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Analysis of Problem Formulation Skill of High School Students

Dian Erawarni✉, Wiyanto, Ian Yulianti

Postgraduate Universitas Negeri Semarang, Semarang, Indonesia

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Abstract

This study aims to analyze the pattern of problem formulation skills and hypothesize students of class XI MIPA at SMAN 2 Grabag and SMA Islam Sudirman Pakis. The research design is qualitative research. The technique used in the data collection was an interview technique with 20 students and two physics teachers, as well as documentation during the research. Before the interview, the students observed 3 physical phenomena, namely (1) phenomenon 1 regarding the effect of oxygen on the flame of a candle, (2) phenomenon 2 regarding water surface pressure on razor blades and needles, (3) phenomenon 3 regarding eggs that put in various solutions with different density. The data analysis technique was qualitative analysis. Based on the research, all students were able to formulate problems according to the video of the observed phenomena, and based on the problem formulation proposed by the students found that there are three patterns of problem formulation in phenomenon 1, two patterns of problem formulation in phenomenon 2, and three patterns of problem formulation in phenomenon 3, with all problem formulation patterns proposed by students being problem formulations that correspond to each previously observed phenomenon. This shows that all students have good problem formulation skills, it can be seen that students can identify problems in each video phenomenon and ask them in the form of questions. The results showed 2 question words, those are "why" as much as 77% and the question word "what" as much as 23%. Students who formulate problems using the question word "why" can be categorized at the formal operational stage and students who formulate problems using the question word "what" can be categorized at the concrete operational stage. This difference in students' cognitive development can be a guide for teachers to use a student-focused learning model.

✉Correspondence:
Postgraduate Universitas Negeri Semarang
Jalan Kelud Utara III No.37, Kota Semarang, Indonesia 50237
e-mail: dianerawarni@gmail.com

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INTRODUCTION

Physics is part of science which is essentially a collection of knowledge, ways of thinking, and investigation (Fitriani, *et al.*, 2017). Physics learning includes science processes that require interaction with real objects and interactions with the learning environment (Wiyanto & Yulianti, 2009). Scientific process skills in learning aim to involve students in research or investigations in understanding nature and being able to integrate knowledge into scientific processes and understand how scientific knowledge is obtained (Yildirim, *et al.*, 2020). Scientific process skills consist of observing, classifying, experimenting, recording data, measuring, using, and modeling data, establishing hypotheses and changing and controlling variables (Ozkan & Kilicoglu, 2021; Gultepe & Kilic, 2015; Kurt & Sezek, 2021). Scientific process skills are defined as basic skills in the form of scientific methods and methods to facilitate the learning of science that allows students to think scientifically.

Physics learning has a role in creating quality and skilled human resources. Competencies that must be achieved by students in learning Physics at the upper secondary level according to Regulation of the Minister of Education and Culture No. 21 of 2016 are formulating problems related to physical phenomena, formulating hypotheses, designing and carrying out experiments, taking measurements carefully, recording and presenting results in tables and graphs, concluding, and reporting the results orally and in writing. Curriculum objectives in Regulation of the Minister of Education and Culture No. 37 of 2018 include 4 competencies, namely (1) spiritual attitude competencies, (2) social attitudes, (3) knowledge, and (4) skills. Competency skills that must be possessed by students are competency to process, reason, and present in the concrete and abstract realms related to the development of what they learn in school independently, act effectively and creatively and able use methods according to scientific rules. Physics learning uses scientific methods in the learning process, one of the methods is to formulate problems related to physical phenomena. The competence to formulate this problem is a basic competency that must be possessed by students to solve a problem.

Schwenk & Thomas in Hippel & Krogh (2016) stated that problem formulation is an activity that not only involves finding the problem but also in-depth exploration of the underlying causes of the observed problem, the underlying cause that is found then becomes a problem to be solved. Problem formulation in research is usually presented in the form of questions. Research questions are a way for researchers to express their interest in a problem or phenomenon. Each question must be clear and specific, refer to the problem or phenomenon, reflect on the experimental research, and record the target population or participants (Boudah, 2011). Identifying questions research will provide a greater focus on research or clarify the direction of the investigation, whether the research is descriptive or experimental. Based on the above definition, the problem formulation is a basic activity to find the causes of the observed problems presented in the form of questions.

Research conducted by Alsied & Ibrahim (2018) stated that students still had difficulties in conducting research, one of which was not knowing how to formulate research questions. Camacho & Christiansen's (2018) research also identified that students still had difficulty in formulating problems related to critical thinking skills. Research by Saidawati, *et al.* (2022) regarding the profile of high school students' science process skills on heat material showed that problems formulating of students was in low level. Van der Graaf, *et al.* (2019) stated that teachers helping students to formulate questions and come up with arguments and ideas is an approach that could enrich students' scientific thinking. However, based on discussions with Physics teachers at SMAN 2 Grabag, Magelang Regency, it was found that Physics learning in SMAN 2 Grabag only emphasizes understanding concepts, mastering theories, and discussing questions, while practicum activities are still limited and have not been able to train scientific process skills such as formulating problems.

Problem formulation skills are skills that must be possessed by high school students, however, several studies show that students' problem formulation skills are still low and high school students' problem formulation patterns have not been analyzed. Based on the pattern of problem formulation proposed by students, the teacher can determine students' understanding of the background knowledge of students during learning and students' cognitive development.

METHODS

The research was conducted at SMA N 2 Grabag and SMA Islam Sudirman Pakis. The research design used in this research was qualitative research using the snowball sampling technique. The snowball sampling technique is a data sampling technique that is initially small in number, then the study increases the number of samples so that the number of samples becomes large (Sugiyono, 2018). The increase of data in the snowball sampling technique was carried out until the desired data reaches a saturation point or the data is constant. The research was started at SMA N 2 Grabag, then samples were added from SMA Islam Sudirman Pakis. The research subjects were selected using a purposive sampling technique with total of 20 students of class XI MIPA, which were ten students for each school. The focus of this research focuses on the problem formulating skills of high school students in learning physics. The instruments used in data collection were 3 videos of physical phenomena and interview guides. Phenomenon videos used include:

1) Phenomenon 1

Figure 1. Video of Phenomenon 1

Video of phenomenon 1 shows an experiment about the role of oxygen in combustion. Experimental tools and materials used in the phenomenon 1 video were glasses, plates, matches, candles, and colored water. The experiment began by lighting a candle placed on a plate filled with colored water. Then, the candle is covered by a glass and the flame starts to dim and then goes out. Further, the water in the plate was sucked up into the glass. When the candle flame is covered with glass, the smoke comes out from the gap between glass and the plate since the hot gas in the glass expands and creates a higher pressure than the atmosphere. The high pressure will not let oxygen in, even if there is a gap in the bottom of the glass. Therefore, the candle flame is off because of the lack of oxygen in the glass. Huang (2013) divides the process of rising water into three phases, we can see the most significant increase occurs in the second phase, due to a sudden decrease in temperature after the candle goes out, namely: 1. Combustion (with a cylinder cover): the water barely rises, 2. The moment after the candle goes out: the water rises suddenly and dramatically, 3. Cooling: The water slowly rises as the temperature is returned to room temperature. The reason for the rising of the water in the first phase is a chemical reaction and the contraction of the second and third phases of the heated air. The temperature in the cylinder and the water rise ratio are measured simultaneously.

2) Phenomenon 2

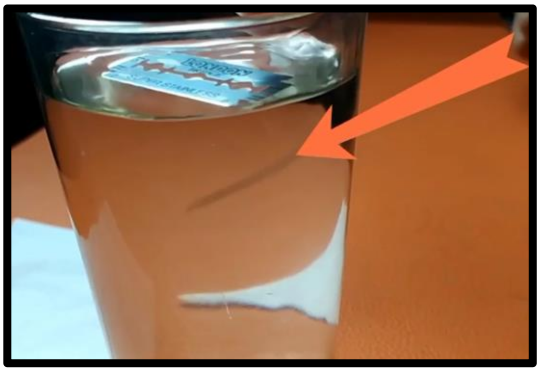

Figure 2. Video of Phenomenon 2

Video of phenomenon 2 shows the pressure experiment on the surface of a liquid. The tools and materials used in the Phenomenon 2 were clear glass, razor blades, needles, and water. The activity of phenomenon 2 begins with inserting a razor into a glass filled with water and the razor floats on the surface of the water. Then, a needle was put into the glass. It was observed that the needle was sank. The phenomenon can be explained by the concept of fluid pressure. Fluid pressure is influenced by the force acting on the object, which can be in the form of gravity and the surface area of the object. The greater the force acting on the object, the greater the fluid pressure. The larger the cross-sectional area of the object, the lower the fluid pressure experienced by the object.

3) Phenomenon 3

Figure 3. Video of Phenomenon 3

Video of Phenomenon 3 shows three eggs placed in different solutions. The first glass was filled with water, the second glass filled with water with 3 tablespoons of salt and the third glass was filled with water with one tablespoon of salt. Then, an egg was put in each glass. In the first glass, the egg was sunk, while in the second glass and the third glass, the eggs were floated on the surface of the water and floated in the water, respectively. An object that is immersed in liquid experiences a buoyant force. Archimedes' principle states, "an object completely or partially submerged in a fluid is lifted by an object equal to the weight of the fluid displaced".

The interview instrument used in this study was an interview guide which were: (1) can you find the problem in this video?; (2) if so, please state what problems you found from this video!; (3) after you watch the video of this phenomenon, what questions arise?

RESULTS AND DISCUSSION

The research began by asking students to watch 3 videos of physical phenomena, namely (1) phenomenon 1 regarding the effect of oxygen on a candle flame, (2) phenomenon 2 regarding water surface pressure on razor blades and needles, (3) phenomenon 3 regarding eggs. After the students watched the video of the physical phenomena, the students were interviewed by referring to the interview guide instrument.

The first interview was conducted at SMA N 2 Grabag with a sample of 10 students from class of XI MIPA. Then the interview was conducted at Sudirman Pakis Islamic High School with a sample of 10 students from class XI MIPA to add the data. Based on the results, the problem formulation proposed by students related to video of phenomenon 1 were:

1. The problem formulation of "After being closed by the glass, why did the candle flame go out and why did the water on the plate rise into the glass?" was submitted by students R1, R2, R3, R4, R5, R7, R8, R10, R13, R14, and R17.
2. The problem formulation of "Why does the water rise into the glass after the candle goes out?" was submitted by students R6, R9, R11, R18, R19, and R20.
3. The problem formulation of "What causes water to rise into the glass after the fire is extinguished?" was submitted by students R12, R15, and R16.

After students were interviewed using video of phenomenon 1, students were then asked to observe video of phenomenon 2. The problem formulation proposed by students related to video phenomenon 2 were:

1. "After being placed on the surface of the water, why does the razor float while the needle sinks?" was submitted by R1, R2, R3, R4, R5, R7, R8, R9, R11, R13, R14, R17, R18, and R19.
2. "What causes the razor to float and the needle to sink after being placed on the surface of the water?" was submitted by R6, R10, R12, R15, R16 and R20.

Meanwhile, the problem formulation proposed by students related to video of phenomenon 3 were:

1. "Why does an egg that is put in fresh water sink while an egg that is put in water that is given a lot of salt floats and an egg that is put in water that is given a little salt floats?" was submitted by R1, R2, R3, R5, R6, R8, R9, R10, R11, R12, R14, and R19.
2. "What causes the egg to sink, float, and float in phenomenon 3?" was submitted by R7, R15, R16, and R20.
3. "Why does salted water cause eggs to float?" was submitted by R4, R13, R17, and R18.

Based on the results above, it is shown that, for the three phenomena, both schools have the same problem formulation patterns which were 3 problem formulations. This shows that the data obtained related to the problem formulation of all phenomenon conducted at SMA N 2 Grabag and SMA Islam Sudirman Pakis have experienced saturation in the 3 patterns of problem formulation. The results also showed that students from SMA N 2 Grabag and SMA Islam Sudirman Pakis have skills in problem formulation. Therefore, it can be said that students have the ability of formulating problem indicators, namely being able to identify problems, determine types of problems, and formulate problem in the form of questions (Gulo, 2002).

The problem formulations proposed by the students of SMA N 2 Grabag and SMA Islam Sudirman Pakis for the three phenomena indicate that the formulation of the problems presented is following each phenomenon observed by the previous students. Based on the formulations proposed by students, there are 2 different focuses of problem formulation: focusing on using the question word "what" and focusing on using the question word "why". The data on question word patterns used in formulating student problems are shown in Table 1.

Table 1. Data on Question Word Patterns for Skills in Formulating Student Problems

Phenomenon	SMAN 2 Grabag		SMA Islam Sudirman Pakis		Total
	What	Why	What	Why	
Phenomenon 1	0	10	3	7	20
Phenomenon 2	2	8	4	6	20
Phenomenon 3	1	9	4	6	20

Based on Table 1, it can be seen that students of SMAN 2 Grabag and SMA Islam Sudirman Pakis chose 2 question word patterns, namely what and why. From the overall data, it can be concluded that the problem formulation with the question word "what" is 14 questions or 23% of all the questions asked by the students and the formulation of the problem using the question word " why" as many as 46 questions or as much as 77% of all the questions on the formulation of the problem posed by students. Pandean (2018) states that the use of the question word "what" indicates the object aspect, while the use of the question word of "why" indicates the circumstances or cause and effect. Nugraha & Herlina (2021) state that the question word of "what" is a type of question to find out about what is going on or about a topic in general, while the question word of "why" is a type of question used to seek information by focusing on reasons or the background of the incident in question.

Therefore, the students of SMA N 2 Grabag and SMA Islam Sudirman Pakis are more likely to formulate problems by emphasizing the background, reasons, and causes that are manifested by the question word "why". These results were occurred since high school students are already at the stage of cognitive development at the formal operational stage. Based on the stages of student development proposed by Piaget in Schunk (2012), the formal operational stage has an approximate age range of 11 years to adulthood. At this stage, students no longer only focus on things they see, but students can think about presuppositional situations with reasoning and thinking in more than one dimension.

However, as many as 23% of SMA N 2 Grabag and SMA Sudirman Pakis students formulate problems with the question word "what" which emphasizes questions about objects or topics that are considered from the three phenomena. Students who propose a problem formulation with the question word "what" can be categorized at the concrete operational stage. According to Piaget in Schunk (2012), at the concrete operational stage students only focus on the observed object. Different stages of student development can affect how students learn and how students acquire new knowledge. These different stages can be influenced by factors of different levels of student understanding and the learning model used by the teacher in the classroom.

Background knowledge has an important role in problem formulation skills (Park, 2006). The background knowledge of students can be influenced by the teaching methods used by the teacher when learning in the classroom. This is in line with Carpenter & Pease in Peters-burton & Stehle (2019) which states that a learning environment designed for knowledge construction can encourage students to become independent and purposeful learners. Learning methods that involve students directly can help students build their knowledge and reasoning abilities. Sumarli, *et al.,* (2018) stated that physics learning becomes more effective if the learning can practice various skills that provide direct experience for students in constructing their knowledge. Reasoning skills must be trained for students who are at the stage of concrete operational thinking and formal operations by teachers through learning (Shofiyah & Wulandari, 2018).

Research conducted by Shofiyah, *et al.*, (2013) and Erlina, *et al.* (2018) show that inquiry learning can improve students' scientific reasoning abilities since it brings students to build new understandings with the knowledge gained to new situations through deepening of concepts. Research by Af'idayani, *et al.* (2018) shows that the inquiry model is considered to have an impact on the development of students' science process skills. In addition, the learning process using scientific processes will improve students' cognitive and skills (Wardani, *et al.*, 2018). Scientific process skills are specific skills that facilitate science learning, activate students, develop a sense of responsibility, and teach students research methods. In addition, scientific process skills are also students' thinking skills to get information, think about problems, and formulate results (Karamustafaoğlu, 2011). Through the exploration of scientific process skills based on a constructive approach, students can learn science meaningfully (Suryanti, *et al.*, 2020). The application of inquiry-based physics learning in the classroom is expected to be able to provide a learning environment that allows students to develop scientific reasoning and master scientific process skills, especially problem formulation skills.

CONCLUSION

Based on the results of research conducted at SMAN 2 Grabag and SMA Islam Sudirman Pakis, Magelang Regency, it can be concluded that as many as 20 students were able to formulate problems according to the phenomena shown previously. Based on the results of interviews, it was found three patterns of problem formulation in phenomenon 1, two patterns of problem formulation in phenomenon 2, and three patterns of problem formulation in phenomenon 3. This shows that all students can identify problems in the observed phenomena video and express the problem in the form of questions. The results showed that there were two question words used by students in formulating problems, which were the question word "why" as much as 77% and the question word "what" as much as 23%. Students who formulate problems using the question word "why" can be categorized at the formal operational stage and students who formulate problems using the question word "what" can be categorized at the concrete operational stage. This difference in students' cognitive development can be a guide for teachers to use student-focused learning models such as inquiry learning.

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