively interact with each other, and also relying on prior knowledge as a scaffold for deeper understanding of concepts.

Findings from this study could provide valuable insights for teacher education programmes, informing curriculum design and instructional approaches in pre-service teacher training institutions. Specifically, policymakers and educators can be guided in integrating interactive and student-centred strategies, such as POE, into pre-service science teacher education, ultimately improving the quality of science education in Ghana and across the globe. These are underscored by previous studies that emphasise the pivotal role pre-service teacher training and continuous professional development programmes play in preparing both pre-service and professional teachers to effectively implement innovative teaching strategies [40]-[43]. Integrating the POE model into pre-service science teacher education programmes can equip teachers with the necessary skills needed to implement this effective teaching strategy in their future classrooms.

Empirical Studies on the POE Model-based Strategy

The POE model-based strategy has been found to enhance scientific understanding and critical thinking among students. Several studies have demonstrated its effectiveness in various educational contexts by engaging students in predicting outcomes, observing phenomena, and explaining results, thereby fostering deeper comprehension and retention of scientific concepts [44]-[46]. In a study conducted by Erdem Özcan and Uyanık [47], fourth grade students, split into experimental and control groups were evaluated on the impact of the POE model on their academic performance and attitudes toward science. The findings showed a significant improvement in academic achievement and a positive shift in science attitudes within the experimental group when compared to the control group. Moreover, a retention exam administered five weeks after the intervention indicated a notable advantage for the experimental group, suggesting the potential of POE model in enhancing both understanding and retention of science concepts.

Similar results were obtained in a previous research by Karamustafaoğlu and Mamlok-Naaman [48] who employed the POE technique on first-year electrochemistry students. Their results indicated that students exposed to the POE approach exhibited a significantly enhanced understanding of electrochemistry compared to those who received traditional lecture-based instruction. Thus, the study emphasised the effectiveness of the POE approach in promoting a deeper comprehension of complex science concepts. Rahmawati [49] also examined the impact of the POE model on students' conceptual understanding in Chemistry at Senior High School 1 Gondang using classroom action research design of 35 students. Findings revealed an improvement in comprehension, with mastery increasing from 71.4% in cycle I to 82.9% in cycle II, highlight the POE model's effectiveness in enhancing students' understanding of chemistry concepts.

3. RESEARCH METHOD

This study employed an educational research approach using a convergent parallel mixed-methods design to provide a comprehensive understanding of the research problem, and to enhance the validity of findings [50]. In this design, both quantitative and qualitative data were collected, analysed separately, and then merged for interpretation. The integration of both datasets ensured data triangulation, thereby increasing the credibility and reliability of the results [51]. Quantitative data measured participants' conceptual gains, while qualitative data captured their perceptions and experiences of the POE model-based teaching strategy.

The target population comprised all pre-service teachers enrolled in the Integrated Science programme at a teacher education university in Ghana. Due to the large student numbers across levels, a purposive sampling technique was used to select an intact group of 73 first-year pre-service teachers as the study sample. This group was selected because, as first year students, their experiences with the POE model were novel and therefore critical for assessing both conceptual gains and perceptions.

Two main instruments used to collect data were Pre-Test and Post-Test Instruments, and the Cognitive Perceptions of the POE Model-Based Teaching and Learning (CPPOE) Questionnaire. The pre- and post-tests were developed using test items obtained and modified from the Conceptual Physics textbook Hewitt [52], a well-recognised and widely accepted resource material in science and physics education. Meant to obtain quantitative data, the items were selected to reflect concepts in Heat and Thermodynamics, and to assess students' conceptual understanding and reasoning. The pre-tests, comprising three open-ended questions (total score: 10 marks), were administered during the prediction stage to determine participants' prior knowledge. The post-tests, designed with two-tier questions from the same concepts (also 10 marks), were administered after the observation stage, that is, at the explanation stage to measure conceptual gains.

The CPPOE questionnaire, designed by the researcher, was used to elicit both quantitative and qualitative data on the participants' perceptions of the use of the POE model-based teaching and learning strategy, and its influence on their conceptual learning of the science concepts. The instrument consisted of ten items, of which four were closed-ended and six were open-ended. The closed-ended items employed a five-point Likert scale ranging from Strongly Disagree (1) to Strongly Agree (5), and measured participants' perceptions about their conceptual learning of science through the use of the POE-based strategy. The open-ended items sought participants' written views, experiences, and opinions about the strategy, enabling deeper insight into their learning processes. Participants who indicated Agree or Strongly Agree on positive items were classified as having positive perceptions, while those who marked Disagree or Strongly Disagree were considered to have negative perceptions.

The twelve-week intervention consisted of five lessons on concepts of Heat and Thermodynamics taught using the POE model. During each lesson, the POE cycle was implemented through the three stages of prediction, observation, and explanation. In the prediction stage, the pre-service teachers answered questions (pre-tests) about the outcome of a phenomenon based on their prior knowledge. The observation stage exposed them to demonstrations, simulations, and collaborative discussions, enabling them to test their predictions. It was characterised by student-student, student-facilitator and student-learning materials interactions. Finally, during the explanation stage, they reconciled their initial answers with scientific explanations (post-tests), leading to conceptual change and reflective reasoning. The post-test results were compared to the pre-test results to determine any improvements or conceptual gains ⟨g⟩. In determining ⟨g⟩, pre-test, post-test and maximum scores can be calculated for individual learners or for a group. This study calculated the conceptual gain ⟨g⟩ for the intact sample to determine the effectiveness of the POE model-based strategy in enhancing conceptual understanding. The CPPOE questionnaire was administered at the end of the intervention period.

To check for face validity, the pre- and post-test items, derived from [52], were reviewed by three experts in Physics and Science Education to ensure alignment with the concepts of Heat and Thermodynamics. Same was conducted for the CPPOE. Content validity for the CPPOE was determined by rating each item's relevance and representativeness on a 4-point scale (1 = Not Relevant, 4 = Highly Relevant) following the Content Validity Index (CVI) procedure [53]-[54]. The Content Validity Index (CVI) for the instrument was 0.86, indicating strong expert agreement. To establish internal consistency, Cronbach's alpha reliability was computed for the CPPOE instrument, yielding a coefficient of 0.80, demonstrating good reliability for the items.

Quantitative data from pre- and post-tests and CPPOE were analysed using normalised gain formula [32] and descriptive statistics with SPSS v25.0 respectively. Hake [32] defined the normalised gain procedure in assessing learners' performance on pre-test and post-test items [55]: Normalised gain ⟨g⟩ is expressed mathematically as: $\langle g \rangle$=(Post-test score-Pre-test score)/(Maximum score-Pre-test score)

Three levels of ⟨g⟩ as indicated by Hake are as follows Table 1.

Table 1. N-Gain Score

Category	Score
High	$(g) > 0.7$
Medium	$0.3 \leq (g) \leq 0.7$
Low	$(g) < 0.3$

Qualitative responses from open-ended items were analysed using thematic analysis to identify recurring themes, such as engagement, collaboration, and effective of learning. The integration of quantitative and qualitative findings enabled triangulation and provided a comprehensive interpretation of both conceptual learning and perceptions. Ethical approval for the study was obtained from the Ethical Review Board of the University concerned. Participants were informed about the study and provided their consent prior to data collection, with anonymity and confidentiality strictly maintained.

4. RESULTS AND DISCUSSION

The study sought to determine the effect of the POE model-based teaching and learning strategy on pre-service science teachers' conceptual understanding of selected science concepts, as well as their perceptions of the strategy. Quantitative and qualitative data were analysed concurrently to address the research question.

Conceptual Gains

Pre-test and post-test scores were analysed to determine the level of conceptual gains achieved during the intervention. Descriptive statistics for the pre-test, post-test, and normalised gain scores are presented in Table 2.

Table 2. Normalised gain ⟨g⟩ score for the POE model-based strategy

Test (n = 73)	Mean Score	SD	Minimum Score	Maximum Score
Pre-test	4.40	0.90	2.50	6.50
Post-test	6.86	1.17	3.50	9.50
Absolute gain	2.47			
Normalised gain ⟨g⟩	0.44			

As shown in Table 2, the mean pre-test score for the respondents was 4.40 (SD = 0.90) out of 10, while the mean post-test score increased to 6.86 (SD = 1.17), yielding an average absolute gain of 2.47 (SD = 0.79). In the pre-tests and post-tests, the minimum scores obtained by an individual were 2.50 and 3.50, while the maximum were 6.50 and 9.50 respectively. The overall normalised gain ⟨g⟩ obtained was 0.44, indicating medium range, and suggesting that the POE model-based strategy produced a meaningful conceptual gain in participants' learning of the science concepts.

Perceptions of the POE Model-Based Strategy

Participants' perceptions of the POE model-based strategy on their conceptual learning of the science concepts were determined from their responses to the CPPOE questionnaire. Table 2 presents the distribution of responses to the closed-ended items on the Likert-scale (n) and their corresponding percentages (%).

Table 3. Distribution of participants' responses on perceptions of the POE model-based strategy

Perceptions of POE indicators	Strongly Agree n (%)	Agree n (%)	Neutral n (%)	Disagree n (%)	Strongly Disagree n (%)	Total n (%)
Awareness of importance of Science	42 (57.5)	23 (31.5)	6 (8.2)	1 (1.4)	1 (1.4)	73 (100.0)
Understanding of concepts made easier	32 (43.8)	30 (41.1)	8 (11.0)	3 (4.1)	0 (.0)	73 (100.0)
Not confused during lessons	33 (45.2)	35 (48.0)	5 (6.8)	0 (0.0)	0 (0.0)	73 (100.0)
Relating concepts to daily life	45 (61.6)	27 (37.0)	1 (1.4)	0 (0.0)	0 (0.0)	73 (100.0)

Table 3 summarises the pre-service teachers' perceptions of the use of the POE model-based teaching strategy on their conceptual learning of science concepts. Results indicated that majority became aware of the importance of science in daily life (57.5% strongly agreed, 31.5% agreed), and also, the POE model made their understanding of science concepts easier (84.9% strongly agreed and/or agreed). Additionally, many reported that they did not feel confused during POE model-based lessons (45.2% strongly agreed, 48.0% agreed), and also revealed that the POE helped them relate concepts learnt to daily life (61.6% strongly agreed, 37.0% agreed). Overall, over 80% of participants strongly agreed or agreed that the POE model enhanced their understanding, reduced confusion, and helped them connect science concepts to daily life.

The data from Table 2, visualised in Figure 1 as a chart, show a consistent trend of high positive responses across all items, confirming positive perceptions of the POE model-based strategy.

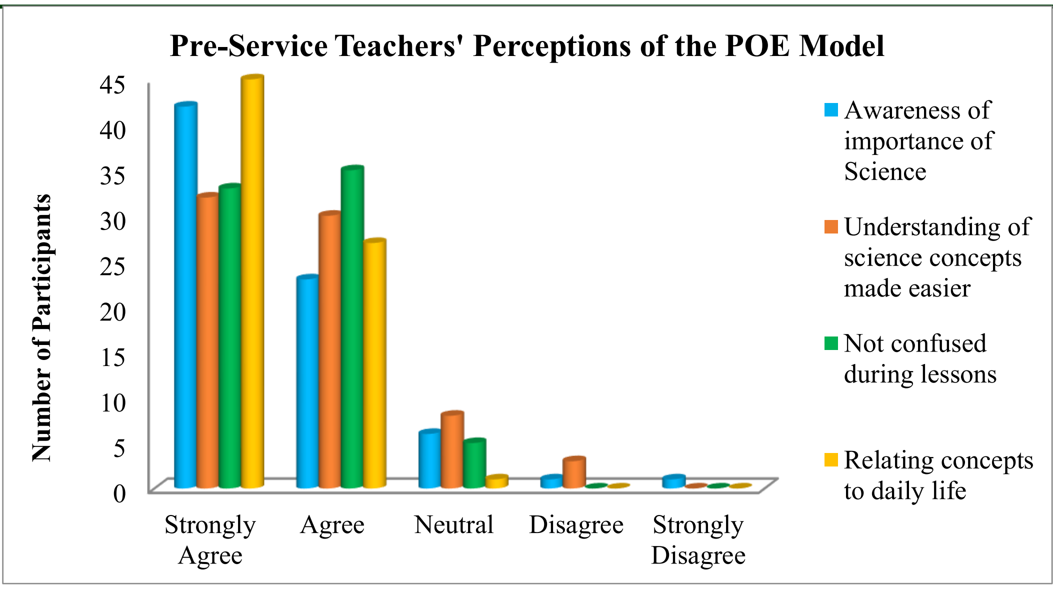

Figure 1. Graphical distribution of participants' responses on perceptions of the POE model-based strategy

Figure 1 shows the trend of the students' perceptions of the use of the POE model-based strategy on their conceptual learning of the science concepts. The graph, showed that overall, majority of the students' responses to the items were in the ranges of strongly agrees (SA) and agrees (A), indicating positive perceptions. Strikingly, the item 'Relating concepts to daily life' had almost all students agreeing, and only one staying neutral.

The qualitative responses gathered through the open-ended items of the CPPOE questionnaire revealed key themes that highlighted the impact of the POE model-based strategy on the students' learning of the science concepts. Three major themes that emerged were engagement, collaboration and effectiveness of learning.

Engagement in Learning Science Concepts

All participants indicated in one way or the other that the POE model deepened their levels of engagement with the Heat and Thermodynamics concepts, making them more relatable and applicable to everyday phenomena. Findings revealed that the POE strategy enhanced students' engagement in learning by encouraging significant active participation in discussions, increasing curiosity and boosting critical thinking. The processes of predicting phenomena, observing and explaining concepts helped them in becoming more involved in their learning, enabling critical thinking and deeper understanding of concepts. One student remarked:

> *"Science enlightens the mind, it gives room to explore, and science made me think critically."*

Similarly, others shared how the stages of the model sparked their interest in science, reinforcing their engagement in learning, and motivating them to explore scientific concepts more rigorously. Others expressed:

> *"Finding things for myself influenced my perception about science, knowing that different things come together to produce what we see today. I was always curious."*
> *"It makes me confirm my predictions, with evidence and facilitates my understanding."*

Excerpt of responses also revealed how students actively sought knowledge and made meaningful connections between scientific concepts and real-world phenomena, leading to sustained engagement. As expressed by a student:

> *"Because science has more to do with daily life activities, that led me to a positive perception of science."*
> *"Science enlightens the mind, it gives room to explore, and science made me think critically."*

These responses suggested that the POE model stimulated curiosity and encouraged more active engagements in the learning process.

Collaboration and Peer Learning of Science Concepts

The role of collaboration and peer interactions in reinforcing students' learning of the science concepts were evident through majority of responses received from the questionnaire. A few excerpts of responses showed how the POE strategy encouraged teamwork, discussions and knowledge sharing among the students, which helped them in their learning of the science concepts under study. One student highlighted the value of collaborative learning by expressing that:

> *"The factors that led to my positive perceptions about science were that I was able to relate the concepts taught in class to everyday life, and I was able to get more ideas from my colleagues whenever they answered questions."*

Another participant emphasised how the POE model facilitated structured learning environments allowing them team up as colleagues working together to explore and apply scientific ideas:

> *"This course and POE model-based teaching have increased my level of critical thinking and even that of my friends, and our preparedness towards learning."*

Additionally, the interactive nature of the strategy allowed students to engage in deeper discussions, fostering critical thinking and problem-solving skills:

> *"A POE model-based strategy gives advanced understanding about science, improves creativity and critical thinking, and provides a problem-solving environment."*

The results gave high indications that the POE model-based strategy promoted collaboration and peer discussions among the pre-service science teachers. Further, the POE model created an inclusive and interactive learning environment where students could learn from each other and develop a shared understanding of the science concepts.

Effectiveness of the POE Model in Learning Science Concepts

Majority of the students overwhelmingly perceived the POE model as an effective instructional approach that helped them overcome pre-existing misconceptions about the science concepts and made learning more relatable. Several responses indicated that the strategy helped them connect scientific concepts to real-life applications. For instance, a student's response:

> *"I never understood some concepts in science, which made me feel that science was just something people had developed with no proof. But upon using the POE model, I've got to know that science is a daily activity. Especially, I didn't understand why ACs were placed at the top corners of rooms."*

Other responses portrayed how the POE model helped them understand scientific concepts that previously seemed abstract. There were indications that the model helped reshape students' attitudes toward science, making it more approachable and less intimidating. Excerpts revealed:

> *"I was having the mindset that science is a very difficult subject, but through the POE model-based strategy, I have been able to understand science very well and relate it to my daily life."*

Moreover, students recognised that science is a tool for organising knowledge, solving problems, and applying concepts in different contexts. As one indicated:

> *"It enhances my ability to collect more information about science, which helps me to organise and test my ideas, solve problems, and apply what I have learned."*

Therefore, the POE model was perceived as an effective teaching strategy that improved students' learning experiences and shaped their positive perceptions towards the study of science.

The findings of this study collectively demonstrated that the POE model-based strategy had a positive effect on both the conceptual understanding and perceptions of pre-service science teachers. This directly answered the research question by showing that participants did not only achieve measurable conceptual gains ($\langle g \rangle = 0.44$), but also developed positive perceptions towards learning science. The evidence of improved conceptual gains confirmed that interactive, inquiry-based methods such as the POE are effective for the teaching and learning of abstract topics like Heat and Thermodynamics. This is consistent with the work of [29]-

[33], who reported that interactive engagement strategies yield significantly higher learning gains than lecture-based approaches. These findings also strongly align with existing literature that identifies the POE model as an effective constructivist teaching approach for fostering meaningful science learning through the systematic cycle of prediction, observation, and explanation [3]-[7]. Studies by Karamustafaoğlu and Mamlok-Naaman [48] and Rahmawati [49] similarly reported that students exposed to POE-based instruction demonstrated higher academic achievement and more positive attitudes toward science compared to those taught through conventional methods. Additionally, research by Zahra et al [23] all found that the POE strategy enhances conceptual understanding by confronting misconceptions and encouraging learners to reconstruct knowledge through reasoning and reflection.

The findings also validate Piaget's theory of cognitive development [25], particularly the processes of assimilation, accommodation, and equilibration, and Bruner's discovery learning theory Bruner [24], both of which emphasise active engagement and problem-solving. Through the POE cycle, participants integrated new information into existing mental structures, re-evaluated misconceptions, and achieved cognitive balance, leading to mastery in constructing their own knowledge. This theoretical grounding reinforces the robustness of the POE approach as an instructional model for effective science education. Complementary evidence from the qualitative findings revealed enhanced curiosity, improved evidence-based reasoning, and greater ability to relate abstract concepts to concrete experiences. These outcomes support earlier assertions by Tsoumanis et al [9] that instructional strategies that promote engagement, critical thinking, and contextual relevance positively influence pre-service teachers' perceptions of science teaching and learning.

Furthermore, the qualitative findings also highlighted that the POE model fostered engagement and collaborative learning, attributes strongly associated with meaningful learning. These findings were consistent with Nalkiran and Karamustafaoglu [8], Sakyi-Hagan [16], who found out that interactive engagement strategies not only deepen understanding but also improves retention. By promoting peer discussions and linking science concepts to everyday contexts, the model helped students construct knowledge in socially and culturally relevant ways, enabling lifelong learning, which is a key aspect of the constructivist instructional approach.

The study's findings contribute to the growing body of literature supporting the integration of the POE strategy into pre-service teacher education. In the Ghanaian context, where science instruction remains largely teacher-centred [16], [19], this research provides empirical evidence that active learning methods can improve both conceptual understanding and positive perceptions. The novelty of this study lies in its ability to demonstrate, within a Sub-Saharan African pre-service teacher education setting, how the POE strategy bridges theory and practice, promoting inquiry-driven learning aligned with global science education reforms. The findings imply that integrating POE into pre-service science teacher training could equip future teachers with pedagogical competencies for inquiry-based science teaching. Such integration may enhance learners' engagement, conceptual development, and application of scientific ideas, thereby contributing to improved quality of science education at the pre-tertiary level in Ghana and similar educational contexts.

Despite the positive outcomes of the study, it was limited to a single teacher education university and an intact class of 73 pre-service teachers, and these constrain generalisability of the findings. Additionally, the duration of the intervention was twelve weeks; perhaps, a longer exposure might yield more robust evidence of conceptual change. Finally, the study also relied on self-reported perceptions, which could be influenced by social desirability biases.

5. CONCLUSION

This study concludes that the POE model-based strategy enhances pre-service science teachers' conceptual understanding of Heat and Thermodynamics and is positively perceived as an engaging and effective instructional approach. Evidence from both quantitative and qualitative findings indicates that the POE strategy improved conceptual learning, strengthened connections between classroom content and real-life situations, reduced confusion, and increased learners' awareness of the relevance of science. Grounded in Piaget's cognitive development theory and Bruner's discovery learning, the cycle of prediction, observation, and explanation facilitated cognitive restructuring through active engagement, critical thinking, peer collaboration, and contextual application of knowledge. These outcomes underscore the effectiveness of constructivist, student-centred pedagogies over conventional teacher-centred methods. Overall, the findings revealed that the POE model holds strong potential for transforming science teaching and learning in the Ghanaian pre-service teacher education and similar educational contexts. The POE model-based strategy should be integrated into pre-service science teacher education curricula to enhance conceptual understanding and inquiry-based learning skills. Science teacher educators should receive professional development and training on the effective design and implementation of POE model-based instructional approaches. Future studies should involve larger samples and adopt longitudinal designs to examine the sustained impact of the POE strategy on teacher practice and student learning outcomes, as well as explore the integration of POE with digital simulations or blended learning environments to further enhance its instructional effectiveness.

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AUTHOR CONTRIBUTIONS

NASH designed the study, conducted the analysis, collected the data, and wrote the manuscript.

CONFLICTS OF INTEREST

The author(s) declare no conflict of interest.

USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY

The authors declare that no artificial intelligence (AI) tools were used in the generation, analysis, or writing of this manuscript. All aspects of the research, including data collection, interpretation, and manuscript preparation, were carried out entirely by the authors without the assistance of AI-based technologies.

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