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Research Artikel

EXPLORATION OF NOVICE STUDENTS IN PROBLEM SOLVING OF STATIC FLUID PHYSICS MATERIAL

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Abstract
One essential ability in physics is problem-solving ability. Problem-solving and physics are inseparable. This research aims to reveal how students solve physics problems. This research is quantitative descriptive research, namely describing students' problem-solving abilities in Static Fluid material. This research was conducted on 28 Physics education students at one of the State Universities in East Java. Data was collected through tests and in-depth interviews. The research instrument was two test items on statistical fluid problem-solving. The results show that the students' physics problem-solving abilities are still in the beginner category. Learners need to work on solving problems correctly with incomplete problem-solving aspects. The interviews showed that students' difficulties in the problem-solving process were mainly in determining the physics approach to use and bringing the physics approach to specific conditions. This analysis can help further studies of improving novice physics problem-solving abilities.

Keywords*: Expert; Fluid Statics; Problem Solving; Novice; Skills.*

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INTRODUCTION

Fluids are an essential physics content for students. In everyday life, students inhale and drink it in liquid or gas form (Karen Cumming, Priscilla Laws, Edward Redish, 2016). Students are required to have the ability to understand static fluid principles to support understanding of other principles in fluid mechanics (Kusairi et al., 2020). However, several difficulties are still encountered in solving physics problems, especially in static fluid materials. These difficulties include, difficulties in determining factors that influence buoyancy force, determining buoyancy force on substances that are not liquids, applying Pascal's Principle in hydraulic machines (Ammase et al., 2019; Kusairi et al., 2021), difficulties when solving problems non-routine on the Archimedes Principle (Koes-H et al., 2018, 2019), misconceptions that still occur, especially on the Archimedes Principle (Heron et al., 2003; Irawati et al., 2022; Ünal & Tu, 2005), determine The magnitude of the buoyancy force experienced by objects with different floating phenomena (Puspita et al., 2019), describes the position of the object relative to the magnitude of the buoyancy force experienced (Berek et al., 2016). Some of these difficulties still challenge increasing students' understanding of static fluid concepts. Students' success in applying static fluid principles cannot be separated from the quality of students' physics problem-solving.

Problem-solving and physics are two things that cannot be separated. One reason is that problem-solving is a key component of most physics studies (J. L. Docktor & Mestre, 2014). One of the goals of teaching physics is to educate fluent problem solvers who can transfer their knowledge and skills to real-world situations (Balta, 2019; Walsh et al., 2007). Apart from that, solving physics problems is the estuary of the goals of physics education, realized by developing student competencies (Niss, 2018). In practice, physics teachers usually use problem-solving as a mechanism for teaching physics content and assessing the level of mastery of that content (J. L. Docktor et al., 2016). The instructional goals of many introductory physics courses include helping students develop expert-like problem-solving skills while learning physics concepts (Mason et al., 2019).

Another reason is not only in physics; problem-solving skills are also a crucial ability demanded by society and a vital element to increase students' knowledge and understanding and prepare them to face life's challenges in the future (Rahman, 2019). One of them is in the business and industrial fields, which require mastery of problem-solving skills (World Economic Forum, 2020). In various fields of business and engineering, it is related to management, engineering, and science, and methods, techniques, and procedures for solving problems are the core things that must be mastered (de Mast et al., 2023). If problem-solving is used as a method, then not only expert problem solvers but also all problem solvers need to develop their problem-solving skills (Ince, 2018b).

Problem-solving in physics learning emphasizes expert problem solvers and novices. The characteristics of novice problem solvers are the opposite of expert problem solvers. Novices have a fragmented knowledge structure, while experts have comprehensive knowledge (Chen et al., 2020). Novices often experience strategy impasse in solving further problems, while experts conduct evaluations by monitoring progress in problem-solving (J. L. Docktor et al., 2012). Novices often experience strategy impasse in solving further problems, while experts conduct evaluations by monitoring progress in problem-solving (J. L. Docktor & Mestre, 2014). Novices tend to use a mathematical approach first, while experts understand problems and concepts first (Ince, 2018a). Novices need to recheck their problem-solving answers while experts check their answers to see if they make sense and spend more time planning their approach (Ali, M., Abd-Talib, C., Ibrahim, N. H., Surif, J., Abdullah, 2016; Burkholder et al., 2020; Chi et al., 1981). To become an expert, there must be the development of expert-like problem-solving and problem-solving skills (Balta, 2016). Developing conceptual understanding can be achieved by solving many problems (Buteler & Coleoni, 2016).

Studies to improve the physics problem-solving abilities of novice students must continue to be carried out. Although there is some research on how experts solve introductory-level physics problems, research is limited to the types of problems solved (J. L. Docktor & Mestre, 2014; Leak et al., 2017). Research that overcomes the limitations of problem types and studies how novices solve problems needs to be studied further. Additionally, identifying common difficulties in problem-solving processes opens up the possibility of predicting where various obstacles might arise (Niss, 2018). Identifying difficulties and measuring physics problem-solving abilities is expected to reveal several characteristics of physics problem-solvers. It is hoped that this can help students improve their physics problem-solving abilities.

METHOD

This research is descriptive quantitative research, describing students' problem-solving abilities in a static fluid material. Participants consisted of 28 second-year physics education students who had taken Basic Physics courses. Students consist of 25 female students and three male students.

The research instrument consists of two problem-solving test items. The test instrument developed is intended to reveal students' problem-solving abilities in static fluid material. The instrument was developed based on material in university physics books. Descriptions of the test items developed are shown in Table 1.

Table 1. Description of test item problems

Item	Content
First	Determine the type of material that makes up a metal statue which has a difference in mass when weighed in air and in water.
Second	Determine the number of buoys needed to accommodate a floating stall.

In-depth interviews were conducted to learn more about students' problem-solving abilities and identify students' problem-solving difficulties. Interviews were conducted after completing the problem-solving test. Interviews were conducted with several students representing several criteria found based on the student problem-solving test worksheet shown in Table 2.

Table 2. Interview Participant Criteria

Criteria	Description
First	Students who consistently answer incorrectly and have incomplete problem solving steps
Second	Students who consistently answer incorrectly and complete problem solving steps
Third	Students who consistently answer correctly and complete the solution steps
Fourth	Students who answer correctly but the problem solving steps are incomplete

The type of data produced is quantitative and qualitative data. Quantitative data results from working on problem-solving tests in the form of problem-solving scores at each problem-solving step, while qualitative data is in the form of interview data. Problem-solving test data was analyzed using descriptive analysis using a rubric developed by (J. L. Docktor et al., 2016). Aspects of problem-solving steps measured in the rubric are functional description, Physics Approach, Specific Application of physics, Mathematical Procedures, and Logical Progression. Scoring is in the range 1 to 5. The minimum score is 1, and the maximum score is 5. A complete description of each aspect of problem-solving is shown in Table 3.

Table 3. Categories of physics problem solving abilities

Indicators	Criteria	
	Expert	**Novice**
Useful Description	Describe the problem by summarizing relevant information in symbolic form of influential variables, images and verbally accurately and completely	Describe the problem by writing down the influencing variables which are incomplete, partially missing or contain errors
Physics Approach	Write a physics approach that is useful as a solution to the problem accurately and completely	Some of the physics approaches written down are not correct, are still wrong, and even skip this step
Specific Applicatio n of Physics	Select relevant equations as a solution by applying them to the problem	Just writing down the general equation without applying it according to the

	correctly and completely	problem, is incomplete, still contains errors, and doesn't even write it down
Mathematical Procedures	Carry out calculations according to procedures to obtain accurate and complete results	Processing and obtaining data is still inaccurate, incomplete, or even does not carry out calculations at all
Logical Progression	The solution process used is clear, focused and precise so that it is able to prove the suitability of the results obtained with the solution used	The solution process used is not clear, only rewrites the results obtained, and does not relate the results to the process used as a solution

((J. Docktor & Heller, 2009; J. L. Docktor et al., 2016; Hull et al., 2013)

The problem solving categories shown in Table 3 are used to categorize problem solving, especially in the field of physics education.

RESULTS AND DISCUSSIONS

Based on the physics problem solving test given, a score was obtained that describes students' problem solving abilities. The results of the analysis of the average scores of students' physics problem solving abilities in each aspect for each test item are shown in Figure 1.

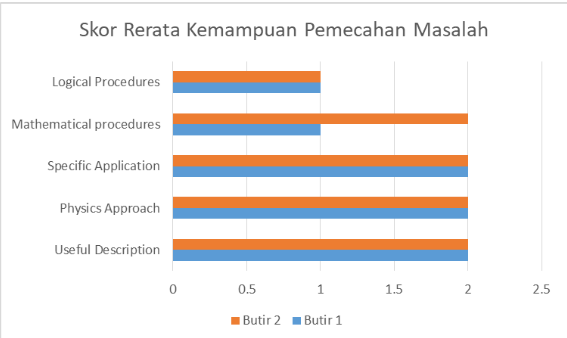


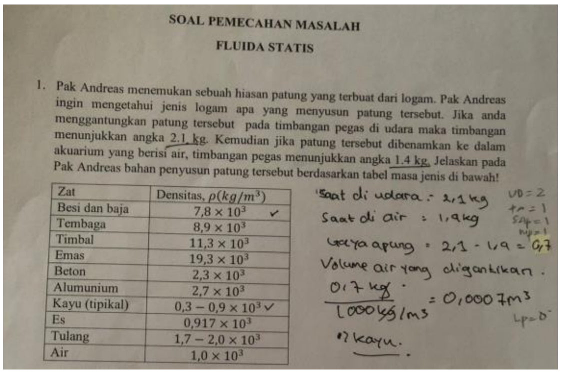
Figure 1. Average problem solving score in each aspect

Based on Figure 1 presents the results of students' physics problem-solving tests. It was found that most of the students were novice problem solvers (novices). It is shown that the average aspects of Useful description, physics approach, and specific application get a higher score than the aspects of mathematical procedures and logical progression. Some students have provided descriptions, but the descriptions still need to be completed. Students only repeat the information that has been included in the question items. In the physics approach aspect, students have provided a physics approach, but the approach is based on memorization and needs to be adapted to the context of the problem. In the specific aspect of the application, it is shown that it is still not appropriate to bring the context of the problem more specifically. The logical progression aspect shows that the average student gives unclear, unfocucould clearer, more focused, and consistent known that experts monitor their progress when solving problems and evaluate the reasonableness of their answers (Reif et al., 2016). Students must be able to reflect on and metacognitive about their learning. Students who do not perform well lack content knowledge and metacognitive skills that allow them to recognize their deficiencies in content knowledge (Lindsey & Nagel, 2015; Sularso et al., 2017).

Based on the quantitative data analysis carried out, several problem-solving patterns were found by students. The work results of several students were analyzed in depth to describe the quality of students' problem-solving abilities. It was found that some of the students' problem-solving abilities were still in the beginner realm. In-depth interviews were conducted with several categories of students to find out more about the quality of problem-solving.

First category

The first category is students who are consistently inaccurate in solving problems with incomplete problem solving steps. The results of student answers to item 1 are shown in Figure 2.


SOAL PEMECAHAN MASALAH

FLUIDA STATIS

1. Pak Andreas menemukan sebuah hiasan patung yang terbuat dari logam. Pak Andreas ingin mengetahui jenis logam apa yang menyusun patung tersebut. Jika anda menggantungkan patung tersebut pada timbangan pegas di udara maka timbangan menunjukkan angka 2.1 kg. Kemudian jika patung tersebut dibenamkan ke dalam akuarium yang berisi air, timbangan pegas menunjukkan angka 1.4 kg. Jelaskan pada Pak Andreas bahan penyusun patung tersebut berdasarkan tabel masa jenis di bawah!

Zat	Densitas, $\rho (kg/m^3)$
Besi dan baja	$7,8 \times 10^3$ ✓
Tembaga	$8,9 \times 10^3$
Timbal	$11,3 \times 10^3$
Emas	$19,3 \times 10^3$
Beton	$2,3 \times 10^3$
Alumunium	$2,7 \times 10^3$
Kayu (tipikal)	$0,3 - 0,9 \times 10^3$ ✓
Es	$0,917 \times 10^3$
Tulang	$1,7 - 2,0 \times 10^3$
Air	$1,0 \times 10^3$

Saat di udara : 2,1 kg
Saat di air : 1,9 kg
Gaya apung = 2,1 - 1,9 = 0,7
Volume air yang digantikan .
0,7 kg / 1000 kg/m3 = 0,0007 m3
kayu.

Figure 2. Student answers to item 1

Based on Figure 2, it is known that students only use verbal representations in problem-solving.

Students solve problems with poor quality. Students have not used the right approach to physics; students have not used Archimedes' Law approach. Students divide the difference in mass of objects in air and water by the density of water. A more in-depth explanation of the problem-solving process was explored through in-depth interviews. The following are the results of in-depth interviews conducted by researchers with students.

Researcher: *What are the difficulties in working on the questions?*

Student: *I need help understanding the conditions of objects in water and air and why their weight can be different.*

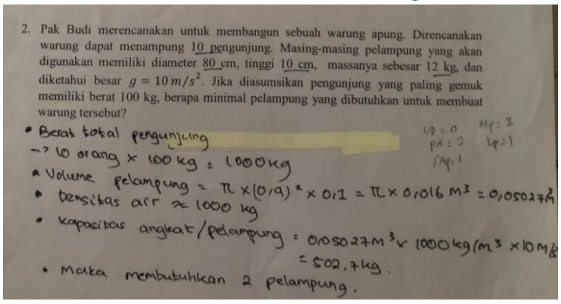
Researcher: *What is the context for solving question 1?*

Student: *As far as I remember, in fluids, when an object in water, for example, spills water, the weight of the spilled water is the same as the weight of the load that was immersed.*

Researcher: *How do you calculate the density of the statue so you can find out what type of material the statue is made of?*

Student: *You can find out by reducing objects in the air and in water. So, from the buoyancy force, I concluded that the volume of water replaced.*

The results of student problem solving in the second item are shown in Figure 3 below.



2. Pak Budi merencanakan untuk membangun sebuah warung apung. Direncanakan warung dapat menampung 10 pengunjung. Masing-masing pelampung yang akan digunakan memiliki diameter 80 cm, tinggi 10 cm, massanya sebesar 12 kg, dan diketahui besar $g = 10\, m/s^2$. Jika diasumsikan pengunjung yang paling gemuk memiliki berat 100 kg, berapa minimal pelampung yang dibutuhkan untuk membuat warung tersebut?

- Berat total pengunjung
  → 10 orang × 100 kg = 1000 kg
- Volume pelampung = π × (0,4)² × 0,1 = π × 0,016 m³ = 0,05027 m³
- Densitas air ≈ 1000 kg
- Kapasitas angkat/pelampung = 0,05027 m³ × 1000 kg/m³ × 10 m/s²
  = 502,7 kg.
- Maka membutuhkan 2 pelampung.

Figure 3. Student answers to item 2

To find out more about the problem solving process, researchers conducted in-depth interviews with students in number 2. The results of the in-depth interviews are shown as follows.

Researcher: *How is the solution for item 2?*

Student: *First, I found the mass of people occupying the buoy by multiplying the mass by the number of people. It is known that the buoy contains the diameter and height of the buoy, so I looked for the volume of the buoy. So, to find the float's capacity by multiplying the float's volume, the density of the water and gravity. So, approximately two floats are needed.*

Researcher: *Why do you need two buoys?*

Student: *The lifting capacity is 500 N, and it is known that the person's mass is 1000 kg. If the buoy lifting capacity is 500, then 2 are needed to accommodate 1000 kg.*

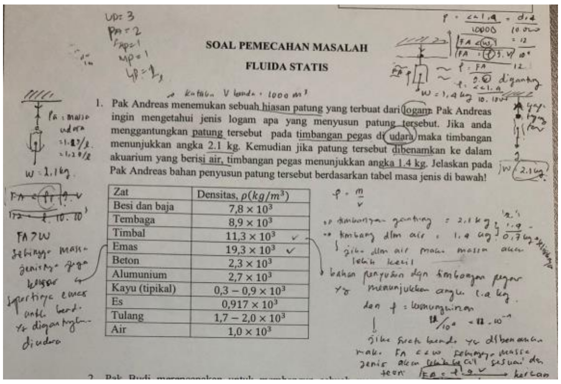
Researcher: *What help is needed to facilitate the problem-solving process?*

Student: *I have difficulty understanding the context of the problem; help by providing initial instructions leading to the physics approach used.*

Based on tests and in-depth interviews, it is known that students are categorized as novice problem solvers. Student test answers show that students need to describe the problem completely, the physics approach used needs to be completed, only general equations are written, data is processed using short calculations, and the results are not related to the process used. The main difficulty for students is understanding the problem, determining the physics approach to use, and bringing it to specific conditions. The problem-solving approach students use is not specific to certain physical principles; the physical principles that should be used are Newton's First Law and Archimedes' Law. The student's approach must be more superficial, leading to rote memorization. In the second point, students only review the condition of the buoy based on the lifting force on the buoy. Students need to review the overall system, namely that there are other conditions, namely the gravity experienced by the submerged buoy. So, students tend to think that the buoyant force will increase if the object's volume is increased (Kiray et al., 2015). If students review the entire system, students will be able to understand the problem comprehensively, not just in parts.

Second Category

The second category is students in the problem solving category who consistently answer incorrectly with complete problem solving steps. The problem solving carried out by students in point 1 is shown in Figure 4 below.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Es	$0{,}917 \times 10^3$
Tulang	$1{,}7 - 2{,}0 \times 10^3$
Air	$1{,}0 \times 10^3$

Figure 4. Student answers to item 1

Researchers dig deeper into solving student problems in number 1 by conducting in-depth interviews. The results of the interview are as follows.

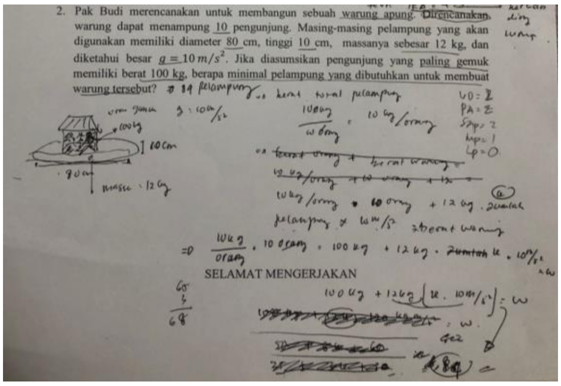
Researcher: *What are the difficulties encountered in problem-solving?*

Student: *When solving a problem, I wonder whether what I understand and imagine does not match the answer that should be. Does the formula suit the context of the question given?*

Researcher: *How do you explain the solution to question 1?*

Student: *Point 1 is about density, with ρ=m/v, but I am confused about connecting the weight of an object in the air and water with the density approach*.

The problem solving carried out by students in the second point which discusses determining the number of buoys needed to accommodate the floating stall is shown in Figure 5 below.


2. Pak Budi merencanakan untuk membangun sebuah warung apung. Direncanakan warung dapat menampung 10 pengunjung. Masing-masing pelampung yang akan digunakan memiliki diameter 80 cm, tinggi 10 cm, massanya sebesar 12 kg, dan diketahui besar $g = 10\,m/s^2$. Jika diasumsikan pengunjung yang paling gemuk memiliki berat 100 kg, berapa minimal pelampung yang dibutuhkan untuk membuat warung tersebut?

SELAMAT MENGERJAKAN

Figure 5. Student answers to item 2

Based on Figure 5, it shows that students are problem solvers who tend to describe problems in the form of pictures. Students draw a floating stall with visitors inside and float underneath. However, because they had not yet received a definite answer, the students described a giant buoy holding the floating stall. When they have to bring these problems to a physics approach for solving, students experience difficulties. Students do not bring problems to a specific physics approach, where students should be able to use Newton's first law and Archimedes' law. The problem-solving process can be explored more deeply through the results of the following interview.

Researcher: *How to solve question 2?*

Student: *I answered carelessly, not based on the laws of physics. I imagined this problem with pictures. However, I needed help determining the use of the formula.*

Researcher: *That is right, you gave a pretty good initial description by describing and giving verbal explanations. Does it help?*

Students: *It would be beneficial if pictures/illustrations were given in the questions (because students misdescribe the buoys, the size of the buoys is enormous)*

Researcher: *What physics approach is used, and why do you use this physics approach?*

Student: *Archimedes' law approach, namely sinking, floating, and drifting.*

Based on test answers and interviews, it is known that students are novice problem solvers. It was found that although the problem-solving steps taken were complete, some needed to be corrected. It was shown that when solving the problem on the first test item, students used a physics approach, namely density. When bringing the case to specific physical conditions, students need help determining the relationship between the weight of objects in air and water using the density approach. In the worksheet, students say that an object immersed in a liquid will experience a lifting force of $F_A = \rho \cdot g$. Students cannot continue problem-solving to explain the approach to more specific conditions.

The results of the interviews showed that students realized that the physics approach used when solving problems was based on something other than physical theory. However, students find it helpful if, at the beginning, when solving a problem, they provide an initial description. Students know that the physics approach used should be Archimedes' Law. It is known that solving problems with complete problem-solving steps can help students understand the problem as a whole. The first step is especially to describe the problem with relevant information. Students tend to use pictorial and verbal representations to describe problems.

Third category

The third category is students who consistently answer correctly with incomplete problem solving steps. The results of students' physics problem solving in the first items are shown on the worksheet in Figure 6 below.

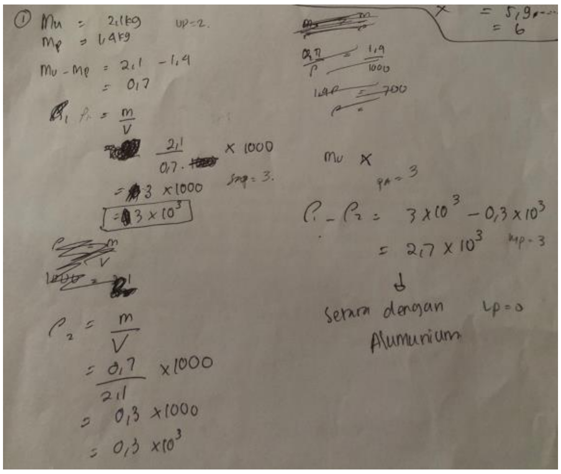


Figure 6. Student answers to item 1

Figure 6 shows that students are problem solvers who do not use detailed initial descriptions in solving initial problems. Students solve problems directly using a physics approach with a few descriptions of the problem's concept. The physics approach used does not refer specifically to the supposed physics approach. Students tend to view the conditions of objects in the air and water separately—the results of the researcher's interviews with students related to the problem of the first items.

Researcher: *What difficulties do you face when solving problems?*

Student: *I often forget the formula*

Researcher: *What physics approach is used in item 1?*

Student: *Archimedes*

Researcher: *How do you solve problem items 1?*

Student: *I tried to solve it with unit analysis. Usually, m^3 is a unit of volume, and kg is a unit of mass. So, I use mass/volume for the solution. There are two masses, namely in air and water; I look for the difference, and then I compare the masses in air and water.*

Researcher: *Why use unit analysis in solving problems?*

Student: *There is no particular reason, but it often happens because they forget the physics approach that should be used.*

Based on the results of interviews with students, it is known that students need to be more expert problem solvers in using a physics approach. However, students solve problems using a unit analysis approach. So, the problem-solving approach is obtained from analyzing units. This is because students need help recalling the physics approach that should be used, in this case, Archimedes' Law, namely the concept of apparent weight. Even so, students solve problems with the right solution.

The results of student problem-solving in the second point can be seen in the student worksheet shown in Figure 7 below.

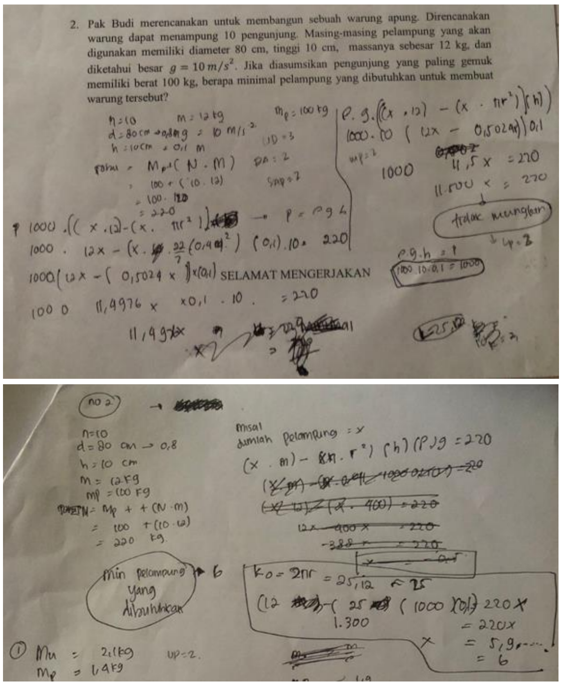


Figure 7. Student answers to point 2

Based on student answers in Figure 7, it is known that the problem solving carried out is not based on a physics approach. In the second point, students are asked to design the number of buoys needed to accommodate a floating stall. Students solve problems using approaches.

Researcher: *What is the explanation for solving the problem in point 2?*

Student: *I tried using the formula for the area of a circle, but the result was too big, so I concluded it was impossible. Then I tried to solve it with the circle's circumference because the floats are circular, so I got the result six floats.*

Researcher: *Why use this approach?*

Student: *Because the item discusses circular buoys, it probably has something to do with the area and circumference of the circle. When I used Archimedes' law, I did not get a solution.*

Based on the results of the author's interviews with students, it is known that students have yet to use a physics approach in solving problems. Students solve problems by using a mathematical approach. Presented by students, the approach used is the area and circumference of a circle approach. This is based on the shape of the float, which is a circle. When using the circle area approach, students get results so large that it is impossible to use that approach. Next, the students used the circumference approach and obtained the results of 6 buoys needed to hold the floating stall. So, it is concluded that students need to be more expert physics problem solvers. However, it was found that these students had quite good mathematical reasoning abilities.

Fourth Category

The fourth category is students who consistently answer correctly with complete problem solving steps. The results of student problem solving are shown on the student worksheet in Figure 8 below.

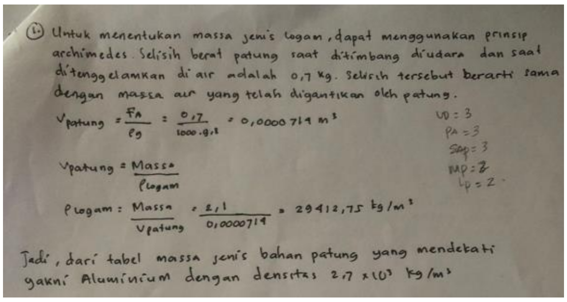


Figure 8. Student answers to item 1

Based on student answers, it is shown that students are problem solvers who tend to use verbal representations. This verbal description leads to the physics approach used to solve the problem. In this case, students use Archimedes' approach to determine the density of the statue so that the type of material that makes it up can be known. However, the solution to this case is still not appropriate and forces the type of constituent material to be aluminum.

Researcher: *What are the difficulties during the problem-solving process?*

Student: *Analyze the problem and determine what physics approach should be used later because the problem does not directly enter the Archimedes formula*

Researcher: *How is problem number 1 solved? What do you think it's about?*

Student: *about Archimedes, especially buoyancy. F_a/ρ to find the volume of the statue. The mass of the statue, seen from the mass of water that spills, is the same as the mass of the statue. So, the density of the metal is obtained by dividing the mass of the metal in air by the volume of the statue.*

Based on interviews conducted, it is known that students have no difficulty determining the physics approach to use. However, difficulties in leading to more specific conditions. The quality of student problem solving is shown in the student answers in Figure 9 below.

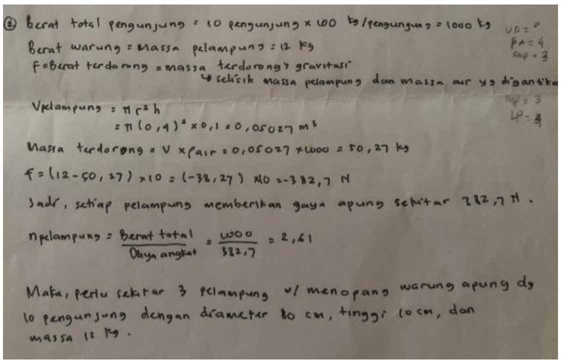


Figure 9. Student answers to item 2

Researcher: *How is question number 2 solved? About what?*

Student: *The solution uses Archimedes' buoyant force. Find the lifting force (F_a) the pushed mass × g.*

Researcher: *Why don't you give an initial description like number 1, which could be verbal or pictorial?*

Student: *sometimes, I write a description at the beginning of problem-solving.*

Researcher*: Did this step help?*

Student: *Yes, very helpful.*

Based on student test answers, it is known that students tend to use verbal representations in the problem solving process. It turns out that these verbal descriptions help students in the problem-solving process because the descriptions are more complete and easier to remember. Students have used the right approach but still view the problem as a separate system when bringing the problem to a specific condition. It is stated that in fact some students have the knowledge needed to solve problems but they do not try to apply it (Gette et al., 2018). Therefore, some students are novice problem solvers. Novices are said to be unable to make connections, especially in complex and difficult problems. At the same time, experts need more time to understand the problem and concepts involved in the problem and to explore the relationship between information and concepts (Ince, 2018b). For example, when faced with the problem of floating and sinking, students are required to provide complex explanations, not just simple relationships (J Radovanović, 2019). Students tend not to try to use the knowledge they have and choose to make simple connections. Based on the results of the interviews, the four students had the same problem, namely the difficulty of bringing a physics approach to specific conditions. However, some students do it differently. One of them is students in the third category who use mathematical representation as an alternative approach.

The problem that is the same in all four categories of problem solvers is the inability to relate the information in the case to the physics approach. This is because students do not view cases based on the system. Students tend to view cases as separate systems. Expert problem solvers can view cases holistically. Therefore, the fourth students are novice problem solvers. Both cases should be solved using Archimedes' law, but students still need help finding the right solution.

This follows the results of interviews with students who expressed the same difficulties. Training students to carry out the problem-solving process with complete and structured steps is recommended. So that students do not view cases in a narrow and separate form. For example, providing descriptions verbally or in pictures can direct students to determine the right approach to physics. The use of representations in problem-solving influences the quality of problem-solving, especially as assistance for some students. Because representation correlates with thought patterns, namely students' views on a phenomenon (Mansyur et al., 2023; Nikat et al., 2021; Taher et al., 2017). The quality of the test instrument influences the student's problem-solving process when given a complex problem the expert should be able to analyze the influencing factors and determine the physics approach used (Ringo et al., 2019). The problems raised can be related to everyday life so that they make a significant contribution to student learning (Jamaludin & Batlolona, 2021; Lutsenko, 2018).

Future research needs to conduct in-depth interviews to explore more deeply the quality of students' problem-solving on different materials. Apart from that, further studies regarding the problem-solving process with complete aspects need to be carried out to improve students' problem-solving abilities. The weakness of this research is that the sample size still needs to be bigger. Studies need to be carried out on other materials with larger samples.

CONCLUSION

Problem-solving carried out by students is still categorized as a novice. In the problem-solving process, students tend to work incorrectly, and problem-solving aspects need to be completed. Some students skip making an initial description and go straight to physics or mathematical equations. The physics approach used is still inappropriate and shallow because students still need help connecting the information in the case with the physics approach used. Students experience these difficulties because students need to view the problem as a unified system, not separate cases from one another. Students also tend to skip the final problem-solving step, namely logical progression. In the future, students need to be trained to carry out problem-solving processes with complete and systematic problem-solving aspects because these systematic problem-solving steps are expected to help students improve their problem-solving skills.

REFERENCES

Ali, M., Abd-Talib, C., Ibrahim, N. H., Surif, J., Abdullah, A. . (2016). The importance of monitoring skills in physics problem solving. *European Journal of Education Studies*. https://doi.org/http://dx.doi.org/10.46827/ejes.v0i0.54

Ammase, A., Siahaan, P., & Fitriani, A. (2019). Identification of junior high school students' misconceptions on solid matter and pressure liquid substances with four tier test. *Journal of Physics: Conference Series*, *1157*(2). https://doi.org/10.1088/1742-6596/1157/2/022034

Balta, N. (2016). Surveying Turkish high school and university students' attitudes and approaches to physics problem solving. *Physical Review Physics Education Research*, *12*(1). https://doi.org/10.1103/PhysRevPhysEducRes.12.010129

Balta, N. (2019). Introductory students' attitudes and approaches to physics problem solving: Major, achievement level and gender differences. *Journal of Technology and Science Education*, *9*(3), 378–387. https://doi.org/10.3926/JOTSE.666

Berek, F. X., Sutopo, S., & Munzil, M. (2016). Concept enhancement of junior high school students in hydrostatic pressure and archimedes law by predict-observe-explain strategy. *Jurnal Pendidikan IPA Indonesia*, *5*(2),230–238. https://doi.org/10.15294/jpii.v5i2.6038

Burkholder, E., Blackmon, L., & Wieman, C. (2020). Characterizing the mathematical problem-solving strategies of transitioning novice physics students. *Physical Review Physics Education …*. https://doi.org/10.1103/PhysRevPhysEducRes.16.020134

Buteler, L., & Coleoni, E. (2016). Solving problems to learn concepts, how does it happen? A case for buoyancy. *Physical Review Physics Education Research*, *12*(2), 1–12. https://doi.org/10.1103/PhysRevPhysEducRes.12.020144

Chen, Q., Zhu, G., Liu, Q., Han, J., Fu, Z., & Bao, L. (2020). Development of a multiple-choice problem-solving categorization test for assessment of student knowledge structure. *Physical Review Physics Education Research*, *16*(2), 20120. https://doi.org/10.1103/PhysRevPhysEducRes.16.020120

Chi, M. T. H., Feltovich, P. J., & Glaser, R. (1981). Categorization and representation of physics problems by experts and novices. *Cognitive Science*, *5*(2), 121–152. https://doi.org/10.1207/s15516709cog0502_2

de Mast, J., Steiner, S. H., Nuijten, W. P. M., & Kapitan, D. (2023). Analytical Problem Solving Based on Causal, Correlational and Deductive Models. *American Statistician*, *77*(1), 51–61. https://doi.org/10.1080/00031305.2021.2023633

Docktor, J., & Heller, K. (2009). Assessment of student problem solving processes. *AIP Conference Proceedings*, *1179*, 133–136. https://doi.org/10.1063/1.3266696

Docktor, J. L., Dornfeld, J., Frodermann, E., Heller, K., Hsu, L., Jackson, K. A., Mason, A., Ryan, Q. X., & Yang, J. (2016). Assessing student written problem solutions: A problem-solving rubric with application to introductory physics. *Physical Review Physics Education Research*, *12*(1), 1–18. https://doi.org/10.1103/PhysRevPhysEducRes.12.010130

Docktor, J. L., & Mestre, J. P. (2014). Synthesis of discipline-based education research in physics. *Physical Review Special Topics - Physics Education Research*, *10*(2). https://doi.org/10.1103/PhysRevSTPER.10.020119

Docktor, J. L., Mestre, J. P., & Ross, B. H. (2012). Impact of a short intervention on novices' categorization criteria. *Physical Review Special Topics - Physics Education Research*, *8*(2), 1–11.

https://doi.org/10.1103/PhysRevSTPER.8.020102

Gette, C. R., Kryjevskaia, M., Stetzer, M. R., & Heron, P. R. L. (2018). Probing student reasoning approaches through the lens of dual-process theories: A case study in buoyancy. *Physical Review Physics Education Research*, *14*(1), 10113. https://doi.org/10.1103/PhysRevPhysEducRes.14.010113

Heron, P. R. L., Loverude, M. E., Shaffer, P. S., & McDermott, L. C. (2003). Helping students develop an understanding of Archimedes' principle. II. Development of research-based instructional materials. *American Journal of Physics*, *71*(11), 1188–1195. https://doi.org/10.1119/1.1607337

Hull, M. M., Kuo, E., Gupta, A., & Elby, A. (2013). Problem-solving rubrics revisited: Attending to the blending of informal conceptual and formal mathematical reasoning. *Physical Review Special Topics - Physics Education Research*, *9*(1), 1–16. https://doi.org/10.1103/PhysRevSTPER.9.010105

Ince, E. (2018a). An Overview of Problem Solving Studies in Physics Education. *Journal of Education and Learning*. https://eric.ed.gov/?id=EJ1179603

Ince, E. (2018b). An Overview of Problem Solving Studies in Physics Education. *Journal of Education and Learning*, *7*(4), 191. https://doi.org/10.5539/jel.v7n4p191

Irawati, R. K., Sofianto, E. W. N., Assidiqi, H., & Rahmawati, I. (2022). Pascal or Archimedes: Which Misconception is Higher? *Journal of Physics: Conference Series*, *2392*(1), 0–6. https://doi.org/10.1088/1742-6596/2392/1/012030

J Radovanović, J. S. and I. S. I. (2019). *Active learning of buoyancy: an effective way to change students' alternative conceptions about floating and sinking*.

Jamaludin, J., & Batlolona, J. R. (2021). Analysis of Students' Conceptual Understanding of Physics on the Topic of Static Fluids. *Jurnal Penelitian Pendidikan IPA*, *7*(SpecialIssue), 6–13. https://doi.org/10.29303/jppipa.v7ispecialissue.845

Karen Cumming, Priscilla Laws, Edward Redish, P. C. (2016). *Understanding physics*. John Wiley & Sons, Inc.

Kiray, S. A., Aktan, F., Kaynar, H., Kilinc, S., & Gorkemli, T. (2015). A descriptive study of pre-service science teachers' misconceptions about sinking-floating. *Asia-Pacific Forum on Science Learning and Teaching*, *16*(2).

Koes-H, S., Muhardjito, M., & Wijaya, C. P. (2018). Scaffolding for solving problem in static fluid: A case study. *AIP Conference Proceedings*, *1923*. https://doi.org/10.1063/1.5019519

Koes-H, S., Suwasono, P., & Pramono, N. A.(2019). Efforts to improve problem solving abilities in physics through e-scaffolding in hybrid learning. *AIP Conference Proceedings of the 6th International Conference for Science Educators and Teachers (ISET)* volume 2081. https://doi.org/10.1063/1.5094004

Kusairi, S., Hardiana, H. A., Swasono, P., Suryadi, A., & Afrieni, Y. (2021). E- Formative Assessment Integration in Collaborative Inquiry: A Strategy to Enhance Students' Conceptual Understanding in Static Fluid Concepts. *Jurnal Pendidikan Fisika Indonesia*, *17*(1), 13–21. https://doi.org/10.15294/jpfi.v17i1.23969

Kusairi, S., Rosyidah, N. D., Diyana, T. N., & Nisa, I. K. (2020). Conceptual understanding and difficulties of high school students in urban and rural areas: Case of archimedes' principles. *AIP Conference Proceedings*, *2215* (April). https://doi.org/10.1063/5.0000752

Leak, A. E., Rothwell, S. L., Olivera, J., Zwickl, B., Vosburg, J., & Martin, K. N. (2017). Examining problem solving in physics-intensive Ph.D. research. *Physical Review Physics Education Research*, *13*(2), 1–13. https://doi.org/10.1103/PhysRevPhysEducRes.13.020101

Lindsey, B. A., & Nagel, M. L. (2015). Do students know what they know? Exploring the accuracy of students' self-assessments. *Physical Review Special Topics - Physics Education Research*, *11*(2), 1–11. https://doi.org/10.1103/PhysRevSTPER.11.020103

Lutsenko, G. (2018). Case study of a problem-based learning course of project management for senior engineering students. *European Journal of Engineering Education*, *43*(6), 895–910. https://doi.org/10.1080/03043797.2018.1454892

Mansyur, J., Werdhiana, I. K., Darsikin, D., Kaharu S. N., Tadeko, N. (2023). Students' External Representation Patterns of Suspending Objects in Static Fluid. *European Journal of Educational Research*, *12*(2), 749–758.

Mason, A., Good, M., & Singh, C. (2019). Surveying physics and astronomy students' attitudes and approaches to problem solving. In *Proceedings of the Physics Education* per-central.org. https://www.per-central.org/items/perc/4969.pdf

Nikat, R. F., Loupatty, M., & Zahroh, S. H. (2021). Kajian Pendekatan Multirepresentasi dalam Konteks Pembelajaran Fisika. *Jurnal Pendidikan Dan Ilmu Fisika*, *1*(2), 45. https://doi.org/10.52434/jpif.v1i2.1449

Niss, M. (2018). What Is Physics Problem-Solving Competency? The Views of Arnold Sommerfeld and Enrico Fermi. *Science and Education*, *27*(3), 357–369. https://doi.org/10.1007/s11191-018-9973-z

Puspita, W. I., Sutopo, S., & Yuliati, L. (2019). Identifikasi penguasaan konsep fluida statis pada siswa. *Momentum: Physics Education Journal*, *3*(1), 53–57. https://doi.org/10.21067/mpej.v3i1.3346

Rahman, M. (2019). 21st century skill'problem solving': Defining the concept*., MM (2019). 21st Century Skill "Problem Solving"* https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3660729

Reif, F., Heller, J., Reif, F., & Heller, J. I. (2016). *Knowledge structure and problem solving in physics*. *January 1982*. https://doi.org/10.1080/00461528209529248

Ringo, E. S., Kusairi, S., Latifah, E., & Tumanggor, A. M. R. (2019). Student's Problem Solving Skills in Collaborative Inquiry Learning Supplemented by Formative E-Assessment : Case of Static Fluids. *Journal of Physics: Conference Series*, *1397*(1). https://doi.org/10.1088/1742-6596/1397/1/012012

Sularso, S., Sunarno, W., & Sarwanto, S. (2017). Understanding students' concepts through guided inquiry learning and free modified inquiry on static fluid material. *International Journal of Science and Applied Science: Conference Series*, *2*(1), 363. https://doi.org/10.20961/ijsascs.v2i1.16746

Taher, M., Hamidah, I., & Suwarma, I. R. (2017). Profile of Students' Mental Model Change on Law Concepts Archimedes as Impact of Multi-Representation Approach. *Journal of Physics: Conference Series*, *895*(1), 0–6. https://doi.org/10.1088/1742-6596/895/1/012101

Ünal, S., & Tu, B. C. O. Ş. (2005). *Problematic issue for students : Does it sink or float ?* *6*(1), 1–16.

Walsh, L. N., Howard, R. G., & Bowe, B. (2007). *Phenomenographic study of students ' problem solving approaches in physics*. *December*, 1–12. https://doi.org/10.1103/PhysRevSTPER.3.020108

World Economic Forum. (2020). *Annual Report*.