The exploration of mechanistic reasoning ability for high school students in static fluids

D D Nooritasari¹, S Kusairi¹,², H Wisodo¹

¹ Department of Physics, Faculty of Mathematics and Natural Sciences, Universitas Negeri Malang, Jl. Semarang 5, Malang, 65145, Indonesia
² Correspondence Author: sentot.kusairi.fmipa@um.ac.id

Abstract. The study aims to explore the mechanistic reasoning abilities of high school students in a static fluid material. This research was survey research using mixed-method. The subjects were 95 students of High School in the city of Batu and Malang. The instrument consisted of 5 question descriptions that were valid and reliable. The results showed the student’s mechanistic reasoning abilities were still in the moderate category. It was found that students had difficulty in analyzing mechanically to connecting physical phenomena with static fluid concepts. Most students mistakenly interpret the principle of hydrostatic pressure and Archimedes' law. Research provides practical benefits on the concept of static fluid, especially regarding the mechanistic reasoning of students' static fluid. The same mistake in each student can indicate a misconception that is difficult to remove. More effort is needed to master the concepts deeply to have good mechanistic reasoning abilities.

1. Introduction
The static fluid is a complex concept in physics. Yadaeni, Kusairi, and Parno states that static fluid material is one of the materials classified as difficult to be mastered by students [1]. The topic in static fluid material relates to the principle of forces in Newton's law so that students still find it difficult to master the concept, [2]. Students who can master the concept of static fluid well must also have coherent prerequisite knowledge, [3].

Several studies on the mechanistic reasoning of student’s static fluids have been carried out. Bolger, Kobiela, Weinberg, and Lehrer states that the ability to reason mechanically can increase student's cognitive knowledge about static fluid material [6]. Also, Besson said there are different types of reasoning (causal, mechanistic, etc.) that are directly related to the learning difficulties of static fluids, [7]. Krist, Schwarz, and Reiser in his research found that mechanistic reasoning can help students build knowledge (concepts) of static fluid as a whole and regularly [8]. According to the research of Young and Meredith, mechanistic reasoning is included in the source of procedural knowledge because it can improve students' cognitive productivity in learning static fluid material [9].

Based on the research above, it is necessary to do further research on the ability of mechanistic reasoning for static fluids. One way is to collect data in depth. A researcher not only sees the results of student’s scores in the form of numbers but also dialogue with students to find the difficulty of static fluids in detail. From the two data, the researcher can find out the extent of student’s ability to break up the mechanistic reasoning of static fluids.

This study aims to determine the ability of student’s mechanistic reasoning in static fluid concepts. The research also aims to describe the difficulties experienced by students in reasoning mechanically...
the concept of static fluid. This is important to study to measure the extent to which students’ abilities in mechanically reasoning static fluid concepts. Besides, it is hoped that the results of this study can be a reference for teachers in designing better learning to improve students’ mechanistic reasoning abilities. It is also expected to be able to become a study for researchers in the development of research into the ability of mechanistic reasoning for static fluid in learning physics.

2. Methods
This study was used as a mixed-method. The research subjects consisted of 95 students of class XII MIPA in the city of Batu and Malang. There are two measurement instruments used in this study, namely quantitative and qualitative measurement instruments. Quantitative measurement instruments used were in the form of problem descriptions about mechanistic reasoning as many as 5 questions with item indicators are presented in Table 1 as follows.

| Indicator Number | Indicator Description                                                                 | Question Number |
|------------------|---------------------------------------------------------------------------------------|-----------------|
| 1                | Presented in the form of a picture of a nurse putting an infusion in a patient, students can mechanically analyze the right position to put the infusion bag based on the hydrostatic pressure principle. | 1               |
| 2                | Presented a picture of a lemon, lime, and coca-cola in the fluid, students can mechanically analyze the events that occur when all objects are inserted into the fluid based on Archimedes’s Law. | 2 and 3         |
| 3                | Presented drawing in the form of a tool called Cartesian Diver and a hydraulic jack, students can mechanically analyze how the tools are based on Pascal’s Law. | 4 and 5         |

The qualitative measurement instrument was used interview guidelines. Some questions were asked to some students randomly. Interviews were held as soon as the questions were given. The results of the interview are useful for knowing the knowledge of mechanistic reasoning abilities and student difficulties in a static fluid material.

Data analysis of quantitative research results uses descriptive statistics, while qualitative data uses student answer coding. Russ and Odden, argues that there are three main aspects of coding on mechanistic reasoning based on mechanistic reasoning in professional science [10]. Students’ explanations of mechanistic reasoning are the identification of phenomenon, identification of the constituent phenomenon, and reasoning strategy are presented in Table 2 below.

| Step                               | Explanation                                                  |
|------------------------------------|--------------------------------------------------------------|
| Identification Phenomenon          | Students begin to recognize a physical phenomenon that occurs in everyday life. |
| Identification of the Constituent Phenomenon | Students then note several structural aspects in physical phenomena, such as conditions, entities, entity activity, the nature of the entity, and spatial organization. |
| Reasoning Strategy                 | Students can construct or reason mechanically a physical phenomenon using three aspects, that is: connecting, analogizing, and modeling. |

Furthermore, the results of encoding student’s answers are categorized into the level of mechanistic reasoning ability as follows: (1) Little Evidence. If the students answer only to the identification of phenomenon, (2) Moderate Evidence. If the student’s answers are not only identification of the phenomenon, but there is also an identification of the components making up the phenomenon, (3)
Strong Evidence. If the student’s answers include everything, from identifying phenomenon, identifying the constituent phenomenon, and reasoning strategies.

3. Results and Discussion

The results of the study stated that there are still many students who have difficulty in understanding the concept of static fluid. One such study was conducted by Wagner, Carbone, and Lindow, who found that students found it difficult to master the Archimedes principle because they had not mastered the concept of buoyancy properly [4]. Michellini and Stefanel, informs that 10-30% of students have difficulty connecting the concept of pressure on fluid with the principles of Pascal's law [5]. On the other hand, Simanjuntak in his research also found that students still have difficulty in solving fluid problems using the Newtonian approach [2]. The descriptive statistics of the research data are presented in Table 2 below.

Table 3. Descriptive Statistic.

| Variable            | Score |
|---------------------|-------|
| Total Students      | 95    |
| Standard Deviation  | 20,6  |
| Minimum Score       | 0     |
| Maximum Score       | 86    |
| Mean                | 46    |

Table 3 shows the minimum score obtained by students which are 0 and the maximum score is 86 on a scale from 0-100. The standard deviation is 20.6 and the average score of 95 students is 46. Descriptively, these results indicate that the mechanistic reasoning of student’s static fluids in the moderate category.

Quantitative data on student’s mechanistic reasoning abilities were analyzed by calculating student’s scores in solving problem descriptions from each question item indicator and calculating the percentage of each question item. Data on student's mechanistic reasoning abilities are shown in Figure 1 as follows.

Figure 1. Graph of Student’s Mechanistic Reasoning.

Based on the average achievement of the item indicators in Figure 1 above, it can be seen that the first indicator is related to mechanistic reasoning about the concept of hydrostatic pressure. The
percentage obtained in the mechanistic reasoning indicator of hydrostatic pressure is 59%. Meanwhile, the second indicator related to the mechanistic reasoning of Pascal’s law concepts obtained the highest percentage of 60%. Furthermore, the last item indicator, namely the mechanistic reasoning about Archimedes’s law concept, obtained the lowest percentage of 50%. From the percentage of the graph, it is known that students can reason mechanically Pascal’s Law better than hydrostatic pressure and Archimedes’s Law. Besides, information was also obtained that the Archimedes’s Law, the students find it difficult to reason mechanically.

The following is the result data of the student answers to question number 1 about the mechanical reasoning ability of the hydrostatic pressure shown in Figure 2 below.

![Figure 2](image)

**Figure 2. Student’s Answers to Question Number 1.**

Figure 2 above shows the results of student answers in item number 1 regarding the application of the concept of hydrostatic pressure in everyday life. The question asks how the working principle of the infusion so that intravenous fluids can enter the patient's body and what physical concepts are the basis of the infusion device. One of the students in the picture above can only describe the phenomenon that can be observed. The student did not explain precisely the working principle of setting an infusion device based on the principle of hydrostatic pressure. Students consider that the infusion is the application of the concept of potential energy because the placement of the infusion fluid bag at a high place so that fluid can easily enter the patient’s body. It causes students to experience misconceptions between height, pressure, and gravity. These results are by following Young, which explains that students build the concept of pressure on static fluids from several resources, one of which is energy [9]. From these resources, students then try to connect it
mechanically with hydrostatic pressure. The qualitative data from interviews with students is presented in Table 3 below.

**Table 4. Student’s Dialogue.**

| Dialogue                                                                 | Evidence                       |
|--------------------------------------------------------------------------|--------------------------------|
| Student A: “Laying the infusion bag should be higher than the patient’s body.” | Identification of phenomenon  |
| Student B: “For intravenous fluids to enter the patient’s blood vessels, the pressure in intravenous fluid must be greater than the blood pressure in the patient’s body.” | Identification of the constituent of the phenomenon |
| Student C: “The higher the infusion bag is located, the greater the infusion fluid pressure, because the height of the infusion fluid causes large potential energy.” | Reasoning strategy            |

From the student answer dialogue above, it can be seen that there are student’s answers that have reached the reasoning strategy. However, the concept used is still wrong. Students assume that the height of the position of the infusion bag can increase the pressure on the infusion fluid. The height of the infusion is precisely associated with the magnitude of the Potential Energy because students refer to the equation.

\[ E_p = mgh \]  

Where there is a height component \((h)\) there. Students do not observe as a whole, that the entity that is the focus in the observation is an intravenous fluid that is classified as a static fluid. The pressure applied by the static fluid is called hydrostatic pressure with the following equation.

\[ P_h = \rho gh \]

From the results of Goszewski research also states that students are often wrong in interpreting the height and depth of the position of objects that are in static fluid [11]. Loverude also found that one of the student’s mistakes in the concept of hydrostatic pressure is when determining pressure points in a static fluid. Some students still misunderstand that the greatest hydrostatic pressure is at the lowest point in the fluid [12].

The Data results of student’s answers to problem number 2 about the ability of mechanical reasoning in Archimedes' law is shown in Figure 3 below.

![Figure 3. Student’s Answers to Question Number 2.](image-url)
Figure 3 above shows the results of student answers in item number 2 regarding the application of Archimedes law concepts in everyday life. The question asks how a lemon can float in water while lime sinks in water. Students are asked to explain what component of the scale that makes up lemons and limes so that both oranges float and sink. One of the students' answers above stated that lime has a density greater than the density of water, so that lime can sink in water. But when the lemon and lime are cut, then the pieces are put into the water, the lemon still floats and the lime sinks. Students assume that the shape (mass) of lime is bigger than lemon. It should be the same, the density of lemons and lime does not change even though it has been cut into pieces. From the student’s answers, it appears that students are still confused in determining the composition of buoyancy in Archimedes law, namely density, not mass. These results are consistent with Besson’s findings, which explain that students obtain information from what is observed. From observable sources, objects that have greater mass have a greater lift. Therefore, students try to connect mechanically the concept of mass with the law of Archimedes. The qualitative data from interviews with students are presented in Table 4 below.

Table 5. Student’s Dialogue.

| Dialogue | Evidence           |
|----------|--------------------|
| Student A: “When it put in the water, the lemon floats, while the lime sinks.” | Identification of phenomenon |
| Students B & C: “The lemon can float because they’re something that causes it to float, namely the mass of the lemon is smaller than the lime. So the lemon floats and the lime sinks.” | Identification of constituent phenomenon |

From the student’s answer dialog above, it can be seen that none of the student answers reached the reasoning strategy. The concept used as a basis for thinking is still wrong. Students assume that the mass of fruit that causes it can float and sink. So students cannot relate this phenomenon to the buoyancy of Archimedes' law. The results of Wagner research found that students still experience misconceptions that assume that buoyancy is proportional to the mass of matter [4]. Students should be able to identify floating phenomena and sink to Archimedes's law concepts. So from this concept, it can be seen that the density affects buoyancy, not mass, as in the following equation.

\[ F_A = \rho_f g V_b \]  

(3)

4. Conclusion
The conclusion that can be drawn from this study is that students' mechanistic reasoning abilities are still in the moderate category. Besides, I also found some difficulties experienced by students on the concept of static fluid, that is, (1) difficulty in distinguishing phenomena between the height and depth of static fluid; (2) difficulty in analyzing Archimedes's law components, specifically the concept of density.

Based on the results of research and discussion, researchers suggest that physics teachers design learning that invites students to interpret the concept of static fluid as a whole and in-depth. The researcher recommends to the teacher to be able to map students' mistakes on important concepts such as hydrostatic pressure, Pascal's law, and Archimedes's law. This becomes very important because it will help students to find out their mistakes. It is also expected that the teacher can improve physics learning and not make an assessment at the end of the course to prevent student difficulties. The researchers are expected to investigate further to be able to find errors in static fluid concepts that have not yet been seen.

Acknowledgment
I thank Mr. Sentot Kusairi and Mr. Hari Wisodo for give feedback on the manuscript.
References

[1] Yadaeni A, Kusairi S and Parno P 2018 Penguasaan konsep dan keterampilan proses sains siswa kelas XII pada materi fluida statis J. Pendidikan : Teori Penelitian dan Pengembangan 3 357
[2] Simanjuntak M P 2014 Efektivitas model pembelajaran problem based learning terhadap penguasaan konsep mahasiswa pada konsep suhu dan kalor Jurnal Inpafi 3 8
[3] Kryjevskaia M, Stetzer, M R, and Grosz N 2014 Answer first : Applying the heuristic-analytic theory of reasoning to examine student intuitive thinking in the context of physics Physical Review Special Topics-Physics Education Research 2 10
[4] Wagner D J, Carbone E, and Lindow A 2014 Exploring student difficulties with bouyancy 2013 Physics Education Research Conference Proceedings 357-360
[5] Michelin M and Stefanel A 2019 Innovation in physics teaching/learning for the formative success in introductory physics for bio area degrees : the case of fluids Upgrading Physics Education to Meet the Needs of Society 153-168
[6] Bolger M S, Kobiela M, Weinberg P J and Lehrer R 2012 Children’s mechanistic reasoning Cognition and Instruction 2 170
[7] Besson U 2010 Calculating and understanding : formal models and causal explanations in science, common reasoning and physics teaching Science and Education 3 19
[8] Krist C, Schwarz CV and Reiser B J 2018 Identifying essential epistemic heuristics for guiding mechanistic reasoning in science learning Journal of the Learning Sciences 28 160-205
[9] Young D E and Meredith D C 2017 Using the resources framework to design, assess, and refine interventions on pressure in fluids Physical Review Physics Education Research 1 13
[10] Russ R S and Odden T O B 2017 Intertwining evidence- and model-based reasoning in physics sensemaking : an example from electronics Physical Review Physics Education Research 2 13
[11] Goszewski M, Moyer A, Bazan, Z and Wagner D J 2013 Exploring student difficulties with pressure in a fluid AIP Conference Proceedings 1513 154-157
[12] Loverude M E, Heron P R L, and Kautz C H 2010 Identifying and addressing student difficulties with hydrostatic pressure American Journal of Physics 1 75-85