Profile of students' critical thinking processes on the topics of Hydrostatic Pressure and Archimedes’ principle

N D Rosyidah¹, S Kusairi¹*, A Taufiq¹ and Y Affriyenni¹

¹Departement of Physics, Faculty of Mathematics and Natural Sciences, Universitas Negeri Malang, Jl. Semarang 5, Malang, 65145, Indonesia

*corresponding author : sentot.kusairi.fmipa@um.ac.id

Abstract. In learning physics, students often have difficulty in understanding concepts. This certainly has an impact on students' critical thinking skill. This study aims to analyze students’ critical thinking skills related to the concept of hydrostatic and Archimedes’ principle. This research was conducted using a qualitative descriptive design. The research subjects were students of class XII MIPA in Malang (N = 127). Data collection was carried out through a series of tests in the form of essay and interview questions. The indicator used to create critical thinking questions refers to the five main perspectives presented by Hughes. The results show that the majority of students have relatively low critical thinking skill. It is shown by the average score of critical thinking skill of students which only reached 36.1 from the maximum score of 90. The main cause of the low critical thinking skill of students was the presence of misconceptions experienced by students. The low critical thinking process of students are also caused by students have not yet accustomed to applying the concepts of physics in daily life.

1. Introduction

Physics is one of the important branches of science to be understood by students. Physics is able to teach students how to analyze natural events scientifically [1]. Physics has a major contribution to the development of technology in various fields such as in the fields of medicine and health, communication, transportation, and industry [2]. The concepts of physics should be understood well by students because technology development is increasing to be sophisticated in every year.

One of the concept of physics that must be understood by students is the hydrostatic pressure and Archimedes’ principle. The concept of hydrostatic pressure and Archimedes’ principle are widely applied in daily life such as in the construction of dams, installation of infusions, and submarine making. This concept is taught to the students with the aim that students are able to apply these concepts in deciding an action or making a tool for certain interests in everyday life [3]. These goals can be achieved by students through the development of a skill that is in accordance with the demands of the 21st century [4].

There are several skills that must be mastered by students in the 21st century. One type of expertise is critical thinking skill [5][6][7]. The ability to think critically is involved in the social and interpersonal condition in daily life such as in decision making and problem-solving [8]. This skill is also very needed in the field of education because it allows students not only keep information but also students will process the information that is served to get more complex understanding [9].
The level of critical thinking ability of students is very important to be analyzed because according to the 2013 curriculum critical thinking is one of the abilities that must be trained to students. Before practicing these abilities, teachers must understand the causes of students' low critical thinking skills. Previous researchers only looked at the average value of all students without identifying more deeply related to the difference in the thought processes of students with high and low abilities. However, studies of critical thinking skills related to the concept of hydrostatics and the Archimedes principle are rarely found. Therefore, this study aims to determine the profile of students' critical thinking skill in physics learning especially on the topic of hydrostatic pressure and Archimedes' principle.

2. Method
This research is a qualitative descriptive study. The researching procedure consisted of: the pra-field phase, the field phase, and the data analysis phase. Activities in the pra-field phase are asking permission to the school side and preparing instruments. In the field phase, students are given tests in the form of questions of critical thinking skill. In the data analysis phase, the activity executed in the analysis of test results. The research subjects were students of class XII MIPA in one of the high schools in Batu and Malang (N = 127). Data collection is done through the provision of tests and interviews.

The instrument used in this research consisted of three essay questions. The number of items in the instrument is limited to 3 pieces in order to obtain a deep understanding of students' critical thinking abilities. The number of these instruments is also intended to prevent student fatigue. Each item is adjusted with indicators that refer to the five main perspectives of critical thinking skill set by Hughes [10], namely 1) an identification hypothesis to recognize the unwritten assumptions of the problem to be addressed, 2) an induction perspective in the form of reasoning to obtain generalizations that can be reliable in the problem, 3) deduction perspective is the relationship between a series of general statements so as to reach a certain logical conclusion, 4) an explanatory perspective to debate and 5) an evaluation perspective to use a set of relevant criteria to determine the quality of the argument. Each item is a separate part of one another, meaning that the first question is not a prerequisite for the next question. The distribution of questions is shown in Table 1 as follows.

| Critical Thinking Perspective | Indicator Item Question                                                                 | Question Number |
|-------------------------------|-----------------------------------------------------------------------------------------|-----------------|
| Induction and Explanation     | Students are able to understand Archimedes's principle concepts through analysis of the final position of beams which have different masses | 1               |
| Deduction                     | Students are able to analyze the final position of an object in water after changing its size | 2               |
| Identification Hypothesis and Evaluation | Based on the discourse-given, students can understand the concept of hydrostatic pressure through the reconstruction of an opinion | 3               |

The research is started with giving a test to students. The resulting test data were analyzed with 4 criteria. The grading for student answers are presented in the following figure.
Figure 1. Grading for Student Answers

Students who answer using the right and deep concepts will get a score of 30, students who answer with the right concepts but the discussion is not exhaustive will get a score of 20, students who give incorrect answers will get a score of 10 and if the students do not answer will get a score 0. This grouping is done with the aim to know the cause of students' mistakes in answering the questions given. Based on the analysis of test results, students are grouped into 2 parts, namely high and low ability students.

After giving tests and analyzing students' answers, the next step is the interview. Determination of respondents to take in-depth interviews is done by purposive sampling technique, meaning that respondents are chosen based on the level of ability of students. The selected respondents are each one of the representatives of students with high and low ability. The purpose of the interview is to find out the direction of the students' thoughts on the questions that have been given and to discuss in more detail the reasons for the students' answers.

3. Result and Discussion

The results of the analysis of students' critical thinking skill on the topic of hydrostatic pressure and Archimedes principle are presented in Table 2-4. Descriptive statistics of students' critical thinking skill can be seen in Table 2.

Table 2. Descriptive Statistics (Maximum Value 90)

| Statistic      | Students' Critical Thinking Ability |
|----------------|-------------------------------------|
| Mean           | 36.1                                |
| Std. Deviation | 10.4                                |
| Minimum        | 30                                  |
| Maximum        | 80                                  |

Based on Table 2 it is known that the average score of students' critical thinking skill is 36.1 with a standard deviation of 10.4. The maximum score obtained is 80 and the minimum score is 30. The data obtained are analyzed for each indicator so that the data obtained in Table 3.
Table 3. Question Analysis

| Critical Thinking Perspective | Indicator Item Question                                                                 | Students Answering Right (%) |
|-------------------------------|----------------------------------------------------------------------------------------|------------------------------|
| Induction and Explanation     | Students are able to understand Archimedes's principle concepts through analysis of the final position of beams which have different masses | 0.0                          |
| Deduction                     | Students are able to analyze the final position of an object in water after changing its size | 7.9                          |
| Hypothesis and Evaluation     | Based on the discourse-given, students can understand the concept of hydrostatic pressure through the reconstruction of an opinion | 5.5                          |

From Table 3 it appears that students are weak on the perspective of induction and explanation. No student is able to answer the question on the first indicator correctly and use a deep understanding of concepts. The following is more detailed discussion on several indicators of achievement by displaying students' response on each answer item. Data on the student test results based on 4 predetermined criteria are presented in Table 3.

Table 4. Student Test Results

| Number | Criteria                                      | Achievement (%) |
|--------|-----------------------------------------------|-----------------|
| 1      | Correct answers and deep understanding of concepts | 0.0             |
|        | Correct answers and understanding of concepts are not profound | 14.2            |
|        | Incorrect answers / students experiencing concept errors | 85.8            |
|        | No answer                                     | 0.0             |
| 2      | Correct answers and deep understanding of concepts | 7.9             |
|        | Correct answers and understanding of concepts are not profound | 5.5             |
|        | Incorrect answers / students experiencing concept errors | 86.6            |
|        | No answer                                     | 0.0             |
| 3      | Correct answers and deep understanding of concepts | 5.5             |
|        | Correct answers and understanding of concepts are not profound | 15.0            |
|        | Incorrect answers / students experiencing concept errors | 78.7            |
|        | No answer                                     | 0.8             |

Table 4 shows that the majority of students experienced misconception in working on the questions given. The following is a more detailed discussion related to students' critical thinking processes through answers and the results of interviews with high and low ability students.

3.1. Question Number 1: Induction and Explanation Perspectives

Question number 1 aims to access students' understanding of Archimedes's principle concept through an analysis of the final position of five beams in the water when the five beams have different masses. In this problem, students are asked to make a conclusion related to the final position of the beam then students must explain the basic concepts used to make such a conclusion. The types of questions used to explore students' critical thinking skill from the perspective of induction and explanation are shown in Figure 2.
Figure 2. Problem Number 1

Based on Table 4 it is known that in question number 1 as much as 14.2% of students had answered correctly but still did not show a deep understanding of the concept, while another 85.8% answered using the wrong concept. Following the models of students' answers based on predetermined ability levels.

Figure 3. Student answers based on level the ability to problem Number 1

Based on Figure 3 it is known that students with high ability have been able to provide conclusions and explanations that fit the concept quite well. It's just that the conclusions made are still incomplete, it should have two assumptions given, but students can only explain one assumption. Students with low ability to give conclusions that are right but not accompanied by an appropriate explanation. In determining the final position of the five beams, low-ability students only consider the mass of the beam without regarding the density ratio of the beam and water. Based on these results, interviews were conducted with representative of students with high and low abilities.

Based on the results of interviews, it is known that high-ability students only remember the terms of objects floating and sinking. Students have not been able to use mathematical equations in answering the questions given. Low-ability students do not remember the concept of Archimedes force including the requirements the objects floating and sinking. This shows that low-ability students still have difficulty in understanding the Archimedes force concept and of course it has an impact on students' critical thinking processes, especially in the explanation perspective.

3.2. Question Number 2: Deduction Perspectives

Question Number 2 aims to access students' understanding of Archimedes's principle concepts through an analysis of the final state of objects in water after changing their volume. In this problem, students are asked to make a reason for the relationship between the volume and density of similar objects so that they reach the right conclusions regarding the final state of the object. The types of questions used to explore students' critical thinking skill from the perspective of deduction are shown in Figure 4.
In Table 4 it was found that in question number 2 as much as 7.9% of students answered correctly and showed a deep understanding of the concept, 5.5% of students answered correctly but the given reasons did not use Archimedes’ force concept in depth, and 86.6% answered using the wrong concept.

Next the students’ answer models are presented for question number 2 according to the predetermined level of ability.

In Figure 5 it is known that highly capable students have given reasons and conclusions that fit the concept very well. Low-ability students have not been able to make reasons and conclusions correctly. This is because students are fooled by the size of the volume of different objects. Based on these results, interviews were conducted with representatives of high and low ability students.

Based on the results of the interview obtained information if high-ability students only remember the conditions of sinking objects and do not use mathematical equations in answering the questions given. However, students already understand when an object is cut into pieces, its density will remain the same as the density of the object before it is cut. Low-ability students know that when an object is cut in volume and its mass will change. But students do not take into account the ratio of the density of objects before and after being cut. This is the main cause of mistaken conclusions made by students of low ability.

3.3. Question Number 3: Hypothesis Perspective and Evaluation

Question number 3 aims to access students’ understanding of the concept of hydrostatic pressure through the reconstruction of an opinion. In this problem, students are asked to analyze an opinion using the concept of hydrostatic pressure. The question models used to explore students’ critical thinking skill from the perspective of hypotheses and evaluations are shown in Figure 6.

In Table 4 it is shown that in question number 3 as much as 5.5% of students answered correctly with a discussion that uses deep understanding of concepts, 15.0% of students answered correctly but the discussion did not show a deep understanding of the concept, 78.7% of other students gave
answers using the wrong concept and 0.8% students did not answer. Next, the students’ answer models are presented in question number 3 according to the predetermined level of ability.

**Figure 7.** Student answers based on level ability in question Number 3

Through Figure 7 it is known that high-capacity students are able to reconstruct opinions and make hypotheses quite well according to the concept of hydrostatic pressure. Low-ability students have not been able to reconstruct opinions properly and the hypothesis made are also still not right. This is because low-ability students assume that the pressure outside the cave is greater than inside the cave. Students also assume that in a wide place the gravity is greater than in a narrow place like in a cave. Based on this information, interviews were conducted with representatives of students with high and low abilities.

Based on the results of the interview, high-capacity students have been able to identify opinions and understand the concept of hydrostatic pressure quite well. Low-ability students know that what affects hydrostatic pressure is density, acceleration due to gravity and depth. However, the students experience misconception by assuming that the volume of water affects pressure. Students assume that cave walls can reduce pressure. This causes students to experience false in determining the ratio of pressure outside and inside the cave.

Based on the results of the analysis obtained information that the majority of students still have low critical thinking skill, but there are some students who already have good enough critical thinking skill. The low ability of students to think critically in this context is caused by the difficulty of students in understanding concepts. In the first question, the majority of students assume that the conditions of floating and sinking are only caused by differences in the mass of objects without calculating the density of water. This is consistent with the results of the study which states if students tend to assume that the factor causing differences in the position of objects in the liquid is only the mass of the object [11]. The false in the second question is because students assume that the size of objects changes the density of objects, this is similar to the results of research which state if students assume that large objects must sink and small objects float [11]. For the next question students consider that outside the cave the hydrostatic pressure is greater because it has a greater fluid volume compared to inside the cave. This is consistent with research which states that the majority of students believe that the volume of fluid affects the amount of pressure [12][13]. This acquisition is in accordance with the results of previous studies which stated that the level of critical thinking skill of students is still quite low [14][15]. Students are only able to solve mathematical equations without being able to relate these equations to the concepts used. Students have not been able to provide an explanation related to these concepts. In addition to the difficulty of students in understanding concepts, the low level of students’ critical thinking processes is also caused by students not accustomed to applying physical concepts in real life [16]. These results are expected to provide information to students, teachers and even other researchers related to the causes of weak students’ critical thinking skills and provide information related to how the differences in the way of thinking of students with high and low abilities. Differences in the way students think are important to note because this process is related to how learning should be done.

The results of this research are expected to be able to provide a detailed description related to the process of thinking ability of students on the topic of hydrostatic pressure and Archimedes’ principle. However, the number of questions and research samples used is still limited in such a way that the representation of the data obtained is less than optimal and may not yet represent the ability of students as a whole. It is hoped that further research can explore with a larger number of questions and research samples so that the results obtained are more credible.

### 4. Conclusion

Based on the results of the analysis and discussion, it was concluded that the majority of students have the ability to think critically which is quite low. Students have difficulty in making or identifying assumptions, students also have difficulty in identifying data that are not provided in the problem-
solving process. The main factor causing the low ability to think critically is the existence of misconceptions, in addition students are also not accustomed to applying physical concepts in everyday life.

5. References

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