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Common False of Student's Scientific Reasoning in Physics Problems

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Abstract. Scientific reasoning is the ability to think about the characteristics of formal development to master concepts and solve physics problems. Physical problem solving requires a high level of thinking that is a combination of reasoning namely conceptual and general mathematical equations. The student's thinking ability that is inconsistent with their formal developmental stage is the cause of the student's scientific reasoning lack. The purpose of this study is to analyze the common false made by students during their scientific reasoning process. This research is a qualitative descriptive with the aim at describing common error of scientific reasoning with the physics problem. Scientific reasoning tests were given to 108 students who had studied physics using mixed methods of lectures and assignments. Results showed the false of each component of the student's scientific reasoning. Student's scientific reasoning was dominated by competence level. The quality of claims, arguments, and levels of student's confidence in giving answers was still low. Students experienced false scientific reasoning and weak concepts when confronted with physics problems. The important recommendation of this study is that the learning process needs an innovation to overcome false and inconfident feeling in the process of scientific reasoning and mastery of student concepts.

1. Introduction

Scientific reasoning is a cognitive ability in formal operations that include activity of minds-on and hands-on to support the process of physics learning [1]. Physics-based learning of scientific reasoning stimulates student's mental and physical activity to achieve scientific knowledge [2]. Students are not only required to know the content of physics in the form of facts, concepts, or principles, but also must be able to investigate, collect evidence, analyse and evaluate the understanding of physics [3]. [4] conveyed that an understanding of physics concepts would be better when they could touch, feel, measure, manipulate, draw, graph, compile data, and when they find and able to explain answers using their understanding. The transfer process in physics learning requires high-order thinking skills that form a combination between reasoning and conceptualization of general mathematical equations [5].

Scientific reasoning is required as a billing of high-level cognitive abilities but this skill has not yet been trained to activate the students' mindset [6]. Evaluation bills in learning are still simple fact-recognition as the lowest cognitive level although scientific methods and scientific reasoning efforts become the provision of learning competencies [7]. Relevant research results show that teachers rarely



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use questions (e.g. analysis and evaluation) and help students develop their scientific thinking skills [8]. The student's thinking ability that is inconsistent with their formal developmental level causes a person not to reach the level of formal thinking during his lifetime [9].

The fact of scientific reasoning ability in physics learning has not been satisfactory. Results showed student's scientific reasoning in 11th grade of high school only reached the average score of 38.7 (low category) [12]. Students have difficulties in defining experimental variables, interpreting, and analyzing graphs or data. The result of the preliminary study also showed that the high school students' scientific reasoning is still low amounting the average score of 27.22. The questionnaire data included physics learning process conducted by physics teacher in the high school that had not trained the skill yet [13]. The involvement of students in mastering physics is limited to applying the principles, methods, requirements, and theories of physics [14].

The involvement of scholarly reasoning requires students in connecting evidence on investigative activities to support scientific arguments. The ability of scientific reasoning is increasingly structured and evident from the quality of scientific arguments. Reasoning results in conclusion of thought, clarity, and firmness to explain why something happened or what will happen. Reasoning refers to the mental processes involved in making and evaluating logical arguments [16]. The preparation and evaluation of scientific arguments related to evidence and reasoning [17]. The student's ability to explain information is based on belief and desire in the process of reasoning [18].

This study focus on enabling students to do scientific reasoning with arguments and students' metacognitive skills in the form of three-tier test. Three-tier test is a better development of two-tier test applied in scientific reasoning component in which the three-tier test of scientific reasoning requires students to choose the alternative choice of answers. The test comes with a level of confidence in producing answers and reasons that show the process of realizing scientific reasoning. The research provides easy analysis and description of the common false about the process of scientific reasoning.

14 Research method

This research used qualitative and descriptive approach by the aim of describing common false of scientific reasoning in the physics problem. The subjects of this study were 108 high school students in Jember, East Java, Indonesia, with mechanical topics in the odd semester of 2017. The test was used as a data collection technique. The study was conducted by giving the test to the students after conducting the learning process with lecturing mode, task and question, and answer. The test used was a three-tier test based on scientific reasoning components covering: (a) Proportional Thinking (PPT) to determine relationships and to compare between variables using numbers, mathematical equations, tables, and graphs, (b) Control of Variables (CV) to identify independent variables and bound variables, (c) Probabilistic Thinking (PBT) to predict the probability of results obtained during repetition, (d) Correlational Thinking (CT) to create a reciprocal relationship (related or unrelated) between variables, and (e) Hypothetical-Deductive Reasoning (HDR) to construct hypotheses based on general concepts to specific concepts [10]. Data obtained from the three-tier test were analyzed based on scientific reasoning component. Expert level was achieved when the students were able to choose the first choice correctly, the reason was perfect for the second level, and was confident with the given answer (score 4). In coping with the level of experience, students were able to choose the first option correctly, the reason was less perfect on the second level matter and confident with the answer (score 3). The competent level was shown by the students who were able to choose the first option correctly, the wrong reason on the second level and confident with the answer (score 2). At the novice level, students were convinced by the wrong choice from the first answer (score 1) and the students were convinced by the wrong answer or was not sure of the answer (score 0) [13].

3. Results and Discussion

This research produced the level and description of common false of each component of student's scientific reasoning in physics learning. Figure 1 shows the frequency of scientific reasoning ability in each component determined by using scientific reasoning tests.

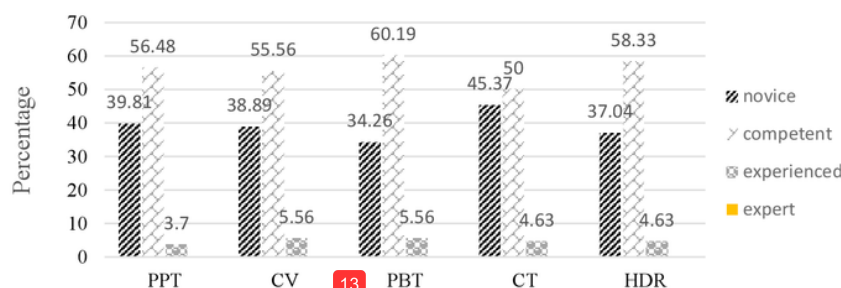


Figure 1. Level of scientific reasoning

Figure 1 shows the percentage of levels based on student's scientific reasoning components. The largest percentage at this level was achieved on the PBT component. The competent level indicated the ability of the students in choosing the right and convinced choice of answers even though the argument against the answer was wrong. Students gave answers only based on their memory. This result explained that learning process using lecturing mode, duty and question, and answer had not been effective in delivering the students' ability at expert level. Theoretical learning tent to ignore evidence to determine consistent answers [19]. Learning that had become students' routine had not been able to build arguments and to summarize the knowledge correctly and logically based on the process and the results of scientific reasoning. Scientific reasoning can be trained and transferred, also giving a long-term impact on student's achievement [11].

Figure 1 presents the percentage of novice levels occurring in each component of scientific reasoning of more than 30 percent. Students at the novice level had a weak belief in the outcome of the answer. The student's knowledge still lacked and there was a misconception in doing scientific reasoning. Teachers usually did not emphasize student's reasoning about the predictions they made [20]. Reasoning referred to the mental processes involved in making and evaluating logical arguments and problem-solving. Problem-solving could develop student's reasoning because it required students to explain why something happened or what would happen [16]. The development of scientific reasoning was influenced by conceptual change as a constructivist approach. It related to the basic reasoning process involved in the investigation, experimentation, evaluation of evidence, inference and argument made to achieve conceptual change or scientific understanding [21].

The level of scientific reasoning achieved in Figure 1 was dominated by the competent level. Students' answers were based on the results of memory that had not been yet clarified and the results tent to lead to weak support for the development of student's thinking. Table 1 describes the test results illustrating the false of student's thinking patterns.

Table 1. Causes of common false of scientific reasoning

Components	Causes of False
Proportional Thinking	1. Not applying the concept of physics in comparison operations 2. Unable to use mathematical operations in comparison relationships
Control of Variable	1. Unable to describe them operational definition of the variable 2. Unable to determine free and bound variable
Probabilistic Thinking	1. Fail to predict though to give the perfect argument 2. Provide the same assumption on different circumstances 3. Incompleted arguments 4. Weak concept
Correlational Thinking	1. The truth about the concept in the argument did not have a logical relationship to the problem 2. Weak concept

Components	Causes of False
Hypothetical-Deductive Reasoning	1. The students' logical thinking ability was not used to relate concepts to the solutions needed in the problem 2. Application of the wrong concept

The common false of the components of scientific reasoning were described below with the accompanying examples. Proportional thinking could be conceptualized by identifying two variables, i.e. extensive variables and intensive variables. Extensive variables (depending on the amount of material measured) applied to the problem as a linear function and comparison where intensive variables remained constant [10]. The first and second common false of alternatives selected by the students indicated an error when doing the proportional thinking. Students gave an incomplete reason to support the answer. The first error occurred when faced with a proportional problem in a graph showing a circular moving object. Students were able to provide a logical argument using a comparison of values of $v_{0A}/v_{0B}=R_A/R_B$. Students showed correct calculation results based on the value comparison relationship. The student's strategy error was that they did not include the centripetal force equation into the mathematical relationship including the square of a magnitude so that the results obtained by the student were false. A common false that also occurred in other mechanical topics was that students did not give mathematical arguments. The first and second common false were relevant to the results of the study showing student's false when doing the proportional thinking. Students more struggled when swapping the ratios or units and failed to use proportions [15].

Control variable was the ability to evaluate the evidence generated from controlled experiments in scientific investigations and experiments. Constant variables were required during experimental activities [22]. The first common false was that the student was able to answer the alternatives correctly but the reason for supporting the answer was wrong. Students were able to determine the distance between points as a result of the speed of an object. Students gave false arguments about the description of the variables involved, for example, the times required from the starting to the end points was described as the distance. The second false was that the students was unable to determine the free and bound variable. This error was supported by research results which showed that students generally failed to determine constantly the maintained variables [15]. For example, students were unable to determine the magnitudes that affected the linear velocity of an object placed on a rotating record.

Probabilistic thinking skills included high-level thinking processes. Probabilistic thinking was a situation that generated a certain amount when repeated in the same state in a larger context [10]. The first and second false when students did probabilistic thinking was that students failed to predict so the answer was wrong. For example, a student was expected to predict the time required for 1, 2, and 3 cars with some types and directions of the passage. Students were able to analyze the length of the passage through the case of car 1, but they failed to determine the type and direction of the track. Students assumed that car 1, 2 and 3 went through the same type and direction (students did not support the type of track used by car 1). Students were able to provide perfect arguments but students' predictions were wrong. Common false that occurred in the third and fourth false were those that made students unable to present a complete and correct argument. For example, how did the student's ability to predict the speed, the influence of gravity, and the acceleration of the ball at the highest point if the player repeated the ball with a trajectory much farther than before? Students did not understand the concept of speed at the highest point and the influence of gravity on the vertical and horizontal planes. The weaknesses experienced by students who tried to achieve reasoning skills were still not able to reach the expert level. Students did not consider any factors that might have an effect on probability [15].

Correlational thinking determined the strength of the interrelationships between variables that made possibility to manufacture predictions during scientific exploration [10]. Correlations were used to describe the degree of dependence between two or more variables [11]. The first common false could be identified based on the wrong student's choice of answers with the correct and complete reason. The reasons given by the students were not related to the student's choice of alternatives. For example, students were able to provide arguments in the form of trueness but illogical concepts with problems.

Students' argument stating that every object connected would be related to gravity, time, acceleration and speed. Things that fell to the ground were determined by gravity, time, acceleration and speed. Students showed a wrong answer that the large speed of the horizontal object was related to the gravity. Student answering to other mechanical topics showed weak concepts during the correlational thinking process. Students' correlational thinking was based on their original knowledge [15].

Hypothetical-deductive reasoning as a characteristic of the reasoning process resulted in the development and organization of possible solutions to deal with problems in every step and domain of life [10]. Hypothetical reasoning was the process of creating and making conclusions about the possibilities so that what was believed (reality) could be compared to some alternatives [23]. Table 5 shows two common false in the deductive-hypothesis reasoning component. The first false was that the student gave an incomplete reason even though the chosen alternative was correct. Students were able to provide a logical argument in which the path taken by an increasingly long boat cause the boat longer to cross. The students' logical thinking ability was not adapted to the topic in question so that the students were not able to formulate the argument correctly. The second error was a special error that could lead to failure to construct a deductive hypothesis. The hypothesis was based on the theoretical basis so that the application of concepts to solve the problems affect the success. For example, the concept of horizontal axis velocity was not appropriately applied to motion problems in the vertical axis direction. Common false that supported false in reasoning deductive hypotheses was predicted insufficient to support and, moreover, did not match the hypothesis [15].

4. Conclusion

The conclusions of this research indicate the emergence of common false made by students during the scientific reasoning process. Student's scientific reasoning was dominated by competent level. Student's answers were based on the results of memory that had not been clarified yet and the results tend to lead to weak support for the development of student's thinking. The quality of claims, arguments, and levels of student confidence in the answers was still low. Students experienced false scientific reasoning and weak concepts when confronted with physics problems. Types of common false in every component of scientific reasoning in learning targets were in the forms of innovations to overcome false and confidence in the process of scientific reasoning and the mastery of student concepts.

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