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Analysis of Students' Ability with Inquiry Laboratory Activities in Archimedes' Law Learning

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Abstract

This research is aimed to know which ability students can develop through inquiry laboratory activities in Archimedes' law learning and its application to cognitive learning result. This research used mixed method. The quantitative data which were pre-test, post-test, and students' worksheets were taken to know the cognitive learning outcomes of students. Qualitative data presented in this research were video assisted observations and interviews with students as learning process. Those data were used to analyze the ability in observing, questioning, hypothesizing, designing, experimenting, interpreting data, and concluding which students can develop through inquiry laboratory activities in Archimedes' law learning. The N-gain shows that the inquiry laboratory activities in Archimedes' law learning improves students cognitive learning outcomes in SMP Islam Al Azhar 29 Semarang, SMP N 18 Semarang, and SMP Islam Al Azhar 14 Semarang. The Students' ability in observing, questioning, hypothesizing, designing experiments, experimenting, interpreting data, and concluding can develop with inquiry laboratory activities in Archimedes' law learning.

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INTRODUCTION

Physics learning is supposed to be able to develop the students competences ranging from the realm of cognitive, attitudes, and skills. Physics plays an important role to find and to process information from various sources (Khidman, 2012; Uki, 2017). The fact goes other ways, students have difficulties in learning and they misunderstand in almost all physics subjects (Ergin & Atasoy, 2013) because their idea and thought do not change in students' mind. (Ergin & Mesleki, 2016).

Physical material often misunderstood is Archimedes' law. Archimedes' law is a difficult material for students to comprehend (Pratiwi & Linuwih, 2017) and they are frequently mistaken in the analysis of the concept of density and in connecting to floating and sinking (Ningrum, 2015; Loverude, et al., 2003). Archimedes' law and its application develop students competence of conceptual understanding and direct observation. The reality at school is that Archimedes' Law material is difficult for students to comprehend. That is the reason why it becomes the focus of this research material.

Based on the result of daily test value on Archimedes material in class VIII of Islamic Junior High School Al Azhar 29 Semarang 2015-2016, from 56 students only 40% got score according to Minimum Learning Mastery Standart with minimum material limit of 75%. It is confirmed by Salma (2016) that 75% students of Senior High School 9 Semarang have difficulty in understanding static fluid material especially Archimedes' law. Students' comprehension does not reach 75% on Archimedes material because the teacher still using teacher centered method and they take much time in explaining the material theoretically.

Pratiwi & Linuwih (2017) stated that the use of props for the learning of Archimedes' law can change the students' thinking pattern in science related to reading textbook and seriousness in doing the task. This study will deepen the analysis about students' skill and attitude toward scinence and other competencies that students can develop in the material of Archimedes. The material of Archimedes requires laboratory activities to enhance the mastery of the concepts and the development of the students abilities, thus obtaining conceptual and theoretical knowledge through practical observation by means of observation or experimentation and working together in groups to act as scientists (Wiyanto, 2006).

Based on the conditions above, the laboratory activities in this study were integrated with inquiry learning as deemed in accordance with the legal material of Archimedes. Inquiry learning can improve the ability to discover, investigate and express students' own ideas (Turnip, 2016), and produce higher performance levels, analyze data, and find their own concepts using experimental data (Kaltacki & Oktay. 2011).

Integration of inquiry laboratory activities are very suitable in involving all the knowledge, skills, and attitudes of students to search and investigate so as to formulate their own invention (Nuritasari, 2016). The implementation of inquiry laboratory activities has been proven to be effective in physics learning (Sarwi, 2016), and in improving students' critical thinking skills (Riyadi, 2008). Jou (2015) also found that based on the results of pre-test and postes, inquiry laboratory study can improve students'cognitive results including descriptive ability, process ability, and comprehensive ability in mechanics materials, thus improving the students' conceptual understanding and achievement (Supasorn, 2014; Gupta, 2012; Longo, 2011).

Through the integration of inquiry laboratory activities, students are expected to link the concept of Archimedes with the concept of floating and sinking, as well as density so that students can develop more complex abilities or competencies and improve cognitive learning outcomes.

METHOD

The researches were conducted in SMP Islam Al Azhar 29 Semarang, SMP N 18 Semarang, and SMP Islam Al Azhar 14 Semarang. The sampling technique used in this research was purposive sampling. The treatments were given to the VIII graders of SMP. The details were 29 students from SMP Islam Al Azhar 29 Semarang, 31 students from SMP N 18 Semarang, and 26 students SMP Islam Al Azhar 14 Semarang.

The researcher used pre-test and post-test in the study. Pre-test was used to find the basic concepts of students about Archimedes' law and post-test was used to find the improvement of cognitive learning outcomes through the integration of inquiry laboratory activities in Archimedes' law. Instruments of quantitative data were pre-test, postes, and student worksheets. Qualitative data were obtained through video-assisted observations and interviews with students while they were studying. Qualitative methods were used to analyze students' ability in observing, questioning, hypothesizing, planning experiments, experimenting, interpreting data, concluding that students can develop through integration of inquiry laboratory activities in Archimedes' law.

RESULT AND DISCUSSION

Quantitative Data

The samples are some classes from SMP Islam Al Azhar 29 Semarang, SMP N 18 Semarang, and SMP Islam Al Azhar 14 Semarang. The class must have the same early conditions before being treated. Analysis of pre-test data shows that the normality test results of each class has significance value of > 0.05 so that the three classes are normally distributed. Homogeneity test results value of 0.716. It shows that the three classes are homogeneous and depart from the same situation.

Analysis of pre-test and post-test data in each class showed the significant difference after the learning process by using integration of inquiry laboratory activities in Archimedes law. Pre-test, post-test, and N-gain data can be seen in Table 1.

Table 1. Average pre-test, post-test and N-gain pre-test-post-test

Class	Students	Average		N-Gain
	N	Pre-test	Post-test	
SMP I Al Azhar 29	29	55,34	85,69	0,68
SMP N 18	31	51,21	78,62	0,56
SMP I Al Azhar 14	26	55,58	82,88	0,62

Based on Table 1, the completeness of student learning outcomes in this study proved that the learning through integration of inquiry laboratory activities can be used as one of the model to improve cognitive learning outcomes and student conceptual. Jou (2015) also found that based on pre-test and post-test, inquiry laboratory learning can improve students cognitive outcomes including descriptive of ability, process of ability, and comprehensive of ability in class 11. In line with Bridges (2015) that learning using worksheet based inquiry is able to improve students cognitive learning outcomes in basic chemistry and stoichiometry, student activities that develop knowledge and understanding of scientific ideas, understanding of how scientists nature (Longo, 2011). Sarwi (2016) also stated that inquiry laboratory study on the subject of Quantities and Measurement has positive correlation between the value of conservation character and mastery of concept on high and very significant category.

Qualitative Data

The qualitative data were from observation data (video-assisted) and Student Worksheet. The data were then analyzed to get the description of students' activity data during the learning process. The phase of inquiry laboratory activities (Harlen, 2014) can be seen in Figure 1.

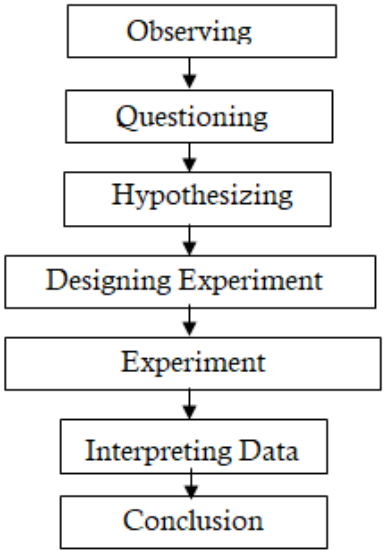

Figure 1. Phase of Inquiry Laboratory Activities

Observing

Teacher opened the lesson with motivation and apperception about material relating to the law of Archimedes. "Why does small nail sink when immersed in glass that contains water, while a large ship can float while sailing in the ocean?". The measuring instrument is the Ohaus Quadruple Beam Balance MB-311 Balance with the volume of objects, type of liquid, and mass of different objects as shown in Table 2.

Table 2. Teacher Questions and Students Answers on Demonstrations

Demo	Teacher Questions	Students Answers
1	Why does small nail sink when immersed in glass filled with water while a large ship can float while sailing in the ocean?	- Because size of the glass is smaller than the ocean so the spikes can drown - Sea contains lots of salt so the ship can float - The shape of nail taper so it can sink - The bottom of the vessel is hollow and contains air so the ship becomes light
2	How is the mass of object in the air and in the liquid for different shapes?	- The value is same because they are similarly in the form of solid - The value is different because the shape is different - The value is same because the type of material is same

Based on Table 2, measurements of objects weighed in the air, the results were different compare to the weight in the liquid. Students observe the scale on the raised arm of the Ohaus Balance if the object is immersed in a liquid, then deduce that all the objects dipped in the liquid have a lighter weight than in the air. Students respond with ideas that have been formed based on previous thoughts and experiences. Students try to understand new events or new phenomena if there is no

evidence to support their ideas (Nedungadi, 2015). In accordance with Harlen's (2014) that observing is the basis to collect data in practical situations by attention to the small details of the differences.

Questioning

Based on the demonstrations conducted by teachers, students wrote about the appropriate questions on a small piece of paper about phenomena in the observation phase according to the Table 3. Question expected of tudent is "Why is the object immersed in the liquid becoming lighter?".

Table 3. Data of Student Questions in Questioning Phase

Sample	Questions	Students
SMP Islam Al Azhar 29	- Why is the object lighter if immersed in water?	20
	- Why is the weight of the object in the air different from the weight of the object in the water?	6
	- Does the voume of the object affect the mass of the object in the water?	3
SMP N 18	- Why is the object lighter if immersed in water?	25
	- Why is the mass of the body in the water reduced?	6
SMP Islam Al Azhar 14	- Why is the object lighter if immersed in water?	15
	- Why is the mass of a thing bigger in the air than in water?	11

Students ability to observe differently leads to different thinking. In line with Gormally (2011) pointed out that differences in student's answers were due to differences in the ability of observations to include early knowledge of the source of information sought and the level of concentration when observing.

Based on Table 3, students who asked with the question were 66 out of 86 students in 3 school samples so the students ability to ask can increase based on observing. The questioning phase develops the ability to properly convey the question and the courage to express what is disturbing in the mind to solve the problem. Questions make students think what needs to be done, not wait for the teacher to inform the students. In line with Laxman (2013) that laboratory inquiry generates questions and explanations supported by evidence, students are able to engage in higher levels of cognitive reasoning in the classroom.

Hypothesizing

The teacher discussed and interviewed students in hypothesizing process. Table 4 explains that most students did the hypothesis correctly. It showed the students' ability in hypothesis were increasing although it must be proved by experiment. In line with Jou (2015) that the expected results may be incorrect or incompatible with the hypothesis so that students can check the results after the experiment. Students' hypothesis for 3 variables investigated can be seen in Table 4.

Table 4. Students Hypothesis

No	Hypothesis	Student answer	
		Yes	No

1	What is the volume of dyed objects affect the Archimedes' force?	76	10
2	What is the type of fluid affect the Archimedes' force?	81	5
3	What is the mass of dyed objects affect the Archimedes' force?	71	15

Based on Table 4, in the hypothesizing phase, students were asked to tell not only what would happen, but also why or how it happen and to prove it in an experiment. In line with Bekiroğlu (2014) that inquiry laboratory activities were potentially able to facilitate the students' development of concept to improve their skills in identifying variables and hypothesizing.

Experiment Designing

Teacher gives 10 minutes for each experimental design in one meeting. The first design to prove the first hypothesis concerning the influence of the volume of objects immersed in Archimedes' force. The second design to prove the influence type of liquid on Archimedes' force. The third design to prove the mass of dyed objects on Archimedes' force. The time needed by the students to design experiment is shown in Table 5.

Table 5 shows the designing of second experiment took less time than first experiment and all groups could complete the design according to the time given. Students finished the design for the third experiment much faster compared to the first and second design. Students have the ability and experience to design experiment before conducting an experiment. In line with Harlen (2014) that students gain greater experience and ability to plan before experimenting so that students can be encouraged to think further and faster.

Table 5. The Time to Design Experiment 1 (Volume of Dyed Object), Experiment 2 (Type of Liquid), Experiment 3 (Mass of Dyed Object) Against the Archimedes' Force

School	Group	Designing 1 Time (minute)	Designing 2 Time (minute)	Designing 3 Time (minute)
SMP Al Azhar 29	1	0:09:30	0:07:45	0:06:50
	2	0:09:50	0:08:50	0:07:50
	3	>10 minute	0:08:45	0:07:30
	4	0:09:10	0:08:15	0:07:20
	5	>10 minute	0:09:15	0:08:00
	6	0:09:30	0:07:30	0:06:50
SMP N 18	1	0:09:50	0:08:15	0:07:30
	2	>10 minute	0:09:50	0:08:15
	3	>10 minute	0:09:30	0:08:00
	4	0:09:20	0:09:00	0:08:30
	5	0:08:15	0:07:15	0:06:15
	6	>10 minute	0:08:50	0:08:15
SMP Al Azhar 14	1	0:08:30	0:07:30	0:06:30
	2	0:09:15	0:09:15	0:08:15
	3	0:08:50	0:08:00	0:07:30
	4	>10 minute	0:08:50	0:07:30
	5	0:09:45	0:09:15	0:08:30
	6	>10 minute	0:08:30	0:07:15

Experiment

The group experimented with an experimental design. Measurements made in the experimental phase to determine the mass changes of objects (Δm) are in the air minus the mass in the fluid. When there is a difference or mass change between object A and object B, that variable influences of the Archimedes' force.

Students used to interact with the teacher in the first experiment because they were unfamiliar with the experiment designing before experiment. For example students chose variables

of tool and material used about the mass of dyed objects, the type of fluid, the volume of objects dyed. The second and third experiments run independently and smoothly because students had accustomed to and had experience in the first experiment. In accordance with Gormally (2011) that early inquiry laboratory study is difficult for students although with teacher guidance, but at the end of learning most students say interested and do not want to go back to learning the old model.
The result of the observation indicated barriers when students perform experiments. Students used ropes that are hung not tight enough, thus affecting the measurement results. Several groups occur difference of Δm between object A and B. The observation results show that due to the factor of lack of accuracy in the measurement, the Ohaus Balance tray there is a water spill affecting the changes of mass (Δm). When using a different type of fluid, the students immediately slip the second object of the liquid so that the liquid mixes and affects the data. In line with Harlen (2014) that some obstacles occur in conducting experiments that slightly affect the experimental results.

Interpreting Data

This phase helped students comprehend explanation consistently with evidence provided based on observations and data collection from the results of the experiment. Students analyzed the factors that influenced the mass change of objects (Δm) and the definition of Δm. Teacher linked the gravity material (W) to analyze the mass change of the object (Δm) because Weight (W) is the multiplication of mass (m) and the acceleration of gravity (g). The change of mass of the object (Δm) multiplied by the gravity was the Archimedes' force (F_A).

The inquiry laboratory activities described that teachers guided students to collect and analyze data with specific instructions according to the students' worksheet. In line with Nedungadi (2015) that the teacher guided the students if there was mistakes and asked the students to verify the results of the experiment by answering the questions in worksheet, then the students formulated the explanation in the form of tabulation and data graph. The process of data interpretation enabled students to actively connect the collected variables according to the data from results of the experiment, so that teachers only gave reinforcement and direction. In accordance with Sujarwata (2009) that the learning process outlined by the curriculum was more focused on the active role of students in learning activities, a teacher was only as a facilitator and motivator.

The third hypothesis was incompatible with results of the experiment and data interpretation because many students considered the mass of dyed objects was equal to the volume of dyed objects. In line with Nedungadi (2015), some cases explained that expected results may be incorrect or not in accordance with the hypothesis so that students can check the results after the experiment. In line with Harlen's (2014) research that the phase of interpreting the data made the direction of the study went according to the explanatory formulation of the problem under investigation.

Based on data analysis and observation, students ability in data interpretation increased by analyzing hypothesis, designing experiment and was proven by experiment. Students collected and analyzed data, and also developed an approach or pattern of answers to interpret many kinds of data (Gormally, 2011). Reinforced Supasorn (2014) stated that students formulated an explanation of the data they had collected, and described their findings into everyday life.

Conclusion Phase

Students worked together in their respective groups and came to the conclusion of factors influencing the Archimedes' force and the equations for determining the magnitude of the Archimedes style. Conclusion phase can be conveyed through communicating, questioning-answering, and evaluating. Students could communicate their thoughts to others to help clarify ideas.

Based on the data in the data interpretation phase, the students' ability to infer the data increased. It was a verification of the correctness of the hypothesis. Each group defended the idea as a process of supporting the conclusion with the evidence that had been investigated. In line with Nedungadi (2015) that students discussed conclusions whether their hypothesis was true or false and summarized of answers to the questions given. The exchange of ideas was very useful for students' comprehension so they asked each other about the various explanations. In according with Harlen (2014) that students discuss about things that have been found in group activities for the development of an understanding of data collection, data interpretation, and conclusions.

CONCLUSION

Inquiry laboratory activities in Archimedes' law learning based N- gain improved students' cognitive outcomes in SMP Islam Al Azhar 29 Semarang, SMP N 18 Semarang, and SMP Islam Al Azhar 14 Semarang. Students' abilities can be developed thoroughly in the Archimedes law learning which was stated in phases in the inquiry laboratory activities starting from the observing, questioning, hypothesizing, designing experiments, experimenting, interpreting data, and concluding. Further research suggests the integration of inquiry laboratory activities learning can be used for other materials in physics subjects, as well as analyzing abilities another inquiry laboratory with material other than the Archimedes' law.

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