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Exploration of Students' Conceptual Understanding in Static Fluid through Experiential Learning Integrated STEM with Formative Assessment

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Abstract. One of the main goals in learning physics is that students are able to understand concepts correctly. Students who understand the concepts correctly will be able to understand theoretically and apply the concept in solving various problems. However, students still have difficulties in understanding concepts, one of them is the static fluid. The aim of this study was to explore increasing students' understanding of concepts through experiential learning integrated STEM with formative assessment. The employed was a mixed-method with an embedded experimental model. This study involved 36 students from class XI Natural Science and used the Conceptual Understanding Test with 12 multiple-choice questions with the reliability of 0.762. Analyze were performed quantitatively based on pre-test and post-test data using descriptive statistics, paired sample t-test, N-gain and effect size. At the same time, the qualitative data obtained in the form of students' reasons, interviews, and observations were analyzed by data reduction, coding, data presentation, and drawing conclusions. The results showed that there was a significant change in students' conceptual understanding, with an N-gain score of 0.56 (moderate category), and effect size score of 3.46 (strong category). Moreover, it was also known that students had difficulty in determining the magnitude of hydrostatic pressure, using the pressure equation in applying Pascal's law, and determining the magnitude of buoyancy force on objects immersed in the fluid. However, an increase in students' understanding of the concept of static fluid indicates that experiential learning integrated STEM with formative assessment can be used in learning.

INTRODUCTION

The static fluid is one of the most widely applied physics topics in engineering and daily life, so it becomes important to learn. Even so, the concept of static fluid is still considered difficult for students. Research conducted by Sutarja *et al.* (1) stated that there are still many students who have difficulty understanding and applying the concept of static fluid even though learning has been applied. Students have difficulty in determining the magnitude of hydrostatic pressure (2–4), understanding the mathematical equation in the concept of Pascal's law (1,5), and determining the magnitude of the object's buoyancy in the concept of Archimedes' law (1,5,6). One of the causes of student learning difficulties is the student's lack of understanding of the concept (1,5).

One important aspect of learning physics is that students are able to understand concepts well. By understanding the concepts, their conceptual framework is more coherent so that the approach used will be more scientific (7). In addition, students' conceptual knowledge also affects students' abilities and approaches to solving the problems they experience in their daily activities (7,8). But in reality, it is difficult to instill conceptual understanding to students. Based on data search through the Publish or Perish application, it is known that as many as 998 studies indexed by Google Scholar in the last ten years discuss the existence of student misconception in understanding physics. Several

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studies on learning difficulties and misconception have been carried on static fluid, including hydrostatic pressure, Pascal's law, and Archimedes' law (3,5,6,9).

Because there are still many difficulties experienced by students, while the static fluid sub material is important to learn, it is necessary to apply appropriate learning. Several previous studies have been applied to improve students' conceptual understanding, including the application of cooperative learning (10), pictorial riddles (11,12), and Think-Talk-Write (12). However, there are several weaknesses in this studies including, 1) the lack of a process of building a knowledge-based on student experience, 2) learning is less oriented towards direct project activities so that students cannot create, innovate, and apply science, technology, engineering, and mathematical skills in real-life situations, and 3) lack of teacher and student interaction in learning.

Experiential learning can be used as an alternative to improve students' conceptual understanding. Experiential learning is holistic learning that comes from direct experience and is concrete as a basis for observation and reflection (13,14). Experiential learning creates two important experiences for students, namely the acquisition of concepts and design experiences and the implementation of innovative teaching and learning activities (13). Through experiential learning, students' conceptual understanding can increase (15).

In addition, it is important to apply 21st-century skills which require students not only to have knowledge of the material being taught, but also include critical thinking, problem-solving, creativity, and collaboration (16). Therefore, integrating experiential learning and STEM can facilitate student learning to achieve these goals through engineering project activities involving science, technology and mathematics. Through STEM learning, students will get meaningful learning experiences (17). STEM has the advantage of building a deep understanding of concepts (18) and through this approach, students can apply their knowledge to work together in groups to solve problems in daily life (17,19).

To help students guide their own learning, formative assessment is included in learning. Formative assessment is a process during learning that involves the teacher and student interaction by providing feedback that aims to increase student achievement in learning (20). Formative assessment focuses more on improving student learning than on evaluating what they have learned (21,22). During learning, the teacher must activate students as a resource between one another through collaborative activities, provide feedback, and allow students to self-assess (21). The application of formative assessment in learning can create a classroom environment that appropriates with the way science works (23).

This study applies STEM integrated experiential learning with formative assessments to improve students' students' conceptual understanding of the static fluid topic. This study aims to explore students' conceptual understanding of the static fluid topic after the application of STEM integrated experiential learning with formative assessments.

METHODS

The study was conducted in class XI Natural Science SMA Negeri 7 Malang with the number of subjects as many as 36 students. This study used a mixed-method with an embedded experimental design (24). The study was started by collecting qualitative data in the form of difficulties and misunderstandings of students on static fluid material before being given STEM integrated experiential learning accompanied by formative assessments. During the learning process, there was an observer who observed the implementation of the learning. In addition, qualitative data collection was carried out in the form of interviews, video lessons learned, and photos. Quantitative data on conceptual understanding was obtained through pre-test and post-test before and after the intervention.

Experiential learning has four syntaxes which include concrete experience, reflective observation, abstract conceptualization, and active experimentation (14). Furthermore, the steps for STEM learning activities according to Sutaphan and Yuenyong include: 1) identification of social issues, 2) identification of potential solutions, 3) need for knowledge, 4) decision making, 5) development of prototype or product, 6) test and evaluation of the solution, and 7) socialization and completion decision stage (25). Formative assessment is carried out during learning by activating students through three activities, namely collaborative, providing feedback, and self-assessment. Experiential learning syntaxes are combined with STEM and formative assessment activities so that students' conceptual understanding of static fluid material increases.

This study used 12 Conceptual Understanding Test questions adopted from various pieces of literature (26–29). Based on the results of field trials involving 86 students of class XII SMA, the instrument reliability obtained was 0.762 and included in the medium category.

The pre-test and post-test quantitative data were analyzed using paired sample t-test, calculation of N-gain (30), and d-effect size (31). Meanwhile, qualitative data obtained from students' reasons for answering questions, interviews, and observations were analyzed by data reduction, coding, data presentation, and drawing conclusions (32).

RESULTS AND DISCUSSION

The data on the results of students' conceptual understanding were analyzed quantitatively through descriptive and inferential statistics. The results of data analysis can be seen in Table 1.

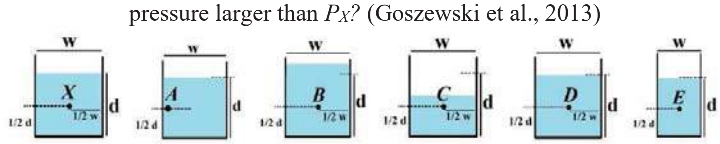
TABLE 1. Students' pre-test and post-test results in understanding the concept of static fluid

Statistics	Pre-test	Post-test
Total Students	36	36
Mean	22.114	64.003
Sig (Paired Sample T-test)	0.000 (significant differences)	
N-gain	0.56 (moderate category)	
Effect Size	3.46 (strong category)	

Based on Table 1, it is known that students' conceptual understanding scores on static fluid material have increased from pre-test to post-test. The results of the Paired Sample t-Test show a significance value ($p < 0.05$), thus it can be concluded that there is a significant difference between the pre-test and post-test understanding of the concept as a result of the intervention. The N-gain value obtained was 0.56, meaning that there was an increase in students' understanding of the concept due to the intervention in the moderate category. Furthermore, the effectiveness of the intervention can be seen through the effect size. The effect size value obtained is 3.46 and is included in the strong category. Similar research by applying experiential learning in physics learning states that students who are taught using experiential learning have a higher conceptual understanding when compared to students taught using conventional methods (33). Experiential learning can improve students' conceptual understanding because it can facilitate constructive learning by developing pedagogical skills and innovative learning (34). In addition, combining experiential learning and formative assessment can lead to deeper learning and longer retention of information (35).

Furthermore, students' questions and answers will be presented in understanding the concept of static fluids in the sub-material of hydrostatic pressure, Pascal's law, and Archimedes law. The following questions are related to hydrostatic pressure.

Consider point *X* at the mid-point of a beaker of water of width *w* and water depth *d,* as shown below. The pressure at *X* is measured and found to have a certain value P_X. Which of the labeled points *A-E* in the situations depicted below will have a pressure larger than P_X? (Goszewski et al., 2013)



a. Point A b. Point B c. Point C d. Point D e. Point E

FIGURE 1. Hydrostatic pressure question

To answer this question correctly, students must understand that the magnitude of hydrostatic pressure is affected by depth. From the hydrostatic pressure questions above, the glass that has the greatest depth when measured from surface to point is beaker B. The distribution of student answers and reasons during the pre-test and post-test can be seen in Table 2.

TABLE 2. Distribution of students' answers regarding hydrostatic pressure

Sub Material	Hydrostatic Pressure											
Option	A		B		C		D		E		NA	
	Pre	Po	Pre	Po	Pre	Po	Pre	Po	Pre	Po	Pre	Po
Total	0	0	23	33	0	0	0	0	4	2	9	1
%	0.0	0,0	63.9	91.7	0.0	0.0	0.0	0.0	11.1	5.5	25	2.8

Note: Pre = pre-test Po = post-test Green box = correct answer NA = No Answer

When students answered the pre-test questions about hydrostatic pressure, there were 23 (63.9%) students who could answer correctly in option B. However, only 6 (16.7%) students gave the right reasons according to the concept of hydrostatic pressure. As many as 4 (11.1%) other people answered option E without any reasons, and 9 (25%) students did not provide answers (Table 2). There are several types of reasons identified during the pre-test and post-test of this question. These reasons can be seen in Table 3.

TABLE 3. Students' reasons for pre-test and post-test of hydrostatic pressure

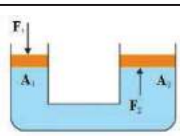
Pre-test		Reasons	Post-test	
%	Option		Option	%
16.7	B*	The hydrostatic pressure at point B is greater. This is because the distance between the surface of the water and the point on glass B is greater (deeper).*	B*	47.2
2.8		Because the volume of water at point B is more, then the pressure at point B is greater.		19.4
25		Because the mass of water in glass B is more		13.9
13.9		Because point B has the highest water level. The higher the water, the greater the pressure.		8.3
5.6		(no reason)		2.8
-	E	Because the cross-sectional area of the beaker E is smaller, the hydrostatic pressure is greater. The formula for pressure is P = F / A, meaning that the pressure is inversely proportional to the cross-sectional area.	E	5.6
11.1		(no reason)		-
25	NA	-	NA	2.8

* = answer and reason are correct

Based on Table 3, it can be seen that during the pre-test students considered the volume and amount of mass of water to affect the magnitude of hydrostatic pressure. Students assume that the more volume of water, the greater pressure will be to a point. This is similar to the study conducted by Besson et al. (9) which states that students often refer to the fact that pressure depends on the quantity or weight of water above a point. So that students think the more water, the greater the pressure (3,9). Furthermore, there were students who reasoned that the water in beaker B was the highest when measured from below. Therefore its hydrostatic pressure was the greatest. Students have a misconception on this reason because they do not understand the depth that should be measured from the surface to a point (3,5,26,27).

Meanwhile, during the post-test, it was seen that there were still students who answered the same wrong reasons during the pre-test (see Table 3). Apart from student reasons, this was also known through interviews conducted. The student who chose answer B stated that "*because the water is higher, the volume is more. So the pressure is getting bigger, Ma'am*". This indicates that it is difficult to eliminate misconceptions in students. This is similar to research conducted Docktor and Mestre which states that misconceptions have a very deep position in students (36). This is due to the time and effort students spent building it. In addition, misconceptions are also resistant to change, even though students actually know the correct answer (37). The student who gave the reason in option E applies the pressure equation to hydrostatic pressure. The reasons given by the students were correct in certain contexts, but not in the context of hydrostatic pressure. Meanwhile, students who understand the concept of hydrostatic pressure correctly state, *"I chose option B because the water depth is greater. Option C has the smallest hydrostatic pressure. Whereas A, D, and E have the same hydrostatic pressure. When I was experimenting (Hartl experiment), I knew that it was the depth and density that affected the magnitude of hydrostatic pressure. The shape of the container has nothing to do with (option E)".*

Furthermore, the students' questions and answers are presented when answering questions related to Pascal's law.



A hydraulic pump as shown in the figure has a diameter d of the first piston and a second piston has a diameter of 2d. When a downward force F is applied to the first piston, then ....

a. the force applied to the second piston is less at F/4
b. the same force is applied to the second piston because the pressure transferred through the fluid is the same
c. the force applied to the second piston is smaller at F/2
d. the force applied to the second piston is 2F
e. the force applied to the second piston is 4F

FIGURE 2. Pascal's law question

This problem is solved by using the concept of Pascal's law which states that the pressure exerted on a liquid in a closed space will continue in all directions equally. Therefore, the equation applied in this problem is $F_1/A_1 = F_2/A_2$. After students calculate using this equation, the correct answer will be obtained in option E. The distribution of students' answers to Pascal's law questions can be seen in Table 4.

TABLE 4. Distribution of students' answers regarding pascal's law

Sub Material	Pascal's Law											
Option	A		B		C		D		E		NA	
	Pre	Po	Pre	Po	Pre	Po	Pre	Po	Pre	Po	Pre	Po
Total	0	3	0	1	17	5	0	5	0	19	19	3
%	0.0	8.3	0.0	2.8	47.2	13.9	0.0	13.9	0.0	52.8	52.8	8.3

Note: Pre = pre-test Po = post-test Green box = correct answer NA = No Answer

When pre-test questions regarding Pascal's law, no student answered option E. As many as 17 (47.2%) students answered option C (14 people with reasons, 3 without reasons) and 19 (52.8%) others did not answer (see Table 4). Meanwhile, during the post-test, 19 (52.8%) students answered option E with the right reasons. The reasons for students' answers during the pre-test and post-test can be seen in Table 5.

TABLE 5. Students' reasons for pre-test and post-test of Pascal's law

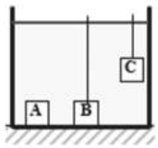
Pre-test		Reasons	Post-test	
%	Option		Option	%
-	-	Because the diameter of the piston 2 is wider, it means that the surface area is larger. Pressure is inversely proportional to surface area.	A	8.3
-	-	Because $F_1/A_1 = F_2/A_2$ Therefore, the force at $F_1 = F_2$	B	2.8
19.4	C	Because the cross-sectional area of the second piston is larger, the force on the second piston is smaller.	C	13.9
19.4	C	$\frac{F_1}{A_1} = \frac{F_2}{A_2} \rightarrow \frac{F_1}{1} = \frac{F_2}{2} \rightarrow F_1 = \frac{F_2}{2}$	C	-
8.3	C	(no reason)	C	-
-	-	The first piston is d in diameter while the second piston is 2d in diameter, so the first piston is F while the second piston has a large force of 2F (the force is doubled).	D	13.9
-	-	$\frac{F_1}{A_1} = \frac{F_2}{A_2} \rightarrow F_2 = \frac{F_1 A_2}{A_1} \rightarrow F_2 = \frac{F(\pi {r_2}^2)}{\pi {r_1}^2} \rightarrow F_2 = \frac{F(\pi d^2)}{\pi \frac{d^2}{4}} \rightarrow F_2 = 4F$ *	E*	52.8
52.8	NA	-	NA	8.3

* = answer and reason are correct

In Table 5, it can be seen that students relate the knowledge of the pressure material that they have obtained from previous learning (during junior high school) by applying the principle that pressure is inversely proportional to the cross-sectional area. According to them, if the cross-sectional area increases, the force exerted will be small. This principle is certainly correct, but it cannot be applied to the above problems. Furthermore, there are some students who already know Pascal's law formula, and they try to apply it. But students have an error because what is known in the problem is the diameter, while the student enters the number directly on the surface area.

Meanwhile, during the post-test, 19 (52.8%) students answered option E with the right reasons (see Table 4). Based on the results of the interview, one of the students answered this problem by connecting the learning he had received. When asked a question about Pascal's law, he stated that *"the answer is between D and E because the F (the force) must be greater so that P (the pressure) is the same. Like the application of Pascal's law in daily life, by applying a small force it can produce a greater force such as the tool used to lift a car in a car wash".* Furthermore, the student tries to solve the question using Pascal's law principles by entering the known variables. After getting the result he stated, *"the answer is E, Ma'am"*. In addition, during the post-test some students also changed their mindset so that the reasons put forward were different during the pre-test. It is known that students still use an intuitive approach by connecting the pressure concept of $P = F/A$ in answering Pascal's law questions. The students' reasons are evidence that there are still student difficulties related to mathematical equations, the tendency to think using naïve intuition in explaining physical phenomena and the tendency to only use one principle in solving problems (1).

For the last one, the students' questions and answers are presented when answering questions related to Archimedes' law.



Three identical blocks are at rest in a water-filled aquarium as shown on the left. Blocks B and C are attached to taut strings. Compare the buoyant force (the net force the water exerts) on the three blocks. (Wagner et al., 2014)

a. The buoyant force is greatest on A and smallest on C
b. The buoyant force is greatest on C and smallest on A
c. The buoyant force is equally great on A and B and smallest on C
d. The buoyant force is the same for all three blocks
e. It cannot be determined from the information given

FIGURE 3. Archimedes' law question

To answer this question, students must understand the concept of floating and sinking objects and relate it to Archimedes' law. In the problem, the three identical blocks are completely immersed in the liquid, which means displacing the volume of the liquid equal to the volume of the object. So, the correct answer is option D.

TABLE 6. Distribution of students' answers regarding Archimedes law

Sub Material	Archimedes' Law											
Option	A		B		C		D		E		NA	
	Pre	Po	Pre	Po	Pre	Po	Pre	Po	Pre	Po	Pre	Po
Total	0	5	3	2	0	20	0	9	5	0	28	0
%	0.0	13.9	8.3	5.5	0.0	55.6	0.0	25	13.9	0.0	77.8	0.0

Note: Pre = pre-test Po = post-test Green box = correct answer NA = No Answer

In the pre-test of Archimedes' law questions, it is known that no student can answer correctly in option D. 3 (8.3%) students answered option B, 5 (13.9%) students answered option E and 28 (77.8%) students did not answer. During the post-test, 9 (25%) students answered with the correct answer in option D, 5 (13.9%) students answered A, 2 (5.5%) students answered B, and 20 (55.6%) the student answers C. Some of the reasons given by students in the pre-test can be seen in Table 7.

TABLE 7. Students' reasons for pre-test and post-test of Archimedes' law

Pre-test		**Reasons**	**Post-test**	
%	**Option**		**Option**	**%**
-	-	The deeper it is, the greater the buoyancy, B (sinking) and C (floating) but it has an upward tension in the string so that the buoyancy is not greater than A which sinks.	A	13.9
-	B	Because block C has a smaller mass (lighter) and is pulled by the string, while block A sinks and is not pulled by the string.	B	5.5
8.3		Block C has the greatest buoyancy because it floats.		-
-	-	Because A and B sink, the buoyancy is the same, while C floats, the buoyancy is smaller.	C	55.6
-	-	Since the blocks are identical, so their density and volume are the same. The three blocks are completely immersed in water, so the magnitude of the buoyancy on blocks A, B and C is the same. *	D*	25
13.9	E	We don't know what kind of object was put into the water, so the magnitude of buoyancy cannot be determined.	-	-
77.8	NA	-	NA	-

* = answer and reason are correct

Students who answer with the right reasons know that identical blocks mean the same as a whole and assume the three objects are actually immersed (completely immersed) in liquid and the string that hangs the object has no effect on the magnitude of the buoyancy. Based on interviews with students who answered options A, B and C, they always said *"because block C is lighter, the buoyancy is smaller"* or *"because block C floats, the buoyancy force is smaller than blocks A or B"*. This shows that students do not actually understand the word "identical" in the questions that have been given. When asked about the concept of Archimedes' law, students mentioned the equation $F_a = \rho.g.V$. The equations mentioned by students are correct, but this shows that they do not fully understand the components of the equation (38). When no number is given, students use the equation incorrectly, incorrectly or not at all (6).

CONCLUSION

Based on the research results, the application of STEM integrated experiential learning with formative assessments shows that there is a significant difference between the pre-test and post-test scores. In addition, the results of the calculation of the N-gain score are in the moderate category. Even so, it is still difficult to remove misconceptions in students. On the topic of hydrostatic pressure, students still relate the volume and mass of water to the magnitude of hydrostatic pressure. In Pascal's law, students use the pressure equation incorrectly. Furthermore, in Archimedes' law students often relate mass to determine the magnitude of the buoyancy of an object. STEM integrated experiential learning with formative assessments can be applied to the school environment on other physics topics. Future researchers need to notice that implementing this learning requires a lot of time in preparing learning activities.

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