Students' scientific reasoning skills in a fluid and its correlation with project activity

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Abstract. Scientific reasoning skills are necessary to be achieved high school students to encounter competition in the 21st century. This study aims to explore the students' scientific reasoning skills in a fluid and its relation to project activities. This research is a qualitative study with a case study design that focuses on students' scientific reasoning skills on fluid. The subjects in this study were high school class XI students who attended project activities. Data were collected by analyzing the results of students' written tests, observations, and interviews. The results of the study show the relationship between students' scientific reasoning skills and project activities in a fluid. These show common mistakes made by students in scientific reasoning, such as testing all variables (including variables that not related to the questions), testing incorrect variables, focusing on one variable, and depending on prior knowledge, could not determine the relationship between dependent and independent variable. Scientific reasoning skills are essential to be trained in learning through project activities. This study recommends teachers to apply project-based learning to explore students' scientific reasoning skills in large and heterogeneous groups.

1. Introduction
Scientific reasoning skills are part of higher-order thinking that essential to be trained in the 21st century. Cognitive assignments such as remembering, memorizing, and applying knowledge have dominated physics learning. However, the 21st century challenges students to be involved in analysis, evaluation, and synthesis [1]. Scientific reasoning skills contribute to science, technology, engineering, and mathematics [2-4]. Scientific reasoning is a priority ability in science education that relates to collect evidence, theory, and data, which consists of hypotheses and experiments. Most approaches to training scientific reasoning in science education research focus on the project, experimentation, and evaluation of evidence [5].

Many studies of scientific reasoning have been done before, such as assessing students' scientific reasoning only in the science domain [6], assessing using computer-based platform [7,8], and assessing students' scientific reasoning in one indicator such as control of variables [9]. In physics education, research about scientific reasoning that has done, such as exploring how undergraduate physics students make evidence-based reasoning and models for electricity and thermal energy [10-13]. However, the study of scientific reasoning on the fluid of high school students has not been done yet.

Scientific reasoning skills are needed in solving physics problems, especially on fluid, so that necessary to be explored and developed. Research that has been done shows that many students have...
difficulty in solving problems and reasoning scientifically on fluids [14], such as difficulty in determining objects to sink or float [15]. Difficulties in understanding buoyancy [16], fail to apply Newton's law correctly in solving hydrostatic problems [17], connecting between kinetic energy and gravitational potential energy per unit volume with the Bernoulli equation, and the inability to establish a relationship between kinematics and dynamics with hydrodynamics [17].

Project activities involve students in complex real-world problems to produce products and improve content knowledge, scientific reasoning, communication, and creative thinking skills [18], [19]. Projects involve students in complex real-world problems to produce products and improve content knowledge, scientific reasoning, communication, and creative thinking skills [18,19]. Learning through the project is relevant to use in integrating science, technology, engineering, and mathematics that combines problem-solving skills and scientific reasoning skills [19,20].

How do students' scientific reasoning skills in a fluid and its correlation with project activities? This question is the problem that needs to be studied. This research aims to explore the students' scientific reasoning skills in a fluid and its relation to project activities. So, this research provides a map of students' scientific reasoning skills affected by project activities.

2. Methods
The methodology in this research is a case study that focuses on student's scientific reasoning problems on the fluid by choosing a representative case to describe the unique case of scientific reasoning problems. The scientific reasoning indicators in this research are based on Lawson's indicator that consists of four indicators; those are proportional reasoning, controlling variables, probabilistic reasoning, and correlational reasoning.

The sample of this research was second-year students of Senior High School in Malang, three students, Ani, Beti, and Dedi (pseudonym) were chosen to be analyzed their scientific reasoning and activity in creating the project. Students were selected based on their written answer, that students who given almost perfect, universal, and lacking answers. The data were collected in 3 ways, essay test, observation, and interview. The essay tests consist of 4 essays with scientific reasoning aspects, proportional reasoning, variable controlling, probabilistic reasoning, and correlation reasoning. Subtopics of fluid that use to assess scientific reasoning were hydrostatic pressure, Pascal Law, Archimedes Law, and Continuity Principle. The observations were used to check the student's activity in creating the project, and the interview was conducted to know the students' scientific reasoning further, to recheck their answer, to know the unwritten answer, and their consideration in designing water jet free energy project.

3. Results and Discussion
Written answer analysis and interviews with three students are described as follows.

3.1. Proportional Reasoning

![Figure 1](https://via.placeholder.com/150)

**Figure 1.** The question to assess proportional

Analysis of the students' answers on proportional reasoning indicators described as follows.

Ani has understood well the ratio of the speed of water flow through pipes with different diameters. Beti was challenging to compare the speed of water flow through the pipe because water passes through the A, B, and C pipes with three different diameters. Beti could only compare the speed of water flow in 2 pipes that have different diameters.

Ani can apply proportional reasoning and has a better understanding of continuity principles. Meanwhile, Beti had difficulty in solving problems of continuity because she lacked understanding the concept of continuity and had low mathematical abilities.
3.2. Controlling Variables

Analysis of students' written answers is described in the as follows. Ani selected controlling variables: 1. Density, and 2. Depth. The highest hydrostatic pressure is at point B because the water in the container is higher than d. So, point B is the deepest point compared to points A, C, D, and E. Beti selected controlling variable only density, the highest hydrostatic pressure is at point B; the water in container B is more than the other containers. Dedi selected controlling variables 1. Density, and 2. Depth, the highest hydrostatic pressure, is at point E because the area of container E is the smallest compared to the others.

Common mistakes made by students in controlling variables are 1) Test all possible variables (including variables not related to questions), 2) Test unrelated variables for problem-solving, 3) Focus on one variable, and 4) Depends on wrong prior knowledge. Based on these criteria, Beti makes mistakes at numbers 2 and 4, while Dedi is at numbers 2, 3, and 4.

3.3. Probabilistic Reasoning

Analysis of students' written answers is described in the as follows. Ani: All blocks have the same shape and size, but the mass is different. So, the density of the five blocks also differs. The blocks $m_1$ floats, the $m_3$ drifts, and $m_4$ sinks. A density determines the final position of the blocks in the aquarium. Beti: The blocks $m_1$ floats, the $m_3$ drifts, and $m_4$ sinks. Beti only considers the effect of mass on the final state of the blocks. Dedi: The blocks $m_1$ floats, the $m_3$, and $m_4$ drift.

Common mistakes made by students in probabilistic reasoning are: 1) Not considering all the factors that influence the probability of the question and 2) Consider factors that are visible from the surface only (such as mass). Based on these criteria, Beti and Dedi get all standard criteria mistakes in probabilistic reasoning.

3.4. Correlational Reasoning

Analysis of students' written answers is described as follows. Ani: Pressure and water flow rate are inversely related. In area A, the flow rate is lower than the area B, so the pressure in A is higher than the pressure in area B. The flow speed in areas A and B differ due to the different cross-sectional area in A and B. The relationship between cross-sectional diameter and water flow rate is inversely
proportional because the debit an area A will be equal to B, so that in areas with a larger diameter, the flow velocity is smaller. Beti and Dedi: Pressure in an area A of less than B, the speed of water flow in area B is increasing due to higher pressure. Common mistakes made by students in correlational reasoning are: 1) Confused in determining the positive or negative correlation, 2) Claim that "correlation is not a causal relationship, 3) Do not review all the data given on the question, and 4) Depend on improper prior knowledge. Based on these criteria, Beti and Dedi have all common mistakes in correlational reasoning.

3.5. Project Activities

Based on observations, analysis of essay tests, and interviews that have been conducted, scientific reasoning relates to students' activities in the project of water jet free energy. Students design the project with a rectangular-shaped water pipe, a bottle is added to the other side of the pipe, and at the end of the pipe is put the hose. In the designing project, students were free to determine the length of the pipe, the diameter of the pipe, the diameter of the hose, and the many bottles were used. Ani selects small diameter pipes and hoses. Ani selects a pipe with a length of 30 cm, then installs the bottle on two sides of the pipe in the middle of which the bottle is installed. When interviewed, Ani revealed that the cross-sectional area affected the flow rate of the fluid, the smaller the cross-sectional area, the higher the fluid flow rate. Based on observations and interviews, it can be concluded that she applied scientific reasoning in completing the project. She considers the relationship between pipe diameter and fluid flow rate that passes through the pipe and knows the correlation between the diameter and the cross-sectional area of the fluid.

Similar to Ani, Beti chose pipes with a small diameter, and the pipe length was more extended than Ani, which was 35 cm. When she was interviewed, she revealed that pipes with a smaller diameter would produce water at a higher rate. Different from 2 other students, Dedi chooses pipes with a larger diameter. When he was interviewed, he prefers to choose a longer pipe so that he has more volume of water flows. However, Dedi ignores the fact that larger diameter pipes produce water with a slower flow rate. So, it can be concluded that Dedi is not able to correlate the water flow-rate factor with the diameter of the pipe. All students use the same plastic bottles.

This research shows that scientific reasoning can be trained by being developed, being improved, and being transferred through training and practicing. Students' activity in making project can train their scientific reasoning. Students' activity in making project can train their scientific reasoning. This approach introduces the students to work in developing the product. Making project activity encourages the students' creativity and scientific reasoning skills [21]. The research about applying a project in learning shows that students' activity in doing a project can increase students learning motivation, create meaningful learning processes, help students to solve the problem in daily life [20], and increase the students' cognitive skills as well. Learning with the project also can increase the students learning motivation and scientific literation [22]. Reasoning requires knowledge content, which is knowledge about the concept, fact, and theory. Developing students' skills through scientific reasoning requires students to get involved in analyzing practice and interpret data, develop and evaluate the experimental design [1].

Many students experienced errors controlling variables as the aspects of scientific reasoning. They test all possible variables (including variables not related to the question), test the wrong variables, focus on one variable, and depend on improper prior knowledge. Most students lack skills to interpret results and draw conclusions based on data provided on physics problems with several variables. The cause of students' main error in the aspect of identifying and controlling variables is that students understand the meaning of "bound" and "independent" variables; however, they do not know how to identify variables in different contexts [23]. Based on the research findings, students who incorrectly control the variables also make mistakes in determining the variables that affect the rate of fluid flow in the construction of water jet free energy projects.

The factor that causes success in controlling variables is recording the variables contained in the case. Students who are correct in controlling variables when working on a project have been able to
identify influential variables and then record these variables. Based on written test answers given by students, it is also known that students who carry out scientific reasoning have an excellent conceptual understanding of fluid. Conceptual knowledge is an understanding of essential parts and causal relationships that exist in a system. Causal reasoning allows students to predict, conclude, and explain events or phenomena encountered [6, 24]. Some researchers have also shown that the knowledge that students have before entering class plays a vital role in how students approach the task of controlling variables or how to interpret evidence [25, 26].

Based on research findings, common mistakes that students make in probabilistic reasoning is that students do not consider all the factors that probably influence and misidentify the factors involved in the problem. This finding is due to insufficient student’s knowledge to identify all possibilities that exist in the problems raised. One characteristic of successful reasoning is a systematic consideration of various explanations. Apart from its essential contribution to valid scientific reasoning, this skill also plays a vital role in probabilistic reasoning. Several studies have documented people's tendency to look for evidence that confirms their previous beliefs immolate of other possibilities (bias confirmation). Students often fail to consider alternative explanations, even when such explanations are reasonably guaranteed by normative logic [27].

Knowledge of students' scientific reasoning and its relationship to student activities in working on projects is essential for educators and researchers. Students can be trained to do reasoning by working on projects, and educators can find out student errors in reasoning when working on projects.

Some limitations in this study are that consideration is needed to apply the results of research widely because research is conducted on a specific domain, namely on one topic in physics. Nonetheless, the insights given in this study are a valuable starting point and have been supported by other studies that show the scientific reasoning abilities of students at the high school level related to student activities in working on projects [6]. However, the fact that mistakes made by students in solving problems in scientific reasoning are common mistakes. Therefore, scientific reasoning skills need to be trained in physics learning to face the challenges of the 21st century. Future research on scientific reasoning can be done on heterogeneous groups and from students from various schools to get results in a more general and accurate scope to determine students' scientific reasoning.

4. Conclusion

Scientific reasoning can be trained with project activities. Else, students' common mistakes in scientific reasoning are caused by a lack of understanding of students' concepts. Therefore, students have difficulty in determining the influencing variables in scientific reasoning of problem-solving, students test all variables even the variables are not related to questions, and students do not consider all factors that likely influence.

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