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The Effect of Using POE Technique and 3D Solid Models in Eliminating Misconceptions: The Case of Particle Structure of Matter and Density

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Abstract: This study aims to identify sixth-grade students' misconceptions about density and the particulate structure of matter and to evaluate the effectiveness of the POE technic and 3D solid models in addressing these misconceptions. The research was carried out using a sequential explanatory mixed method design. In the study, the Prediction-Observation-Explanation (POE) technic was used. POE technic is an effective teaching method to enable students to understand scientific concepts and correct their misconceptions. The study was conducted with 23 sixth grade students studying in a secondary school in Trabzon, Black Sea Region. The students in the study group participated in the study voluntarily. True-false tests, POE forms and 3D solid models were used as data collection tools. As pre-test and post-test, students were given true-false tests consisting of ten items related to density and particulate structure of matter. POE forms were used to record students' predictions, observations and explanations about the experiments carried out within the scope of the study. In addition, three-dimensional (3D) solid models were included in the application process to visualize density and particulate structure of matter and to enable students to better understand the concepts. The qualitative data collected within the scope of the study were analyzed using descriptive analysis method and quantitative data were analyzed using non-parametric tests. Pre- and post-test results were compared and the changes in students' misconceptions were analyzed. POE forms were evaluated by thematic analysis. The findings revealed that students had various misconceptions about density and particulate structure of matter. As a result of the study, it was determined that POE technic and 3D models helped students to realize and correct their misconceptions about density and particulate structure of matter. In the pre-test, significant misconceptions were identified in density and particulate structure of matter, and these misconceptions were largely corrected with the use of POE technic and 3D solid models. In addition, students reached the correct concepts through experiments and visualization tools, thus deepening their conceptual understanding. In this context, it was concluded that the POE technic is an effective teaching strategy in science education and 3D models play an important role in reinforcing students' conceptual understanding. In future studies, it is recommended to apply similar methods on different student groups and subjects.

Keywords: *Misconceptions, POE Strategy, 3D Solid Models, Science Education.*

1. INTRODUCTION

The primary goal of science education is to foster a deep understanding of fundamental scientific concepts and enable students to apply this knowledge in real-world contexts. However, misconceptions that students frequently encounter in this process can negatively affect the learning process and make the development of scientific thinking skills difficult (Aksüt & Bahar 2017). Misconceptions embed incorrect or incomplete understandings in

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students' cognition, which, if left unaddressed, complicate the acquisition of accurate information in subsequent learning stages (Elmas & Pamuk, 2021). A critical responsibility of educators in the learning process is to identify and rectify students' misconceptions. In this context, in a study conducted by Ecevit and Şimşek (2017), the effects of teachers on science concept teaching and their studies on identifying and eliminating misconceptions were evaluated. The research reveals that students' ability to establish a connection between their old knowledge and new knowledge is possible with meaningful learning. Therefore, the identification and correction of misconceptions is emphasized as a critical part of the teaching process (Ecevit & Şimşek 2017).

Research on students' misconceptions reveals both their origins and impacts in detail. For example, in a study conducted by Husnah, Suhandi and Samsudin (2020), students' misconceptions about the concept of boiling were analyzed and the distribution of these misconceptions in certain percentages was revealed. The study conducted by Çalık and Ayas (2005) analyzed students' misconceptions about chemistry and evaluated the effects of these misconceptions in educational processes. This study emphasizes the importance of teaching methods in determining and eliminating students' misconceptions. Similarly, Ecevit and Şimşek (2017) stated the importance of methods for the determination of these misconceptions in studies on science misconceptions. Research indicates the importance of developing effective strategies to equip educators with the tools to identify and correct misconceptions effectively. Such studies help teachers to determine in which concepts learners have misconceptions and make their teaching processes more effective. In addition, in a study conducted by Bektaş (2015), analyses of pre-service teachers' misconceptions and the sources of these misconceptions provide important contributions to the development of teaching strategies. In this context, increasing teachers’ ability to recognize and correct students’ misconceptions is seen as an important goal in the field of science education (Potvin et al., 2024; Timothy et al., 2023). Improving these skills of teachers can improve the quality of education by increasing students' ability to understand and apply scientific concepts correctly (Soria-Barreto & Muñoz-Rubio, 2023). Identifying and correcting misconceptions is of great importance in science education (Mutmainna et al., 2025; Zhang et al., 2023). This process positively affects the overall success of the education system by contributing to the development of scientific thinking skills of both teachers and students (Rosenbrock, 2023). For this reason, it is thought that teacher education programs should focus more on misconceptions and the findings of research on this subject should be integrated into educational practices (Potvin et al., 2024; Timothy et al., 2023).

Misconceptions are seen as an important problem that causes learners to misunderstand scientific concepts, and these misunderstandings negatively affect their learning processes (Guerra-Reyes et al., 2024). Various factors contributing to the formation of misconceptions in learners have been revealed by different studies in the literature (Chi, 2005; Guerra-Reyes et al., 2024; Novak, 1990; Özdemir & Clark, 2007; Posner et al., 1982; Treagust & Duit, 2009; Vosniadou & Skopeliti, 2014; Wandersee, Mintzes, & Novak, 2001) and are listed below:

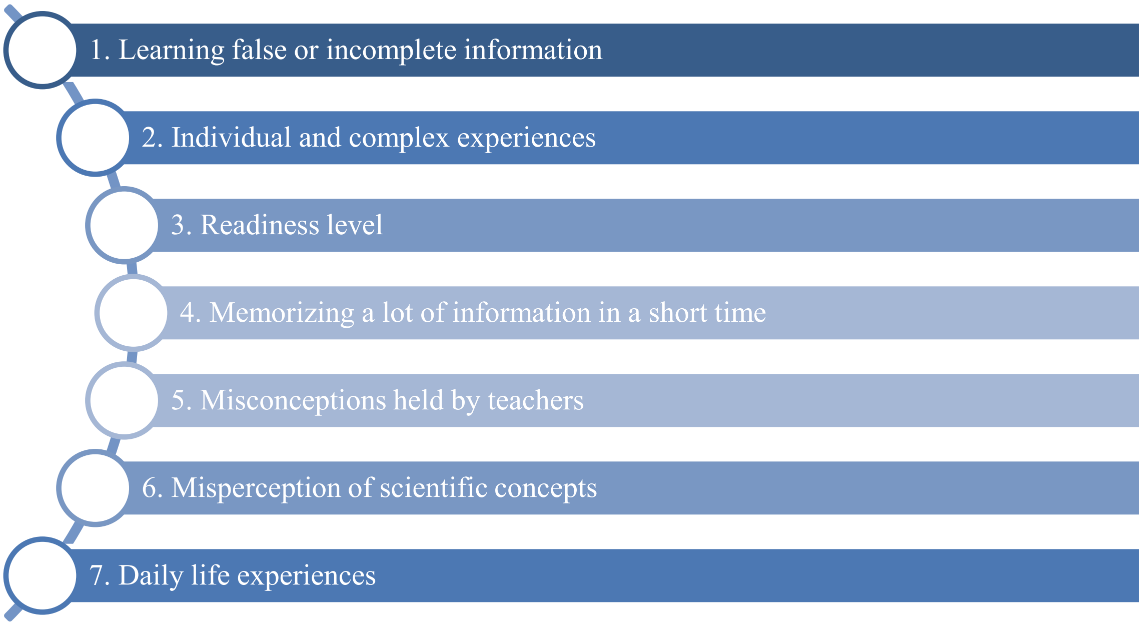

Figure 1. *Factors that Cause Misconceptions to Accur*

Many methods and techniques are used in eliminating misconceptions. One of these methods is inquiry-based teaching. This method provides a better understanding of concepts by encouraging students' active participation (Bostan Sarıoğlan & Abacı, 2017). In addition, the concretization of concepts and the use of visual materials help learners to better grasp abstract concepts (Dinçer, 2022). To eliminate students' misconceptions, it is also recommended to use tools such as concept maps and meaning analysis tables before teaching (Çelikkaya & Kürümlüoğlu, 2023). Such tools help to determine how students understand concepts and in which areas they experience misconceptions. Among effective approaches for addressing misconceptions is the Prediction-Observation-Explanation (POE) technic. This technic provides learners with the opportunity to understand concepts in more depth and supports their learning processes. POE technic stands out as an effective teaching technic especially in science education. This technic aims to develop students' scientific process skills and consists of three basic stages: prediction, observation and explanation. The POE technic initiates with learners predicting the outcome of an event prior to engaging in an experiment or activity. In the second stage, they observe this event and collect the data they obtained. In the last stage, learners are expected to explain the similarities and differences between their predictions and observations (Güleşir et al., 2020; Nalkıran & Karamustafaoğlu, 2020). POE technic is a process that encourages students' active participation and is based on the principle of learning by doing. This process helps learners to think, question and understand scientific concepts better (Harman & Yenikalaycı, 2022; Nalkıran & Karamustafaoğlu, 2020). For example, in a study, the positive effects of the POE technic on the science process skills of pre-service science teachers were observed (Güleşir et al., 2020). In addition, the use of this technique was found to be effective in reducing students' misconceptions (Bolat & Karamustafaoğlu, 2021). POE technique plays an important role in science education by increasing students' active participation, improving their science process skills and reducing misconceptions. Therefore, the integration of POE technique in teaching practices is considered as a critical technique to improve the quality of education (Uriyah, Supardi, & Suryanti, 2023).

POE technique is an effective teaching technique used in science education to develop students' science process skills. In the studies (Kearney, Treagust, Yoe, & Zadnik, 2001; Köse & Uşak, 2006; Liew & Treagust, 1998; White, Gunstone, & Oversby, 1994; White & Gunstone, 2008) which show that this method is an effective learning technique, the gains indicated on Figure 2 were presented:

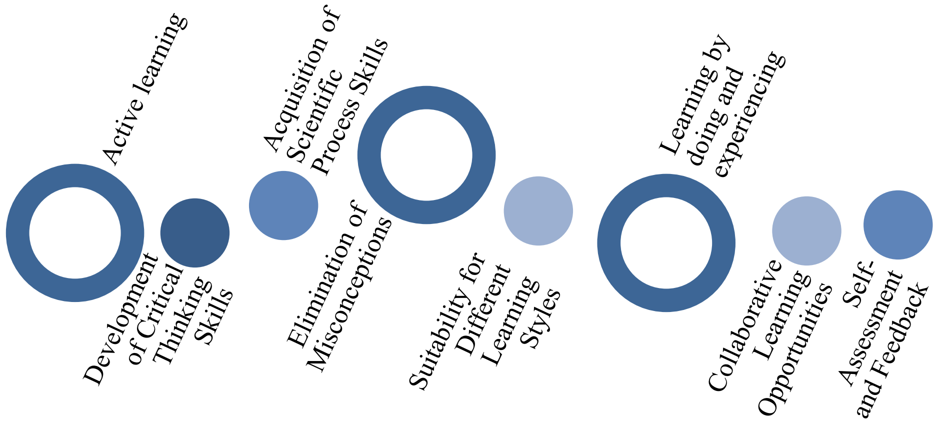

Figure 2. *Advantages of POE Technique compared to Other Methods*

Figure 2 summarizes the advantages of POE technique compared to other teaching methods. The POE technique stands out as an effective technique for eliminating misconceptions in science education. Firstly, POE technique encourages students' active participation and enables them to be more involved in scientific processes. This method improves students' critical thinking and problem-solving skills (Güven & Sülün, 2012). In addition, POE technique helps learners to acquire scientific process skills (Liew & Treagust, 1998) and thus supports the process of correcting misconceptions in science. Another advantage of the POE technique is that it is suitable for different learning styles (Treagust & Duit, 2009). By using this method, learners discover concepts according to their own learning styles and correct misconceptions. The POE technique encourages learning by doing and experiencing (White, Gunstone, Oversby, 1994); this allows learners to understand concepts in a more concrete way. In addition, POE technique helps learners to realize their misconceptions through self-evaluation and feedback processes (Black & Wiliam, 1998) by providing cooperative learning opportunities (Tobin & Tippins, 1996). This comprehensive approach significantly aids students in recognizing and correcting their misconceptions, thereby fostering long-term learning in science education. The effectiveness of the POE technique in eliminating misconceptions in science education reveals the importance of using different strategies together in the learning process. In this context, model and modelling studies are one of the important approaches that enable learners to understand abstract concepts in a more concrete way and develop their scientific thinking skills. Especially in science, modelling contributes to the process of eliminating students' misconceptions.

A model is a representation that represents certain characteristics of a system or process. In science education, models are often used to make complex scientific concepts more understandable. Modelling is the process of creating and using these models. Students learn scientific concepts by experiencing them through modelling (Şahin Çakır & Karagöz, 2021). Modeling in science education serves as a pivotal teaching technique, facilitating students' comprehension of abstract concepts and enhancing their grasp of scientific processes. Studies show that modelling-based learning approach is effective in eliminating students' scientific misconceptions. Modelling develops students' scientific thinking skills and enables them to gain a deeper understanding of how systems work (Taber, 2017). According to research, learners can analyze complex systems and develop critical thinking skills in modelling-based education. Especially in STEAM education, modelling plays an important role in concretizing abstract concepts and correcting misconceptions in courses such as physics, chemistry and biology (Valeeva et.al., 2023). Figure 3 below shows the contributions of using models and modelling in science education:

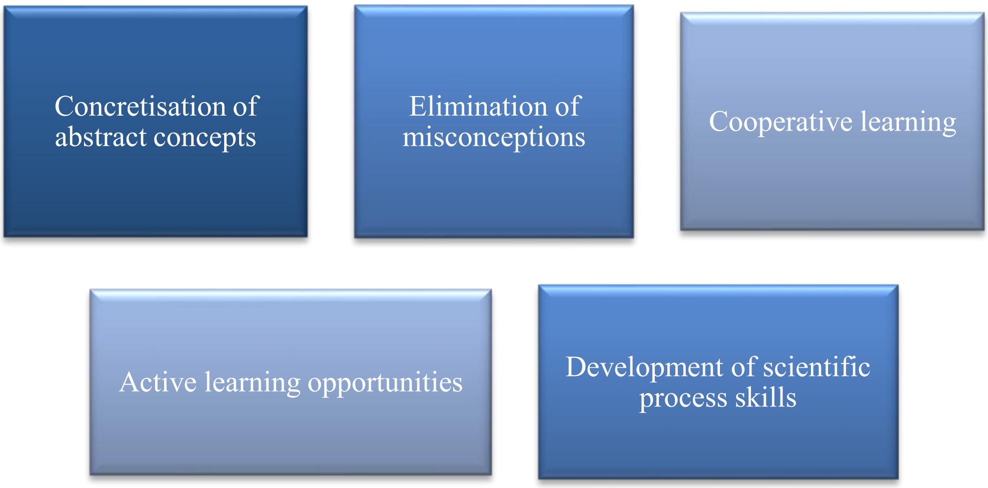

Figure 3. *Contributions of Using Models and Modeling in Science Education*

Modelling-based learning helps learners understand these concepts better by concretizing abstract concepts in science education. For example, concrete examples such as DNA model or solar system model facilitate students' understanding of these concepts (Gülcü & Taşçi, 2020). This approach makes it possible for learners to recognize and correct existing misconceptions. Models provide students with a means to identify and correct their misconceptions, promoting an accurate understanding of scientific concepts (Okumuş & Doymuş, 2018). Learners can experiment, observe and analyze the results using models. This process supports permanent learning (Ayvacı & Bülbül, 2022). In addition, it develops students' scientific process skills such as observing, hypothesizing, experimenting and analyzing results (Şahin Çakır & Karagöz, 2021). Thus, modelling-based learning strengthens students' scientific thinking skills and supports them to solve scientific problems more effectively. Modelling-based learning strengthens students' scientific thinking skills and equips them to develop effective solutions to scientific problems. In this process, students gain knowledge by following certain steps and can transform this knowledge into practical applications. The progress of the students in the modelling process includes the following steps respectively and each step is a preparation for the next one: The process starts with the definition of the problem and continues with the transfer of prior knowledge and the creation of the model. The model is then tested and revised if necessary. With the sharing of the results, the knowledge learnt is related to the real world in the application and extension phase. These stages reinforce the importance of modelling in science education by providing learners with the opportunity for conceptual change and in-depth understanding (Gilbert & Justi, 2016; Schwarz & White, 2005; Windschitl, Thompson & Braaten, 2008).

This process not only encourages students' active participation in science education but also contributes to the development of critical thinking and problem-solving skills. Educators' integration of these steps into their teaching practices helps students to deepen their scientific understanding. In particular, the development of scientific process skills increases the permanence of learning by enabling students to take responsibility for their own learning (Kabaşer & Kapucu, 2023; Kürşad, 2018).

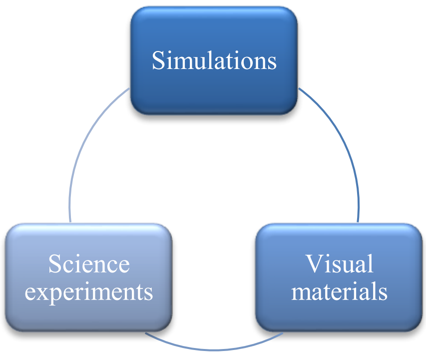

Figure 4. *Model and Modelling Applications*

Figure 4 summarizes the relationship between the three main tools used in science education: science experiments, simulations and visual materials. These tools help learners to gain a deeper understanding of scientific concepts and support the modelling process.

Science experiments enable learners to develop models of the real world based on the observations they make to understand a certain concept. For example, in a chemical reaction experiment, learners can observe and model this reaction (Şahin Çakır & Karagöz, 2021). Simulations, on the other hand, help learners concretize abstract concepts by allowing them to model complex systems and processes with computer-based applications (Ayvacı & Bülbül, 2022). Finally, graphs, diagrams and other visual materials contribute to students' better understanding of concepts in the modelling process. These visual materials reinforce students' learning by integrating them into the process (Elmas & Pamuk, 2021). These three tools come together to provide a holistic learning experience that supports students' exploration and understanding of concepts through modelling.

In science education, models and modelling play a critical role for learners to develop scientific thinking skills and eliminate misconceptions (Gilbert & Justi, 2016). This method, which helps learners to concretize abstract concepts, supports permanent learning by providing active learning opportunities (Clement, 2000). While the modelling process contributes to students' better understanding of scientific processes, it also stands out as an effective tool in providing conceptual change (Windschitl, Thompson, & Braaten, 2008). Effective use of models and modelling strategies by educators' increases success in science education and enables learners to develop scientific thinking skills (Schwarz & White, 2005).

The aim of this study is to determine the misconceptions of 6th grade secondary school students about density and particulate structure of matter and to determine the effect of using POE technique and 3D solid models in eliminating these misconceptions. In this direction, to correct students' conceptual misconceptions, 3D models were integrated into the education process as visualization tools as well as the POE technique. The research aims to evaluate the effects of POE technique and 3D models on the reinforcement of students' conceptual understanding and to develop strategies to support permanent learning in science education.

2. METHODOLOGY

2.1. Research Model

This study adopted a sequential explanatory mixed method design, which consists of two consecutive phases: quantitative followed by qualitative. In the first phase, a quasi-experimental one-group pre-test–post-test design was employed to quantitatively evaluate the effect of the intervention. Initially, a pre-test was administered to the participants to assess their prior knowledge and measure the baseline condition of the dependent variables. Following this, the intervention – which involved the use of the POE technique and 3D solid models – was implemented. After the intervention, a post-test was conducted to measure changes and determine the effect of the instructional method.

In the second phase, qualitative data were collected through semi-structured interviews to explain and interpret the quantitative findings in greater depth. The qualitative insights helped to explore students' learning experiences, attitudes, and conceptual understanding during and after the intervention. This integration of quantitative and qualitative data allows for a more comprehensive interpretation of the research outcomes (Creswell & Plano Clark, 2018)

2.2.Participants

The study involved 23 sixth-grade students enrolled in a secondary school located in Trabzon, in the Black Sea Region. The study group consisted of students who attended the science course and had prior knowledge about density and particulate structure of matter. Participation in the study was voluntary, with students engaging in a range of activities related to the study topics.

2.3. Data Collection Tools

Data collection tools were specifically selected to identify learners' misconceptions and assess the effectiveness of the POE technique and 3D models in addressing these misconceptions. The data collection tools are as follows:

2.3.1. True-False Tests: A ten-item true-false test was administered to identify students' misconceptions regarding density and the particulate structure of matter (Appendix-1). These tests were used to evaluate the misconceptions of the students in both subjects at the pre-test and post-test stages.

2.3.2. POE Forms: POE forms were employed to capture students' reflections during the prediction, observation, and explanation phases of the experiments (Appendix-2). These forms include students' prior knowledge about a particular event or concept, their observations of the experiment and their explanations of the results. In this way, how the students tried to eliminate their misconceptions and the changes in the learning process were monitored.

2.3.3. 3D Solid Models: 3D solid models were used to help students concretize the concepts in density and particulate structure of matter. These models were applied as visualization tools to help students better understand abstract concepts and eliminate misconceptions.

All data collection tools used in this study were developed by the researchers to identify students' misconceptions and assess the impact of the POE technique and 3D models. The true-false test was designed specifically for this study based on common misconceptions reported in the literature regarding density and the particulate structure of matter. The POE forms and 3D solid models were developed by the researchers specifically for this study to match the learning objectives and experimental design. Since no pilot study was conducted, expert opinions were obtained to ensure content validity, and necessary revisions were made accordingly. The KR-20 formula is only valid for true-false items and is applied to tests that contain only two-point values (e.g., 0 and 1). In this study, since the items included a 0-1-2 three-point scoring system (partially correct = 1 point), the Cronbach Alpha value was calculated. This value was calculated as 0.72 for the "Particle Structure" test and 0.69 for the "Density" test.

2.4. Data Analysis

This study employed both qualitative and quantitative analysis methods to evaluate the impact of the POE technique and 3D solid models in mitigating students' misconceptions about density and the particulate structure of matter. Since the data did not follow a normal distribution, the Wilcoxon Signed Ranks Test was used to assess the difference between students' pre-test and post-test results. This non-parametric test was used to determine whether the difference between dependent groups was significant. Student responses on the true-false tests were scored as follows: 2 points for a 'true' response, 1 point for a 'partially true' response, and 0 points for a 'false' response. Qualitative data were analyzed by descriptive analysis method. The prediction, observation and explanation sections in the POE forms were analyzed by thematic analysis to understand the conceptual changes of the students and the developments in their learning processes. While presenting student responses, coding as ‘S1, S2, ..., S23’ was used. Student expressions were indicated as ‘E’ (Expression) on the graphs.

2.5. Implementation

This study was designed to understand and eliminate students' misconceptions about density and particulate structure of matter, and the implementation process started with the application of pre-tests. The process consists of the following steps:

2.5.1. Pre-Test Implementation: Firstly, a pretest was conducted to determine the students' knowledge levels and misconceptions about density and particulate structure of matter. In this test, true and false statements were included to determine students' misconceptions about the subject.

2.5.2. POE Technique and Teaching with 3D Models: Students were involved in the learning process by experimenting with the POE technique within the scope of the ‘Density’ subject. First, basic information about density was conveyed and the conceptual basis was established. Students were asked to predict whether a certain object would float in water and these predictions were noted. After the predictions, two applications were made with experimental materials and students were allowed to make observations (Figure 5). After the observation of the experiment, the students explained the process by comparing their predictions with the observation results.

To help students understand the concept of density more concretely, 3D solid models were used to create visualizations of density. These models allowed the concepts to become more understandable and students to realize their misconceptions.

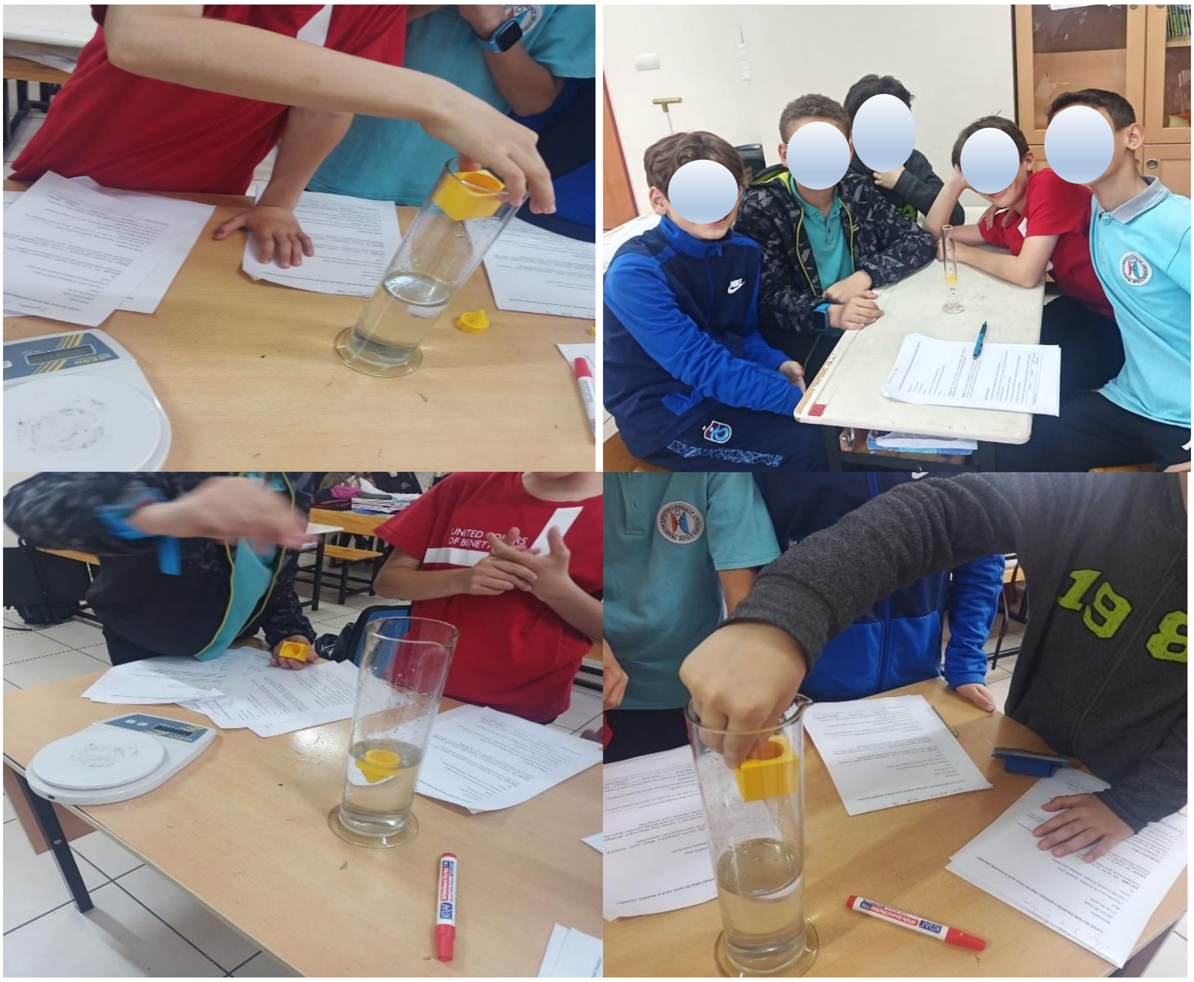

Figure 5. *Visuals of Students Performing the Density Experiment*

After the first subject was covered, a two-week period was left for the students to internalize and reflect on what they had learnt. In this process, students discussed their observation results and their thoughts about the concepts.

In the second part, the subject of 'Particle Structure of Matter' was focused. Experiments and 3D models were prepared and presented to the students to observe the concepts in this subject. Firstly, students were asked to make predictions about the particulate structure of matter, and then particle structures were visually analyzed using 3D models (Figure 6). In this process, students first examined different states of matter through water, ice and vapor samples (first melting ice and then converting it from liquid to water vapor) and observed the differences in the structure of each of them. After the observations, students evaluated their misconceptions by explaining the similarities and differences between their predictions and actual observations.

In the last stage, the students' answers given in the pre-test and the post-test results were compared and the changes in misconceptions were evaluated.

Figure 6. *Student Visuals Examining 3D Models of the Particulate Structure of Matter*

3. FINDINGS

This section presents the findings from the implementations related to the topics of 'Particle Structure of Matter' and 'Density'.

3.1. Findings Related to the "Particle Structure of Matter" Subject

The findings obtained from the student responses to the pre-test and post-test on the particulate structure of matter are given in Figure 7.

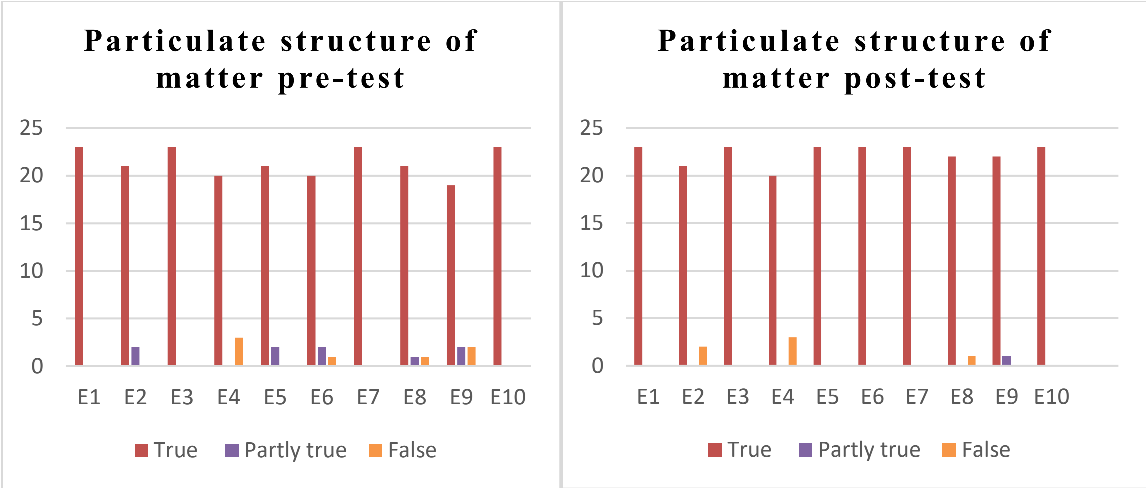

Figure 7. *Numerical Comparison of Pre-Test and Post-Test Data (Particulate Structure of Matter)*

Upon analysis of Figure 7, it becomes evident that there is a notable enhancement in the pre-test and post-test outcomes pertaining to the subject of "Particle Structure of Matter." In the pre-test, while most students provided correct responses, some statements (e.g., E4 and E8) exhibited evidence of misconceptions, and the proportion of incorrect responses remained relatively high. In contrast, the post-test results demonstrated a notable increase in the proportion of correct responses and a substantial reduction in the proportion of incorrect responses.

The results of the pre-test true-false assessment for the particulate structure of matter, along with sample student responses, are outlined below:

E1: Matter is not holistic; it has particulate structure.
(T) S1: Yes, matter has particles.
(T) S12: Matter consists of particles.
All the students correctly stated that matter has a particulate structure in the pretest. No student had a wrong perception about this statement.
E2: The particles of a solid only vibrate.
(T) S9: Yes, they only vibrate.
(PT) S2: No, they vibrate and translate.
Most of the students knew that solids can only vibrate in the pretest. One student (S2) stated that solids can also perform translational motion.
E3: The most regular state of matter is solid.
(T) S12: Correct.
(T) S18: Yes, it is.

In the pre-test, there were no students who gave misconceived answers to this statement. Students accept that the solid state of matter is the most regular state.

E4: The dissolution of sugar in water shows that sugar is composed of particles.
(T) S5: Yes, it shows that it consists of particles.
(F) S11: I think it is wrong.

In addition to the students who stated that this statement was correct in the pre-test, some students (f= 5), such as the student coded S11, did not establish a relationship between granular structure and dissolution.

E5: The dispersion of perfume odor in the room is realized by the vibrational motion of gas particles.
(T) S10: It is dispersed in the room because of translational motion.
(PT) S3: Gases can move differently, and vibration movement can be included in this.

In the pre-test, there is a significant misconception among the students regarding this statement. Some of them (f=2), such as the student coded S8, think that vibrational motion is effective in the spread of odor.

E6: The particles of a substance that changes from liquid to solid accelerate.
(T) S5: It slows down.
(PT) S17: It can make some movements.
(F) S8: There is no change.

In the pre-test, most of the students (f=20) stated that the particle velocities slow down because of the transition of substances from liquid to solid state. While one student (S8) gave a wrong answer, two students (S17, S21) gave partially correct answers.

E7: Compressing a sponge shows that all solids can be compressed.
(T) S1: Not all solids can be compressed.
(T) S7: We can't compress every solid

In the pre-test, all students stated that not all solids can be compressed.

E8: The fact that iodine disperses in alcohol and its color spreads everywhere shows that iodine is granular.
(T) S23: Correct, substances are composed of particles.
(PT) S21: The particles of iodine can be different.
(F) S1: This is a wrong statement.

In the pre-test, there were some students (f=3) who responded to this statement with misconceptions. Some students like S1 think that the situation in the statement is not related to the granular structure.

E9: The particles of a substance that changes state also change.
(T) S12: There may be no change.
(PT) S15: The movement of particles of a substance that changes state changes.
(F) S6: There are particles least in gases and most in solids.

In the pre-test, some students (such as S6 and S19) thought that the structure of the particles and the number of particles changed after the change of state.

E10: The space between gas particles is almost non-existent.
(T) S1: No, it is too much.
(T) S7: The space between gas particles is too much.

In the pre-test, all the students stated that the space between gas particles is too much contrary to what is stated in the statement. This shows that students do not have misconceptions about this statement.

The data obtained from the POE technique and 3D model supported teaching process for teaching “Ice-Water-Water vapor” states with the students after the pretest application are presented below.

3.1.1. Student Responses to the “Prediction” Part of the POE Technique

Table 1 shows the students' responses at the estimation stage regarding the reason why ice, water and water vapor exist in different physical states.

Table 1. *Student Responses to the Prediction Stage*

Prediction Phase: Ice, water and water vapor are different physical states of the same substance. What do you think is the reason why they are composed of the same particles but in different physical states?	Students' Responses
	S1: The temperature between them is different.
	S2: Exposure to heat.
	S3: It is when matter takes heat or gives heat.
	S4: Heat difference between them.
	S6: The particles of gases can stay in the air.
	S11: Being in different states.
	S12: They all have different particles. More in solids.
	S14: Due to heat exchange.
	S17: Raw materials are the same.
	S18: Physical states.
	S20: Due to translational and rotational movements.
	S21: Because of its particles.

When the student responses are analyzed according to Table 1, it is seen that some students associated the differences between the states of matter with heat and temperature. For example, responses such as *T1: "The temperature between them is different", T2: "They are exposed to heat", T3: "It is when matter takes heat or gives heat", T4: "The heat difference between them"* and *T14: "Because of heat exchange"* show that students have a general knowledge on this subject but they cannot clearly distinguish the concepts of heat and temperature. In addition, some students tried to make explanations using the particle model, but misconceptions were also observed here. *S6: "Gases have fewer particles and can stay in the air more", S12: "They all have different particles. Solids have more particles", S20: "Because of their translational and rotational movements"* and *S21: "Because of their particles"* reveal that the particle model was taught but the distinction between particle structure and behavior was not fully understood by the students. However, some students addressed the question in a more general way and their answers were more superficial. Answers such as *S17: "Their raw materials are the same"* and *S18: "Their physical states"* show that students distinguished the existence of different physical states but could not explain the reasons clearly.

After the prediction phase, the researcher put some ice into the beaker and started to melt it with the help of a heater and asked the students to observe this. The researcher asked the students to tell their observations for the ice that was converted into water vapor by continuing the heating process. In addition, the 3D models produced for the internal states of matter (solid, liquid, gas) were examined by the students. The responses given in this direction are shown in Table 2 below.

3.1.2. Student Responses to the "Observation" Part of the POE Technique

Table 2 shows the answers given by the students in the observation phase about which changes occur in the process of conversion of ice to water vapor.

Table 2. *Student Responses related to the Observation Phase*

Observation Phase: What changes do you think have occurred in the process of turning ice into water vapor?	Students' Responses
	S1: Melting of water.
	S2: The same water froze and melted.
	S3: We made the same things, substances
	S4: We did not use different substances.
	S5: We froze and boiled using the same water.
	S6: I don't know.
	S7: They went through different processes.
	S8: We cooled in one and boiled in the other.
	S9: The substances are still the same.
	S10: We did not change the water.
	S11: The process changed; the substance did not change.
	S12: The process changed; the substance did not change.
	S13: We used tap water in all of them.
	S14: Boiling and freezing was the same water.
	Ö15: Normally water is liquid when frozen, solid when frozen and gaseous when boiled.
	S16: The substances are the same.
	S17: Different ways were tried.
	S18: There was only a state change.
	S19: It changed state, but it is still the same water.
	S20: We did not change the water, it changed state.
	S21: We put the same substance in different states.
	S22: The substance did not change, it changed state.
	S23: It only changed state.

According to Table 2, when the student responses are analyzed, it is seen that students had different observations on the changes that occur in the process of ice to water vapor. In general, students understood the concept of physical change of state of matter, but some of them did not focus on deeper concepts such as thermal processes or particle motions in the process. Responses such *as S1: "Melting of water", S2: "The same water froze and melted", S8: "We cooled in one and boiled in the other"* show that students were aware of physical state changes. Likewise, many students stated that the substance itself did not change and emphasized that only the state change occurred. Answers such *as S11: "The process changed, the substance did not change", S18: "It was just a change of state", S19: "It changed state, the water is still the same water"* and S22: *"The substance did not change, there was a change of state"* indicate that the students comprehended the process of state change correctly. However, answers such as *S6: "I don't know"* indicate that some students could not fully understand or observe the process.

3.1.3. Student Responses to the "Explanation" Part of the POE Technique

After the observation phase of the POE technique, students were asked to explain the differences between their predictions and observations. Student responses regarding the explanation phase are shown in Table 3.

Table 3. *Student Responses related to the Explanation Phase*

Explanation phase: What are the differences between your predictions and observations of the experiment?	Students' Responses
	S1: The state changed, and the substance did not change. S2: The state change took place. S3: The same substance changed state. S4: The substance changed state, but it is still water. S5: There was a change of state. S6: The substance was the same, its structure changed. S7: There was a change of state. S8: Matter changed state and entered different states. S9: The substance was the same, it changed state. S10: It changed state. S11: It changed state with different processes. S12: There was a state change. S13: Water entered a state change. S14: Water changed state. S15: There was a state change. S16: It entered different states. S17: The substance changed state with different applications. S18: I was not wrong. S19: As I said, there was a state change. S20: Matter changed into solid, liquid and gas states. S21: There was a state change. S22: I said it changed state, but the matter did not change. S23: There was a change of state.

Table 3 reflects the students' explanations for understanding the differences between their predictions and observations because of the experiment. In general, most of the students correctly understood that matter changes physical state and the structure of matter does not change in this process. For example, responses such *as S1: "It changed state but the substance did not change", S2: "The change of state took place", S3: "The same substance changed state", S4: "The substance changed state but it is still water"* show that the students clearly understood that the structure of the substance remained the same at the end of the experiment and only changed state. In addition, some students associated the state change with various applications or processes, for *example S11: "It changed state with different processes"* and *S17: "Matter changed state with different applications"*, which shows that the students considered the processes in the experiment and understood that these processes led to the state change. In addition, responses such as *S18: "I was not mistaken"* and *S19: "The state change happened as I said"* show that the students thought that their predictions were consistent with the experiment.

At the end of the teaching process on the particulate structure of matter using POE technique and 3D models together, the students were asked about the effects of using 3D models with the experiment. Most of the students realized that despite the differences between the states of matter, the number of particles remained constant and only the movements of the particles changed. For example, *S3: "They all have the same number of particles", S5: "The number of particles turned out to be the same", S9: "Solids, liquids and gases have the same number of particles", S20: "Although their movements are different, they are the same inside"*. However, some students stated that they thought that the number of particles was different before the experiment. Answers such *as S6: "I knew there were more particles in solids", S3: "I knew there were different numbers of particles in all of them", S16: "I knew there were more particles in solids and least in gases. It was equal"* show that students realized that there were differences between their prior knowledge and the results of the experiment and that these differences needed to be corrected. In addition, some students emphasized that particle motions were different, but the number of particles remained the same. Statements such as *S12: "I realized that the differences between the particles are only the motions", S15: "The same and equal number of particles have different motions", S21: "The particles only move away from each other"* show that students understood this important scientific concept.

The findings of the post-test application of the true-false test prepared for the particulate structure of matter and sample student responses are as follows:

E1: Matter is not holistic; it has particulate structure.
(T) S5: Yes, matter has particles.
(T) S18: Matter consists of particles.

All students correctly stated that matter has a particulate structure in the post-test. There were no students with a wrong perception about this statement.

E2: Particles of solid matter only vibrate.
(T) S9: Yes, only vibrational motion.
(T) S7: Solids can only vibrate. They cannot make rotational and translational motion.
All the students correctly stated that solids can only vibrate in the post-test. No student had a wrong perception about this statement.
E3: The most regular state of matter is solid.
(T) S17: The most regular state belongs to solid.
(T) T22: Yes, it is solid.

All the students correctly stated that the most regular state of matter is solid in the post-test. There were no students with a wrong perception about this statement.

E4: The dissolution of sugar in water shows that sugar is composed of particles.
(T) S5: Yes, it shows that it consists of particles.
(F) S6: No, this is not obvious.

A few of the students (f=6) gave misconceived answers, thinking that the dissolution of sugar in water was not due to its granular structure.

E5: The distribution of perfume odor in the room is realized by the vibrational movement of gas particles.
(T) S10: It disperses in the room because of translational motion.
(T) S12: It can disperse in the room by translational motion. Gases also vibrate, but they disperse in the room by translational motion.

All the students correctly stated in the post-test that the dispersion of perfume odor in the room is the result of the translational motion of gas particles. Any students had a wrong perception about this statement.

E6: The particles of a substance that changes from liquid to solid accelerate.
(T) S5: They slow down.
(T) S17: There is a slowdown in their movements.

In the post-test, all the students correctly stated that there is a slowdown in the particles because of the transition of matter from liquid to solid state. No student had a wrong perception about this statement.

E7: Compressing a sponge shows that all solids can be compressed.
(T) S21: Solids cannot be compressed.
(T) S19: Not all solids can be compressed.

In the post-test, all the students correctly stated that the compressibility of the sponge means that not all solids are compressible. No student had a wrong perception about this statement.

E8: The fact that iodine disperses in alcohol and its color spreads everywhere shows that iodine is granular.
(T) S11: Substances consist of particles.
(T) S13: It can disperse thanks to particles.
(F) S20: It is not only particles.

Only the student coded S20 responded to this statement with a misconception. The other students stated that the dispersion of iodine in alcohol was due to the granular structure of iodine.

E9: The particles of a substance that changes state also change.
(T) S12: Particles do not change.
(PT) S18: While changing state, some of them may change.

While almost all the students responded correctly to this statement, the student coded S18 remained undecided and gave a partially correct answer.

E10: There is almost no space between gas particles.
(T) S10: There is a lot of space in gases.
(T) S7: There is a lot of space between gas particles.

All the students gave the correct answer in the post-test by stating that the distance between gas particles is quite large contrary to the statement.

3.2. Findings from the True-False Test on the Particle Structure of Matter Pre and Post Application

To evaluate the effect of the instructional intervention on students' misconceptions about the particulate structure of matter, pretest and posttest scores were compared using Wilcoxon signed-rank test. It was determined by Shapiro-Wilk test ($p < 0.05$) that the data were not normally distributed. Therefore, the nonparametric Wilcoxon test was applied. The findings obtained for the Wilcoxon test are shown in Table 4.

Table 4. *Particle Structure of Matter True-False Test Wilcoxon Signed Ranks Test Result*

Pretest-Posttest	n	Mean Rank	Sum of Ranks	z	p
Negative Ranks	2	3.25	6.50	2.148	0.032
Positive Ranks	8	6.06	48.50		
Ties	4	-	-		

According to Table 4, there was a significant difference between the pretest and posttest in favor of the posttest ($z=2.148$; $p<.05$).

3.3. Findings Related to the “Density” Subject

The findings obtained from the student responses to the pre-test and post-test about density are given in Figure 8.

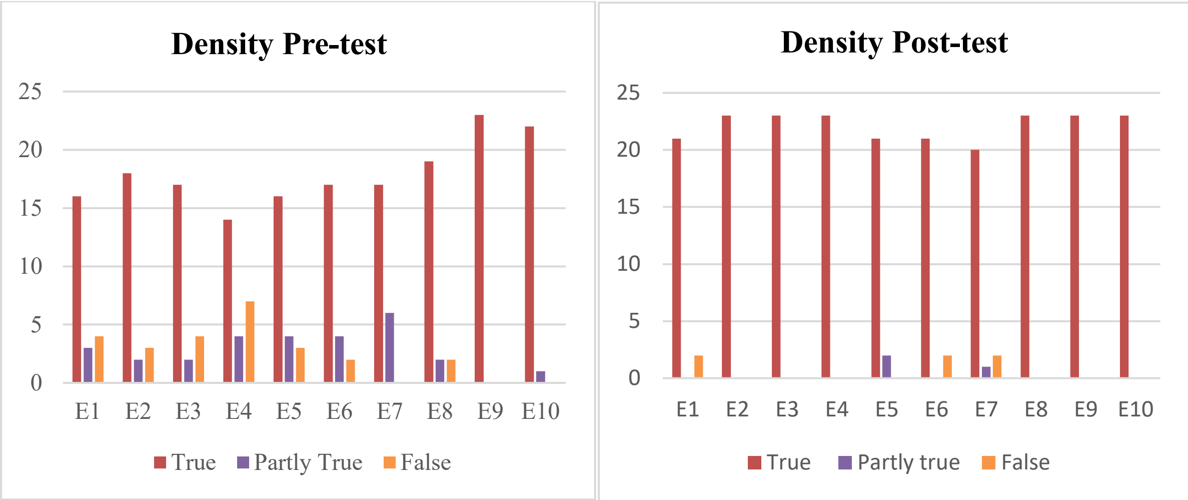

Figure 8. *Numerical Comparison of Pre-Test and Post-Test Data (density)*

Figure 8 shows the correct, partially correct and incorrect answers of the students about “Density”. When the pre-test results are analyzed, it is seen that most of the students have correct knowledge about the concept of density. However, in some questions (especially E1, E3, E4 and E7), students gave incorrect and partially correct answers. In the post-test, it was observed that the rate of correct answers generally increased. Especially in questions E4 and E6, it is noteworthy that most of the students corrected their previous incorrect or partially correct answers and reached the correct answer. While a significant decrease was observed in the number of incorrect answers, partially correct answers almost completely disappeared in the post-test.

The findings of the pretest application of the true-false test prepared for the density topic and sample student responses are as follows:

E1: The amount of matter per unit volume is called density.
(T) S14: Density is the volume divided by mass.
(PT) S1: It can also be related to mass.
(F) S16: It is called mass.

Most of the students correctly defined density and knew that mass must be divided by volume. A few students (f=4) confused the concept by expressing density only as “mass”.

E2: To calculate density, mass must be divided by volume.
(T) S22: Mass should be divided by volume.
(PT) S7: Volume should be divided by mass.
(F) S10: It must be multiplied.

Most students (f=18) knew that density is calculated by dividing mass by volume. However, some students (f=2) had partially correct knowledge and did not fully understand the relationship between volume and mass. The students who gave incorrect answers (f=3) thought that mass and volume should be multiplied. Graph 2 shows that these incorrect answers decreased in the post-test.

E3: The density of ice is lower than the density of water in liquid form.
(T) S18: The density of ice is lower than that of water.
(PT) S6: Density does not only depend on the change of state.
(F) S12: Ice is heavier than water.

Although most of the students (f=17) stated that the density of ice is lower than water, some students (f=4) misunderstood this statement and thought that ice is denser than water.

E4: When air is pressed into a soccer ball, the density of air in the ball increases.
(T) S4: When pressing, pressure is applied and the density increases.
(PT) S5: Because we press on it.
(F) S8: It stays the same.

Some of the students (f=14) correctly understood that the density in the ball increases as the air is pressed. However, some of them (f=6) gave a misconceived response by thinking that the air density in the ball did not change.

E5: We can use a ruler to calculate the volume of any stone.
(T) S23: Yes, we can use an overflow door.
(PT) S1: No, we should use a trap door.
(F) S15: A volumetric cylinder cannot measure everything.

The correct answers to this statement show that most of the students (f=16) knew the appropriate tools for measuring volume, such as a volumetric cylinder instead of a ruler. However, a few students (f=4) made partially correct or incorrect evaluations (f=3) in their answers, thinking that a beaker is necessary or that a volumetric cylinder cannot measure everything.

E6: The density of water increases with the dissolution of salt in water.
(T) S17: Yes, it increases.
(PT) S10: No, the density of water decreases.
(F) S13: Density has nothing to do with the dissolution of salt.

Most students (f=17) correctly knew that the density of water increases when salt is added to water. However, some students (f=4) gave partially correct or incorrect answers (f=2), thinking that the density would decrease or that the dissolution of salt was not related to density.

E7: An increase in mass or volume does not change density.
(T) S1: Volume has nothing to do with density.
(PT) S17: It is not the same, the smaller volume affects the density more.

The correct answers of the students (f=17) for this statement show that they comprehended the relationship between density, volume and mass correctly to a great extent. However, some students (f=6) thought that a smaller volume would affect the density more and gave incorrect answers. Graph 2 shows that this misconception decreased in the post-test.

E8: The density of the wool pressed into the pillow increases.
(T) S1: Yes, because it is compressed.
(PT) S19: There is a change in the pillow.
(F) S9: Wool cannot be compressed because it is a solid substance.

Most of the students (f=19) correctly stated that the density of compressed wool would increase. However, a few students (f=2) gave incorrect answers thinking that wool cannot be compressed. Two students (S11, S19) stated that a change would occur but could not associate this with density.

E9: Liquid substances can be compressed to increase their density.
(T) S2: No, liquids are considered incompressible.
(T) S4: Liquids cannot be compressed.

All students correctly stated that the density of liquids cannot be increased by compressing them. There is no misconception about this statement.

E10: The decrease in the density of water when it freezes has more negative effects on the life of aquatic organisms.
(T) S1: It affects solidity, not density.
(PT) S19: The decrease in the density of water when it freezes has no effect on the life of living things.

Almost all the students (f=22) correctly understood the effect of the decrease in density when water freezes on living life. However, one student (S19) thought that the decrease in density was not important or misinterpreted the effects.

After the pre-test application, the first experiment designed for teaching the concept of "Density" was applied by the students in groups (five groups) based on the POE technique and the process was supported with 3D models. The data obtained from the 3D model supported teaching process are presented below.

3.3.1. Student Responses to the "Prediction" Part of the POE Technique

Table 5 shows the students' predictions about the volume relationship between a 25 ml volumetric cylinder and a 1 cm^3 cube and their short explanations for these predictions.

Table 5. *Student Responses to the Prediction Stage*

Prediction Phase: Compare the 25 ml volumetric cylinder and the cubes and estimate how many ml correspond to 1 cm^3 cube. Briefly explain your estimate.	Students' Responses
	Group 1: A 1 cm^3 cube will displace 1 ml of water. Group 2: The volume of the cube can be 1 ml because it has a small volume. Group 3: The volume of 1 cm^3 seems to be equal to 1 ml of water. Group 4: We think that a 1 cm^3 cube will displace 1 ml of water. Group 5: Our guess is 1 ml, because the volume of the cube is small.

According to Table 5, all groups established a correct relationship between the volume of the cube and the displacement volume of water and concluded that a volume of 1 cm^3 corresponds to 1 ml of water. This shows a correct understanding of basic geometry and fluid displacement principles. Although most of the students based their predictions on an accurate observation, some groups preferred to make visual predictions instead of more mathematical explanations. After the estimation phase, the researcher asked the students to calculate the volume using the known dimensions of the cubes. In this direction, the findings obtained for the two-stage observation are shown in Table 6 and Table 7 below.

3.3.2. Student Responses related to the "Observation" Part of the POE Technique

Table 6 presents the responses of student groups during the first observation stage, where they were asked to calculate the volume of a cube using its known dimensions.

Table 6. *Student Responses related to the First Observation Phase*

Observation Stage-1: Calculate the volume using known dimensions ($V = l \times w \times h$).	Students' Responses
	Group 1: We measured the volume of the cube and calculated it as 1 cm^3. Group 2: Length, width and height measurements showed a volume of 1 cm^3. Group 3: The volume was 1 cm^3, the measurements were verified. Group 4: We calculated the volume of the cube with the formula, the result was 1 cm^3. Group 5: The result was 1 cm^3, we calculated the volume of each cube.

The volume calculations made by five different groups in the observation phase show that the students followed the instructions correctly and used the formula (V = l × w × h) correctly. All groups calculated the volume by measuring the length, width and height of the cube and found the volume of each cube to be 1 cm^3 (Table 6).

Table 7. *Student Responses related to the Second Observation Phase*

Observation Phase-2: Measure the volume of cubes in a volumetric cylinder using the displacement method.	Students' Responses
	Group 1: When the cubes were added to the water, each displaced 1 ml of water. Group 2: The water level in the volumetric cylinder increased by 1 ml. Group 3: When the cube was placed in the water, the water level increased by 1 ml. Group 4: Each cube displaced 1 ml of water in the cylinder. Group 5: When the cube was added, the volume increased by 1 ml, the result we expected.

In the second observation phase, all five groups achieved similar results by measuring cube volume using the displacement method. The students observed that the water level in the volumetric cylinder increased by 1 ml when each cube was added to the water. This result shows that the displacement method of volume measurement was successful and that the students understood this concept correctly. The fact that the students realized that a 1 cm^3 solid object displaced 1 ml of water by correctly applying the volume measurement with the displacement method reveals that both their predictions were confirmed and that they internalized the concept.

3.3.3. Student Responses to the "Explanation" Part of the POE Technique

After the observation phase of the POE technique, students were asked to explain the differences between their predictions and observations. Student responses related to the explanation phase are shown in Table 8.

Table 8. *Student Responses related to the Explanation Phase*

Explanation Phase: Compare the volumes you found in the previous step. What does the fact that one of the cubes floats in the water and the other sinks to the bottom show?	Students' Responses
	Group 1: Same volume with both methods: 1 cm^3. Group 2: The volume of the cubes was 1 cm^3 in both tables. Group 3: One of the cubes floated while the other sank; this is due to the difference in density. Group 4: Floating and sinking are related to the density of substances. The floating cube is less dense, the sinking cube is denser. Group 5: Cubes floating or sinking is related to the density of matter. The cube that stays on the surface is less dense.

At the explanation stage, the responses of five groups of students revealed their level of knowledge in understanding both the volume measurement methods and the density differences of substances. All groups confirmed that the volume of the cubes was the same (1 cm^3) with both methods. This shows that the volume calculations made during the observation phases were consistent and that the students applied both methods correctly. In addition, the situation in which one of the cubes floated and the other sank was explained by the students in terms of the density of the substances. Students correctly stated that the floating cube was less dense, and the sinking cube was denser than water. This shows that the students associated not only volume but also density with the experiment and understood that density is a determining factor in the floating-sinking phenomenon.

The results of the post-test true-false assessment for the topic of density, along with representative student responses, are provided below:

E1: The amount of matter per unit volume is called density.
(T) S12: A correct statement
(T) S23: It is the relationship of objects with weight.

Most of the students (f=22) were able to define density as the amount of matter per unit volume, while some students (f=2) gave incorrect answers.

E2: To calculate density, mass must be divided by volume.
(T) S3: It is mass divided by volume.
(T) S10: A correct statement

All the students knew correctly that mass should be divided by volume in the calculation of density in the post-test and did not give any misconceived answer.

E3: The density of ice is lower than the density of liquid water.
(T) S1: The density of water is higher.
(T) S16: Water is dense.

In the post-test, all the students knew correctly that the density of the solid state of water is lower than the density of the liquid state and did not give any misconceived answer.

E4: When air is pressed into a soccer ball, the density of air in the ball increases.
(T) S5: Pressure is applied, and it compresses.
(T) S8: It increases because it is compressed.

In the post-test, all the students stated that the density in the soccer ball would gradually increase with the addition of air in the ball and did not give any misconceived response.

E5: We can use a ruler to calculate the volume of any stone.
(T) S13: We should use an overflow container.
(PT) S15: We should use different tools.

Most of the students (f=22) did not give any misconceived answer, stating that a beaker would be used to calculate the volume of a stone that does not have a regular geometric shape. However, one student (S15) stated that the volume of the stone can be measured by using different tools.

E6: The density of water increases with the dissolution of salt in water.
(T) S20: Yes, the density increases.
(F) S10: No, the density of water decreases.

Most of the students (f=21) stated that the density increased with the dissolution of salt in water in the post-test. Two students (S10, S13) thought that the increase in density would not be affected by the dissolution of salt and might even decrease.

E7: An increase in mass or volume does not change the density.
(T) S7: It does, if the mass increases and the volume does not change, the density increases.
(PT) S16: There may be cases where it changes.
(F) S9: Density does not change.

Most of the students (f=20) stated that the increase in mass or volume can change the density in the post-test. While two students (S1, S9) stated that density would not increase, one student (S16) thought that there might be situations where density might change.

E8: The density of the wool pressed into the pillow increases.
(T) S22: Yes, because it is compressed.
(T) S17: The density increases because it is compressed.

All the students stated that the density would increase with the increase in the amount of wool in the pillow in the post-test and did not express any misconception.

E9: The density of liquid substances can be increased by compressing them.
(T) S18: No, liquids cannot be compressed.
(T) S14: Liquids cannot be compressed.

All the students gave correct answers in the post-test by stating that the density of liquid substances cannot be increased by compressing them.

E10: The decrease in the density of water when it freezes has more negative effects on the life of aquatic organisms.
(T) S19: There is no harm to the living things under the water.
(T) S14: The upper part of the water freezes and no living thing can live in the upper part. Living things at the bottom can continue to live.

In the post-test, all the students correctly stated that the decrease in the density of water when it starts to freeze due to its special condition does not affect living life negatively.

3.4. Findings from the True-False Test on the Density Pre and Post Application

To assess the impact of the instructional intervention on students' misconceptions about density, pre-test and post-test scores were compared using the Wilcoxon signed-rank test. It was determined by Shapiro-Wilk test ($p<0.05$) that the data were not normally distributed. Therefore, the nonparametric Wilcoxon test was applied. The findings obtained for the Wilcoxon test are shown in Table 9.

Table 9. *Density True-False Test Wilcoxon Signed Ranks Test Result*

Pretest-Posttest	n	Mean Rank	Sum of Ranks	z	p
Negative Ranks	12	6.5	78.0	118.0	0.56
Positive Ranks	11	6.0	66.0	-	
Ties	-				

The Wilcoxon Signed Ranks test yielded a p-value above the 0.05, indicating the absence of a statistically significant difference between pretest and posttest ($p>0.05$).

4. DISCUSSION, CONCLUSION AND RECOMMENDATIONS

The current research examined the effectiveness of the POE technique and 3D models in addressing sixth-grade students' misconceptions in science topics, specifically 'Particle

Structure of Matter' and 'Density.' The POE technique was instrumental in helping students identify, question, and rectify their misconceptions. Students engaged in a learning cycle where they tested their prior knowledge through predictions, validated it via observations, and solidified their understanding through explanations. This hands-on learning approach matches results from studies by Nalkıran and Karamustafaoğlu (2020), Harman and Yenikalaycı (2022), which highlight how the POE technique helps reduce misunderstandings.

The findings of the research demonstrate that combining the POE technique with 3D models is an effective approach for addressing misconceptions in science education. The POE technique encouraged students to critically assess their prior knowledge, acquire new information through experiential learning, and identify their misconceptions throughout this process. Notably, the combined use of the POE technique and 3D models in science education had a positive impact on the development of students' scientific process skills.

Zakiyah, Widodo and Tukiran (2019) also observed the effectiveness of the POE technique in teaching scientific concepts, particularly in the field of thermochemistry. In this study, it was stated that the POE technique enabled students to actively participate in scientific inquiry and contributed to the resolution of cognitive conflicts between prediction and observation stages in this process. Likewise, Rante, Tolla and Arsyad (2022) found that the POE technique fosters student predictions based on prior knowledge and experiences, with observational testing reinforcing conceptual understanding. These findings are in line with the findings obtained in this study, and they provided students with a more profound understanding of scientific concepts and reduced their misconceptions.

The results show that the POE technique and using models help students understand concepts better, proving that these methods are valuable in science education. Integrating 3D models into instructional processes enhances students' understanding of abstract concepts, proving to be a powerful tool in minimizing misconceptions. Through the use of 3D models, students were able to examine abstract topics such as density and the particulate structure of matter in a more concrete manner, facilitating meaningful conceptual change. The use of POE forms and 3D models helped clear up common misunderstandings among students, like thinking of density as a physical "thing" instead of a ratio, and believing that particles in solids are always touching or moving. After instruction, students demonstrated an improved ability to reason that density is mass per unit volume and that in crystalline solids, space exists between particles. This study shows the effect of making science education more visualizable in eliminating misconceptions.

3D models helped transform abstract concepts into tangible representations, enabling students to recognize and correct misconceptions while deepening their understanding. As stated in the studies conducted by Gilbert and Justi (2016), 3D modeling techniques support permanent learning by creating conceptual changes in students' cognitive structures. Especially for students who have difficulty in understanding abstract concepts, 3D models have been found to be an effective tool in eliminating misconceptions. Research by Taber (2017) and Valeeva et al. (2023) further highlights the pivotal role of modeling in fostering conceptual learning and enhancing scientific reasoning skills.

Additionally, it was observed that the impact of combining the POE technique with 3D models on the development of students' scientific process skills. As Gizaw and Sota (2023) emphasized in their study, the structured nature of the prediction, observation, and explanation encourages students to engage in scientific practices such as observing, hypothesizing, and interpreting data. This approach contributes positively to the development of students' scientific process skills and strengthens their scientific inquiry skills (Nadeak & Naibaho, 2020; Syamsiana, Suyatno, & Taufikurahmah, 2018).

Several recommendations emerge for future research. First, applying the POE technique and 3D models to other science topics could further illuminate their effectiveness in addressing various types of misconceptions. Since this study was limited to sixth-grade students, future research could explore the method’s effectiveness across different age groups to assess its impact at varying educational levels. Additionally, incorporating the POE technique over an extended instructional period could help determine the long-term sustainability of its effects.

In this study, the POE technique fostered a constructivist learning environment that fostered collaboration and the sharing of findings. Bilen, Özel and Köse (2016), Banawi et al. (2019) stated that the POE technique provides active participation in learning processes by reinforcing students' understanding of scientific concepts. The findings of this study indicate that integrating the POE technique with 3D models is an effective approach for reducing misconceptions, enhancing conceptual understanding, and strengthening students' scientific thinking abilities.

In conclusion, this study confirms that the POE technique and 3D models are highly effective methods for reducing misconceptions and enhancing students' conceptual understanding in science education. Incorporating these methods into instructional practices can empower students to cultivate scientific thinking and improve problem-solving skills. In this context, the inclusion of POE and modeling-based teaching strategies in teacher education programs would be an important step to support permanent learning in science education.

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Appendices

Appendix-1

THE PARTICULATE NATURE OF MATTER TRUE-FALSE TEST

1. ( ) Matter is not continuous, it has a granular structure.
………………………………………………………………………………………...
2. ( ) The particles of a solid only perform vibrational motion.
………………………………………………………………………………………...
3. ( ) The most orderly state of matter is solid.
………………………………………………………………………………………...
4. ( ) The dissolution of sugar in water shows that sugar is made up of granules.
………………………………………………………………………………………...
5. ( ) The dispersion of the perfume scent in the room occurs through the vibrational motion of gas particles.
………………………………………………………………………………………...
6. ( ) The particles of a substance transitioning from liquid to solid accelerate.
………………………………………………………………………………………...
7. ( ) The compression of the sponge shows that all solids can be compressed.
………………………………………………………………………………………...
8. ( ) The dispersion of iodine in alcohol and the spreading of its color everywhere indicate that iodine is granular
………………………………………………………………………………………..
9. ( ) The particles of a substance changing state also change.
………………………………………………………………………………………...
10. ( ) The space between gas particles is negligible.
………………………………………………………………………………………...

THE DENSITY TRUE-FALSE TEST

1. ( ) The amount of substance in a unit volume is called density.
………………………………………………………………………………………...
2. ( ) To calculate density, mass must be divided by volume.
………………………………………………………………………………………...
3. ( ) The density of ice is greater than the density of water.
………………………………………………………………………………………...
4. ( ) As a result of air being pumped into the soccer ball, the air density inside the ball increases.
………………………………………………………………………………………...
5. ( ) We can use a ruler to calculate the volume of any stone.
………………………………………………………………………………………...
6. ( ) The density of water increases with the dissolution of salt in water.
………………………………………………………………………………………...
7. ( ) Among two objects of the same mass, the one with the larger volume has a higher density.
………………………………………………………………………………………...
8. ( ) The density of the wool pressed into the pillow increases.

…………………………………………………………………………………………………...
9. ( ) Liquid substances can be compressed to increase their density.
…………………………………………………………………………………………………...
10. ( ) The decrease in water's density when it freezes has a more negative impact on the lives of aquatic organisms.
…………………………………………………………………………………………………...

Appendix-2

THE DENSITY EXPERIMENT POE FORM

Materials:
-25 ml graduated cylinder
-Pipette
-2 pieces of 1cm³ cubes
-Ruler
-Water
Prediction:
Compare the cubes with the graduated cylinder measured in ml and predict how many ml correspond to a 1 cm³ cube. Briefly explain your guess.

Observation 1
1- Calculating the volume using known dimensions.
Using a ruler, measure the length, width, and height of the cube to the nearest mm. Write your results in Table 1. If necessary, convert the measurements to cm.
2- Using the formula $V = l \times w \times h$, calculate the volume of each cube. Write the results in Table 1.

	Length (cm)	Width (cm)	Height (cm)	Volume (cm³)
Container 1				
Container 2				

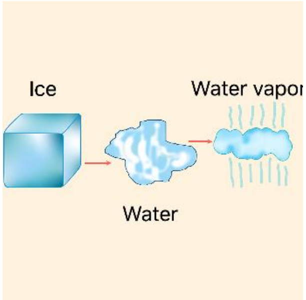
Observation 2: Measuring volume by displacement
1- Fill the graduated cylinder to at least 15 ml. Write the initial volume in Table 2.
2- Place the first cube into the graduated cylinder.
3- Write the final volume in Table 2.
4- Find the difference between the initial volume and the final volume. Write the result in Table 2.
5- Repeat the steps from 1 to 4 using the 2nd cube.

	Initial volume (ml)	Final volume (ml)	Volume (ml)
Container 1			
Container 2			

Explain:
1- Compare the volume of the cubes in Table 1 and Table 2.

2- You observed that one of the cubes in the graduated cylinder floated in the water while the other sank to the bottom. How does this situation affect the area occupied by each cube? In your answer, use what you know about the particulate structure of matter.

THE PARTICULATE NATURE OF MATTER POE FORM



Prediction:
Ice, water, and water vapor are different physical states of the same substance. What is the reason for them being in different physical states despite being composed of the same particles?

Observation:

Explain:
Make comparisons between your predictions and your observations.
Did your predictions come true?
If they didn't happen, please comment on the reasons.