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POE Activity Enriched with Augmented Reality: Conceptual Change on Pressure in Liquids

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Abstract

An experiment thought to be simple is included in various textbooks to test the accuracy of the principle that as the depth of the liquid increases, the pressure it exerts on the surface increases. The enriched prediction, observation, and explanation (POE) strategy was used by combining 3D animations with the interaction, convenience, and three-dimensional visualization of augmented reality (AR) to eliminate this misconception, which is still common today. Thus, this study aimed to perceive a conceptual change in teacher candidates regarding the pressure of liquids. The findings showed that teacher candidates made mistakes in the Prediction stage of POE. It was determined that the candidates observed the distances taken horizontally through their activities during the Observation stage, commented on how the distances changed, and perceived their mistakes. The Explanation stage of POE showed that teacher candidates became aware of the discrepancy between their predictions and observations, which prompted them to think. In this respect, it can be said that establishing the depth context in liquid pressure through the path taken by the fluid moving in the form of a horizontal launch through a small hole opened on the side surface of a cylindrical bottle provides a significant conceptual change. The conceptual change of the candidate teachers was significantly improved in a positive way, and the contradiction between their predictions and observations was eliminated by discussion.

Keywords: Conceptual change; Physics education; POE

INTRODUCTION

Students come to learning environments with a range of non-scientific ideas, many of which differ from scientifically accepted facts. Students' experiences on the subject, misinformation in textbooks, and learning methods (Bayuni, Sopandi, & Sujana, 2018) may cause these informal concepts. Reports Additionally, not all students have the ability to understand concepts well, and therefore, they may misunderstand concepts during the learning process (Maharani, Rahayu, Amaliah, Rahayu, & Saregar, 2019). Informal ideas, non-scientific interpretations, and alternative concepts that contradict scientific facts are often called misconceptions in the literature (Soeharto, CsapÃ, Sarimanah, Dewi, & Sabri, 2019), and this should be taken into account in teaching activities (Suryadi, Kusairi, & Husna, 2020).

Mastery and understanding of concepts in learning science, especially physics is very important (Adriana Sari, Santyasa, & Gunadi, 2021). Misconceptions are a fundamental problem in education, especially in teaching physics, which is difficult to structure for the learner (Anggrayni & Ermawati, 2019; Diani, Latifah, Anggraeni, & Fujiani, 2018; Jubaedah, Kaniawati, Suyana, Samsudin, & Suhendi, 2017) because it will cause students to have difficulty understanding subsequent concepts, and this may affect learning outcomes (Artiawati, Muliyani, & Kurniawan, 2018). Physics is a basic science that deals with natural events by understanding various concepts related to the formation of these events, and many researchers have examined students' concepts regarding activities (Tumanggor, Supahar, Kuswanto, & Ringo, 2020). Some physics topics where misconceptions frequently arise among students are electrical circuits (Yadiannur & Supahar, 2017), kinematics (Saputra, Jumadi, Paramitha, & Sarah, 2019), energy, momentum and impulse (Diyanahesa, Kusairi, & Latifah, 2017), heat, temperature and internal energy (Gurcay & Gulbas, 2015), optical geometry and optical devices (Kaltakci-Gurel, Eryilmaz, & McDermott, 2017). There are also various misconceptions about the concept of liquid pressure (Batlolona, Jamaludin, & Kalean, 2023; Kusairi, Hardiana, Swasono, Suryadi, & Afrieni, 2021; Rasid et al., 2023; Wuttiprom, 2018). This study discusses the misconception regarding liquid pressure. If the height of the liquid in the container increases, the pressure of the liquid applied to the container also increases. In some textbooks and test books (Gizligider, 2023; Kanar & Babacan, 2020; Özalp, 2023; Yancı, 2019), an experiment thought to be simple is included to test the accuracy of the principle that as the depth of the liquid increases, the pressure it applies to the surface increases. The horizontal distances traveled by the liquid coming out of identical holes opened at equal intervals on the side surface of a cylindrical container in a forward horizontal launching motion are examined in this experiment to observe the increase in liquid pressure. The argument traditionally presented in texts on the subject is that pressure increases with depth, and therefore, the pressure of the bottom hole is greater than the other two (Atkin, 1988). Textbooks often ignore that the distance traveled horizontally depends on the speed at which the liquid exits the hole and the flight time until it reaches a horizontal surface (Atkin, 1988; Planinšič, Ucke, & Viennot, 2011). The mentioned relations are formulated in detail below.

Bernoulli Principle

Bernoulli's equation for two different cross-sectional areas is;

$$P_1+\frac{1}{2}\rho V_1^2+h_1dg=P_2+\frac{1}{2}\rho V_2^2+h_2dg \quad (1)$$

Torricelli's Law

If the top of the container is open, the speed at which the liquid gushes out is;

$$V=\sqrt{2gh_1} \quad (2)$$

The horizontal distance of the liquid gushing from the hole with horizontal speed V is;

$$X=2\sqrt{h_1h_2} \quad (3)$$

If the top of the container is open, the speed at which the liquid gushes out.

It is assumed that there is the same atm. pressure at the top of the open-mouthed cylindrical container and at the bottom where the hole is located. The liquid above the container has potential energy, but since its speed is very low, its kinetic energy can be considered as $E_k 0$. Similarly, the potential energy at the bottom of the container can be considered as $E_p 0$. Based on the Bernoulli equation for two different cross-sectional areas,

$$P_1+\frac{1}{2}\rho V_1^2+h_1dg=P_2+\frac{1}{2}\rho V_2^2+h_2dg \quad (4)$$

Thus;

$$P_{atm}+0+hdg=P_{atm}+\frac{1}{2}dV^2+0 \quad V^2=2gh$$

$$V=\sqrt{2gh} \quad (5)$$

The horizontal distance of the liquid gushing from the hole with horizontal speed V.

To find out how long it will take for the liquid gushing forward horizontally from the hole opened at a certain height h_1 from the bottom to reach the ground, from the formula;

$$h_1=\frac{1}{2}gt^2 \text{ t is found as } t=\sqrt{\frac{2h_1}{g}} \quad (6)$$

Thus, from the formula $X=Vt$ x is calculated as;

$$X=2\sqrt{h_1h_2} \quad (7)$$

with

P_1: Liquid pressure in the first section

P_2: Liquid pressure in the second section

ρ: Density of liquid

g: Gravitational acceleration

h: Height

h_1: Distance of the hole from the open surface of the liquid

h_2: The distance of the hole from the bottom of the container

Moreover, the connections made between this experiment and the dependence of hydrostatic pressure on depth often lead to errors in both explanations and drawings, and these errors are copied from one textbook to another and repeated for long periods (Planinšič, Ucke, & Viennot, 2011). The aim of the text writers here is to show that the pressure in a stagnant liquid increase with depth. However, when we consider this experiment for water as an almost inviscid liquid, there is a deficiency in conceptual structuring. It can be thought that conceptual depth will be achieved here by applying Bernoulli's theorem and evaluating the horizontal launching motion in kinematics together. Therefore, incorporating kinematics into the process and taking into account the free fall time (flight time) of the water moving forward from the hole is a model that will contribute significantly to the solution of the problem. This theoretical model, first developed by Torricelli at the end of the 19th century was experimentally almost perfected by mercury, which is less sensitive to air resistance than water. A faulty model of Leonardo da Vinci began to appear in physics and science books at the beginning of the 20th century. This faulty model is still frequently encountered in curriculum textbooks and test books today and causes misconceptions in students. Misconceptions are problems that educators are still working on (Yuberti, Suryani, & Kurniawati, 2020). It is stated that teachers should find concrete solutions to pedagogical difficulties, poor conceptual understanding and misconceptions that arise in their classrooms (Potvin & Cyr, 2017). Recently, POE, an effective strategy for teaching concepts, has attracted attention. POE is a student-centered applied strategy developed by White and Gunstone in 1992 and is used to create a conceptual understanding of a particular topic (Banawi, 2019; Ojo & Owolabi, 2021) through students' scientific skills of predicting, observing, and explaining (Sarah, Khanif, & Saputra, 2021). In the prediction stage, students predict the results of an experiment, demonstration, event, or problem related to learning outcomes (Arminas & Sopandi, 2020; Duman, Kökver, Ünver, & Erdem, 2017; Gönülkırmaz & Çıngıl Barış, 2022; Pujiwati & Susilaningsih, 2020) In other words, students make assumptions based on their prior knowledge or before the experiment (Venida & Sigua, 2020). In the observation stage, students observe the process related to their predictions and are presented with a demonstration experiment in which they make their predictions (Amelia & Yohandri, 2023; Harman & Yenikalayci, 2022). In the explanation stage, students are asked to discuss and resolve contradictions between their predictions and observations (Alfiyanti, Jatmiko, & Wasis, 2020; Ojo & Owolabi, 2021). Having to make a prediction and explain the reason in the POE strategy forces students to find answers, and they have to mentally participate in the lesson (Çıngıl Bariş, 2024). The POE approach is an inquiry-based learning approach to guide students for doing science experiments to deal with a problem (Hwang, Chen, & Chen, 2022; James, Kreager, & LaDue, 2022). According to the research on POE in the literature, it is observed that it helps students expand their understanding of science concepts, encourages student discussions during the learning process, and eliminates alternative concepts (Alfiyanti, Jatmiko, & Wasis, 2020; Karsli Baydere, 2021). Emphasizing student-centred learning, POE is based on learning by doing and reveals misconceptions by taking into account students' prior knowledge (Ojo & Owolabi, 2021). It was observed that each stage of the POE method provided a rich discussion/learning environment and addressed alternative concepts.

Texts, images, videos, and simulation models are used to explain the causes of natural phenomena in science education. Students can only observe and imagine the situation from an egocentric perspective, which often causes some limitations in learning and may even lead to misconceptions (Tarng, Tseng, & Ou, 2022). To increase the quality of teaching, the effective use of modern teaching technologies in teaching concepts is becoming more important day by day (Efe, 2015).

The use of animations has begun to gain significant value thanks to technology, and students' feelings of curiosity towards information are increasing thanks to animation-supported materials prepared in line with the goals of education (Gül & Şahin, 2017). (Çelik, Pektaş, & Karamustafaoğlu, 2021) emphasize that animation can be useful for students to understand detailed systems that are abstract, difficult to solve, and have complex timing relationships and micro steps in constant change. According to Akçayir, Akçayir, Pektaş, & Ocak, (2016), computer animations allow students to explore inaccessible places, reach facts without worrying about time, and interact with real-world conditions. Educators provide their students with a rich learning environment by using educational software. One of the current software applications that can achieve this purpose is augmented reality (AR). AR takes students away from the traditional classroom environment and allows them to interact with objects in real time (Sontay & Karamustafaoğlu, 2021). The essential advantage of AR is that it offers visualization opportunities, and thus, course contents can be developed through 3D visualizations (Gül & Şahin, 2017). AR teaching environments enable students to learn more deeply by increasing students' attention and motivation and providing a different perspective on systems or objects that are difficult to learn (Akçayir, Akçayir, Pektaş, & Ocak, 2016). AR enables the user to take an active role in researching, applying and learning new topics (Sontay & Karamustafaoğlu, 2021). 3D animations were used together with AR technology in this study. The researchers made 3D animation and AR applications. Neither an application of POE enriched with AR and 3D animations nor conceptual change research on the mentioned liquid pressure has been found in the literature. Therefore, this study aimed to perceive the conceptual change in science teacher candidates regarding the pressure of liquids, thanks to POE enriched by combining both 3D animations and the interaction, convenience, and 3D visualization of AR.

For this purpose, solutions were sought for the following problem situations.

1. What is the effect of the activity on the conceptual change of science teacher candidates?
2. What are the pedagogical opinions of science teacher candidates regarding the activity?

METHOD

Research Design: The special case method, one of the qualitative research methods, was used in the study. The case study is a research approach in which the researcher examines one or several situations limited in time in depth with data collection tools such as observations, interviews, documents, etc. (Cohen & Manion, 1994). In this method, the explanatory case study is used to provide information about a situation, make unfamiliar situations familiar, and explain connections to real-life situations.

Sample: The sample consists of thirty teacher candidates studying in the first year of the science teaching program at a state university. An easily accessible case sampling method was used in sample selection. Teacher candidates participated in the research voluntarily.

Data collection tools and analysis of data: POE activities developed by the researchers and filled out by teacher candidates were used as a data collection tool (Figure 1).

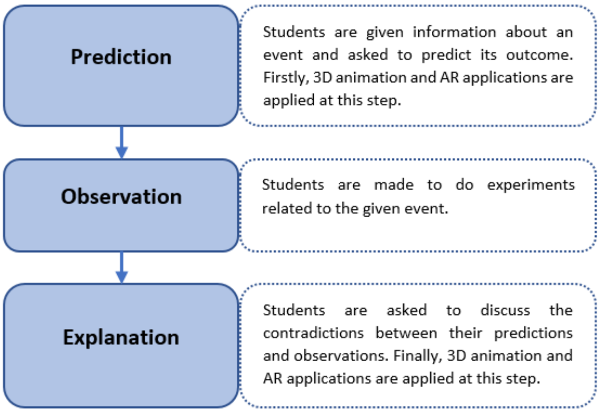

Figure 1. POE flow chart

Document analysis was used for the data. Direct quotations are included to reflect the data strikingly. In addition, teacher candidates' opinions about the POE activity were determined through a focus group interview at the end of the study. The content analysis method analyzed the data obtained from the interview form. In the first stage of the POE activity, an electronic worksheet is given to the candidates, and they are asked to predict the generalization. Then, the Quick Response (QR) code is scanned to test whether the predictions match the 3D animation content. In the second stage, students conduct Activity 1 and 2 in a laboratory environment, allowing the teacher candidates to observe and record data. After the first and second activities, teacher candidates conduct Activity 3 interactively with the help of the smart board in the laboratory. In addition, they can use the application repeatedly on their smartphones with the help of the QR code. Then, the students make a conclusion by answering the questions in the "Let's conclude" section. The findings of the activities are discussed in this section. Permanent learning was tried to be achieved in teacher candidates by comparing the 3D animation contents watched by scanning the QR code.

Application Process: In the first stage of the POE activity, an electronic worksheet was given to the candidates, and they were asked to predict the generalization. Then, the QR code was scanned to test whether the predictions matched the 3D animation content. The method called error-based simulation (EBS) (Horiguchi, Hirashima, & Hayashi, 2023) was used at this stage to create an example of students' misconceptions by simulating erroneous facts based on students' wrong ideas. EBS is an alternative method to provide a preliminary example against students' misconceptions by conducting a thought experiment (Hirashima, Horiguchi, Kashihara, & Toyoda, 1998). A model of the target phenomenon is created based on students' misconceptions in EBS, and then a model-based simulation is performed to demonstrate an erroneous phenomenon. Based on this, in the study, the situation that caused students' misconceptions was shown with an animation containing their misconceptions, and the students were asked to predict.

Atkin (1988) made the unfortunate mistake of thinking in his article that he had considered all the factors involved in the “Great Water Jet Scandal” and overlooked an important factor that makes the biggest difference in the arrangement in which the spacing of water jets created by holes drilled in a cylindrical container should be placed. The principle that pressure increases with depth is not wrong, and if the teacher holds the cylindrical bottle at a certain height, the result will not be misleading or inaccurate. Therefore, three activities were used in the observation stage, which is the second phase of the POE activity. Activity 1 and Activity 2, prepared by the researchers, are made by the students in a laboratory environment at this stage, allowing the teacher candidates to observe and record data. After the first and second activities are completed, Activity 3 is interactively done by the teacher candidates with the help of the smart board in the laboratory. In addition, they can use the application repeatedly on their smartphones with the help of the QR code. Then, the students make a conclusion by answering the questions in the "Let's conclude" section. The findings of the activities are discussed in this section. Permanent learning was tried to be achieved in teacher candidates by comparing the 3D animation contents watched by scanning the QR code. The learning activities related to these stages in the POE activity are given step by step.

Step 1: Informing

Learning activities: Before starting the activity, you need to download a QR code reader application from the Play Store for Android phones and the App Store for iOS phones. After the reminder is given, the prediction stage can be started.

Step 2: Predict

Learning activities: If the height of the water in the container increases, the water pressure applied to the container also increases. The horizontal distances covered by the water gushing forward in a horizontal launching motion from identical holes opened at equal intervals on the side surface of a cylindrical container are examined to observe the increase in water pressure. Students are asked to write their thoughts about the given statement. Then, they are asked to check their answers by scanning the QR code and watching the 3D animation. The QR code and application visual used in this step are given in Figure 2.

Figure 2. QR code and application image used in step 2.

Step 3: Observe

Learning activities: Students were asked to do the following experiments in a laboratory environment to evaluate their predictions.

Activity-1: Water applies pressure to the container.
Tools: One plastic bottle, nail and ruler.
How to do the activity: First, let's pierce a plastic bottle in three points, 5 cm apart. Let's name the holes 1, 2, and 3 from bottom to top. Then, let's place the plastic bottle filled with water, 20 cm high, on the experiment table and place the ruler in front of it horizontally. Let's open the holes and observe the movement. Let's note the results in Table 1.

Table 1. Distance taken horizontally for each hole

Holes	Distance traveled horizontally (cm)
First hole	
Second hole	
Third hole	

Note: The holes must be equal in diameter.

Activity-2: The water applies pressure to the container at a certain height from the ground.
Tools: One plastic bottle, nail, ruler, and wooden wedge.
How to do the activity: First, let's pierce a plastic bottle in three points, 5 cm apart. Let's name the holes 1, 2, and 3 from bottom to top. Then, let's place the plastic bottle on the 10 cm wooden wedge on the experiment table, put the ruler in front of it, and fill it with water up to 20 cm. Let's open the holes and observe the movement. Let's note the results in Table 2.

Table 2. Distance taken horizontally for each hole

Holes	Distance traveled horizontally (cm)
First hole	
Second hole	
Third hole	

Note: The holes must be equal in diameter.

Activity-3: Record the data by changing the variables affecting the liquid pressure with the interactive virtual experiment. Note: This activity can be done interactively with a smart board in a laboratory environment or can be used on a smartphone.

The application visuals used in this step are given in Figure 3.

Figure 3. Application visuals used in step 3.

Step 4: Explain:

Learning activities: Let's conclude by answering the questions given below.

1. What can you say about the horizontal distances of the water coming out of the holes?
2. Did this experiment confirm the hypothesis that as the height of water increases, its pressure also increases? If your answer is no, what new inference would you make?
   Write your answers below.

Then scan the QR codes, watch the 3D animations and check your answers (Figure 4)

Figure 4. QR codes used in step 4.

RESULTS

The findings for "What is the effect of the activity on the conceptual change of science teacher candidates?" sub-problem are given respectively in Tables 3-6.

Table 3. Findings and frequency distribution for the prediction stage of POE activity.

Findings for the prediction stage	*f*
Since the pressure of the water increases as the depth increases, the distance traveled horizontally is directly proportional to the depth.	17
According to the $P = hdg$ formula, the distance traveled horizontally increases with depth.	9
Since the water's speed increases with pressure, the distance traveled horizontally is directly proportional to the speed.	3
Since the speed of the water leaving the holes is the same, the liquids travel the same distance.	1

When Table 3 is examined, the majority of teacher candidates (*f* = 17) stated, "Since the pressure of the water increases as the depth increases, the distance travelled horizontally is directly proportional to the depth." In addition, some of the teacher candidates (*f* = 9) stated, "According to the $P = hdg$ formula, the distance traveled horizontally increases with depth." Additionally, a teacher stated, "Since the speed of the water leaving the holes is the same, the liquids travel the same distance." Considering all these statements, it can be said that teacher candidates have a misconception about this issue. Moreover, when we look at the "Since the speed of the water increases with the effect of pressure, the distance traveled horizontally is directly proportional to the speed." statement of three teacher candidates, the outflow speed of the water indeed increases primarily due to the effect of pressure, but this increase is not directly related to the distance taken horizontally but indirectly. That is, there are other variables that it depends on (for example, altitude and flight time in the air). The findings for the first activity in the observation stage of POE are given in Table 4.

Table 4. Findings for Activity 1 in the observation stage of POE

Holes	**Distance travelled horizontally (cm)**	
	Experimental Environment	**Theoretical**
First hole	17.80 cm	17.32cm
Second hole	21.40 cm	20.00 cm
Third hole	17.20 cm	17.32 cm

When Table 4 is examined, it is observed that the horizontal distances of the water coming out of the first and third holes are approximately the same. However, it can be observed that the horizontal distance traveled by the water coming out of the second hole is greater. Experimental data and theoretical data are the same. The findings for Activity 2 in the observation stage of POE are given in Table 5.

Table 5. Findings for Activity 2 in the observation stage of POE

Holes	**Distance traveled horizontally (cm)**	
	Experimental Environment	**Theoretical**
First hole	30.40 cm	30.00 cm
Second hole	27.80 cm	28.28 cm
Third hole	22.80 cm	22.36 cm

When Table 5 is examined, in the activity carried out at a certain height from the ground, the water coming out of the first hole reached the farthest, the water coming out of the second hole was closer, and the water coming out of the third hole was the closest. These experimental results were approximately the same as the theoretical values. The frequency distribution of the answers given by teacher candidates to the questions in the explanation stage of POE is given in Table 6.

Table 6. Distribution of teacher candidates' answers to the questions in the explanation stage of POE

Questions and Answers	***f***
1. What can you say about the horizontal distances of the water coming out of the holes?	
The distance traveled horizontally depends on another effect other than pressure.	18
As the height of the cylindrical container from the ground increases, the horizontal distances traveled by the water change.	12
2. Did this experiment confirm the hypothesis that as the height of water increases, its pressure also increases?	
No	28
Yes	2
3. If your answer is "no", what new inference would you make?	
Water makes a horizontal launching motion as it comes out of the holes, so horizontal launching principles also apply here.	13
According to Activity 1, the water coming out of the first hole cannot travel very far because it falls to the ground earlier.	10
According to Activity 1, the speed of the water coming out of the third hole is slower, but it stays in the air longer.	3

When Table 6 is examined, it can be observed that the answers given by the teacher candidates in the explanation stage are quite different from the answers given in the prediction stage.

The findings for "What are the pedagogical opinions of science teacher candidates regarding the activity?" sub-problem are given in Table 7.

Table 7. Teacher candidates' opinions and frequency distribution regarding the POE activity.

What are your thoughts on the POE activity?	***f***
The activities made us realize our mistakes.	27
It better demonstrated the differences between prediction and observation.	24
It provided permanent and meaningful learning.	24
Activities have developed a positive attitude towards physics.	22
It was confusing and difficult at first, but then we were happy because it helped us learn.	22
Visual elements such as 3D animations and AR provided more permanent learning.	22
It is interesting and enjoyable.	19
Since we did the activities step by step, we had no difficulty.	18
We tested the predictions through observation.	17
It can be used in any environment.	17
It encourages thinking.	16
It allows to perceive deficiencies.	16
It provides permanence in mind.	13
It teaches how to save data.	8

Examples of the answers given by teacher candidates regarding Table 7 are given below.

ÖA-1: *"Thanks to the applications and animations in the POE activity, I realized my mistakes and learned the correct information".*

ÖA-5: *"Since I had the opportunity to constantly monitor and apply simulations thanks to QR codes, I learned faster and more meaningfully".*

ÖA-8: "*I was very confused at first because I had a lot of contradictions in the prediction and observation stages of the POE activity"*.

ÖA-17: "*I had no difficulty in the explanation stage of the POE activity, thanks to the activities in the observation stage".*

ÖA-22: "*I will apply the knowledge I learned in my professional life. I think I will never forget it."*

ÖA-3: "*Since the activities are integrated into the mobile application, I open it in every environment and watch the animations again."*

ÖA-7: "*I learned even better how to record data in the simplest sense."*

ÖA-12: "*I had a lot of difficulty in the predicting stage. Thanks to the activities I carried out in the observation stage, I answered the questions correctly in the explanation stage. So, I realized my shortcomings."*

ÖA-18: "*I learned quickly thanks to 3D animations and PhET simulation. Also, these applications attracted my attention."*

ÖA-19: *"Even though I was normally a science teacher candidate, I did not like physics very much. My perspective on physics changed thanks to these POE activities. I was no longer afraid of physics."*

DISCUSSION

When the findings regarding the first sub-problem of the study are examined, it is observed that the teacher candidates have misconceptions in the prediction stage, which is the first stage of POE. For example, it was determined that teacher candidates stated, "As the depth of the water increases, its pressure will also increase, so the distance traveled horizontally is directly proportional to the depth." This statement contains a misconception. This finding coincides with Atkin's (1988) finding. According to Atkin (1988), the argument traditionally presented in most texts is that pressure increases with depth, and therefore, the pressure of the lower hole is greater than the other two. According to another finding, textbooks generally ignore that the distance traveled horizontally depends not only on the speed of the liquid coming out of the hole but also on the flight time until it reaches a horizontal surface (Planinšič, Ucke, & Viennot, 2011). It was observed that the teacher candidates observed the horizontal distances thanks to the activities in the observation stage, and based on these observations, they commented on how the distances changed and perceived their mistakes. According to the study, POE materials create a conducive learning environment to improve students' learning habits and increase the quality of learning (Rini, Suryani, & Fadhilah, 2019). Additionally, POE seems to be a good method for students to apply knowledge (Furqani, Feranie, & Winarno, 2018).

During the explanation stage of POE, more than half of the teacher candidates stated that "The distance taken horizontally depends on another effect other than the pressure, " showing that they perceived the discrepancy between their predictions and observations and prompted them to think. Similarly, according to the study, it has been determined that the POE method is effective in increasing students' performance (Nalkıran & Karamustafaoğlu, 2020) and POE-supported applications are successful in increasing students' interest in learning science and ensuring continuity (Hong, Hwang, Liu, Ho, & Chen, 2014). The POE approach can potentially improve students' self-efficacy, learning motivation, and achievement (Fitriani, Zubaidah, Susilo, & Al Muhdhar, 2020; Mamun, Lawrie, & Wright, 2020).

When the answers of the teacher candidates were examined in the explanation stage, they used the statement "Water makes a horizontal launching movement when coming out of the holes, therefore the principles of horizontal launching are also valid here.", "According to Activity 1, the water coming out of the first hole cannot go very far because it falls to the ground earlier." and “Compared to Activity 1, the speed of the water coming out of the third hole is slower, but it stays in the air longer.” So, we can say that the teacher candidates' perspectives on the problem situation have changed, and the observation activities that exist between the prediction and explanation stages have caused a conceptual change in the teacher candidates. This situation can be explained by students' increasing curiosity and tendency towards POE (Erdem Özcan & Uyanık, 2022). It is observed that POE is effective in reducing students' misconceptions (Lestari, Prabowo, & Widodo, 2018). In addition, we can say that the fact that teacher candidates had more practice opportunities in the laboratory environment and were exposed to AR-supported and smart-board applications caused the conceptual change to occur.

According to the findings regarding the second sub-problem, teacher candidates stated that they were aware of their existing misconceptions with the statements "The activities made us perceive our mistakes," "It better demonstrated the differences between prediction and observation," and "It provided permanent and meaningful learning." Students are still learning science and acquiring basic skills at the secondary school level. Interest in science begins to emerge and it becomes important to ensure the continuity of this interest at that age (Sheldrake & Mujtaba, 2020). Therefore, it can be concluded that the widespread use of applications such as POE may cause this interest to arise and increase. In addition, it can be concluded from the statements of the teacher candidates that their physics achievements have also increased. Therefore, POE has been determined to be an effective method for increasing success. This success of POE can be explained by the fact that it suits students' needs and interests, offers learning by questioning, and is a student-centered method (Venida & Sigua, 2020).

As can be understood from the statement, "Activities have developed a positive attitude towards physics," the attitudes of the teacher candidates changed positively. A similar finding was also revealed by Muhibbuddin, Ilyas, & Samya (2019) also revealed a similar finding. In addition, the statement "It is interesting and enjoyable" shows that the activities prepared according to POE are effective tools in the laboratory environment. Similarly, another study also revealed that students enjoyed the activities prepared according to POE (Nalkıran & Karamustafaoğlu, 2020). Another statement from teacher candidates is "It was confusing and difficult at first, but then we were happy because it helped us learn". Similarly, while it is stated that laboratory activities prepared according to POE challenge individuals, it is also stated that the activities make them happy because they encourage them to develop their abilities and learn (Bilen, Özel, & Köse, 2016). Additionally, teacher candidates stated, "Visual elements such as 3D animations and AR provided more permanent learning". Teacher candidates could easily access 3D animations and simulations with their smartphones and could watch the animations again thanks to the AR applications. Similarly, students stated in the study conducted by Butt (2014) that they frequently re-watched video sections containing difficult topics and that re-watching videos related to a concept created a very positive perception. Likewise, Çelik, Pektaş, & Karamustafaoğlu (2021) stated that thanks to the use of AR, students can have the opportunity to watch the recordings many times, ensure their self-control, and support their learning of subjects or concepts. Similarly, Sat, Ilhan, & Yukselturk (2023) concluded in their study that AR-supported applications are effective in ensuring permanent learning in teacher candidates and attract attention.

CONCLUSION

As a result, depending on the POE planned for the pressure-depth relationship in liquids, the contradiction between the teacher candidates' predictions and observations was resolved by discussion. Integrating the path the liquid takes in the form of a horizontal launch through a small hole opened on the side surface of a cylindrical bottle and the depth context in the liquid pressure has significantly improved the conceptual change positively. It is understood from the literature that POE has significant effects on success in learning and conceptual understanding. Teacher candidates can make conceptual changes in different subjects, in different sample groups such as secondary and high schools, and in different disciplines by disseminating such practices. The information mentioned in this study and the experimental activities carried out for this information are constantly used in textbooks and auxiliary reference books about the pressure of liquids in science. Textbooks often ignore that the distance a liquid travel horizontally depends on its exit velocity and the flight time until it reaches a horizontal surface. It is very difficult for secondary and high school students to understand this information. Therefore, activities that measure pressure in liquids directly should be used. This study only examines the misconceptions regarding the relationship between liquid pressure and altitude. However, in the literature review, it was observed that there is a misconception between liquid pressure and density. Activities can be developed to eliminate this misconception.

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