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EVALUATION OF SENIOR HIGH SCHOOL STUDENTS' SCIENTIFIC INQUIRY SKILLS: A PERSPECTIVE FROM PROPOSING ACTION AND INTERPRETING RESULTS

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Abstract

The critical component in science learning today is the students' ability to proficiency the scientific inquiry skills. Inquiry skills are the focus in scientific practice today, especially on proposing action and interpreting results. For this purpose, three experimental worksheets on energy topic were designed and developed. Thirty students enrolled in 11th grade in a public senior high school in the Bulungan Regency, North Kalimantan Province participated in this study. This study used qualitative research methods to collect data in accordance with the principles of classroom natural setting. Participants are involved in teaching and learning process activities that are taught by physics teachers in the schools. The results of the students' written responses were obtained from the experimental worksheet, as well as field note data during observations during the teaching-learning process. The results of the study show that in the category of proposing action and interpreting results the students' abilities are still low. Proficiency in content knowledge according to substantive concepts has a strong effect on students' scientific inquiry skills. The implication of this study is that it emphasizes the formation of scientific culture classrooms to be able to promote and bring science closer to the students.

Keywords: inquiry-based learning, scientific practice, proposing action, interpreting results

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INTRODUCTION

One of the fundamental philosophical questions related to human cognition is, "how do individuals know something?" The conceptual framework of science education, especially in the United States has also changed, namely the emphasis on the use of scientific practice in scientific inquiry activities and in the assessment process which also involves students' scientific inquiry performance (Kruit et al., 2018; Scalise & Clarke-Midura, 2018). These philosophical questions and changes in the conceptual framework of science education are bridged by the notion of philosophical inquiry and scientific inquiry that focus on developing students' abilities to think scientifically (Burgh & Nichols, 2012). These two factors are also closely related to the teaching and learning process of science and substantive concepts in science and the science learning curriculum itself (Davis & Bellocchi, 2018; Qadeer, 2013). In addition, the current practice of the science learning process emphasizes mastery of scientific inquiry skills and content knowledge (Fang et al., 2016). These skills are commonly called scientific inquiry skills. Learning scientific inquiry skills to students is an adaptation to the skills of scientists used when researching natural phenomena (Fadzil & Saat, 2014; Molefe & Stears, 2014; Mutlu, 2020).

Scientific inquiry skills are important skills in understanding the nature of science with a hands-on experience approach and as a provision to solve everyday problems and help the students acquisition the 21st century skills. However, in fact there are still many students who do not have good scientific inquiry skills to support mastery of substantive concepts, even since 7th grade (Lederman et al., 2019). Science learning in Indonesia still tends to use traditional methods that have not emphasized mastering content and are supported by the formation of behavior according to scientific skills (Mahdiannur, 2019). This causes Indonesia's ranking in every measurement of students' science performance at the international level, always be unsatisfactory.

The development of student capacity regarding scientific inquiry skills, especially understanding the design and conceptualization of scientific research is important to do (Davis & Bellocchi, 2018; Nehring et al., 2015). Formal science experience has a vital influence on students' scientific inquiry abilities (Wu et al., 2018). Scientific inquiry skills are themselves skills used by students as scientists use in inquiry-based inquiry environments (Mutlu, 2020). In general, the scientific inquiry skills that are focused in this study are (1) proposing action; and (2) interpreting results (Gutwill & Allen, 2012). Proposing action skills are skills that are implemented before the experiment, while results interpreting skills are skills related to science process skills and procedural concepts to the ability to provide explanations based on the data obtained. Therefore, in this study we focus on exploring the scientific inquiry skills of high school students based on cases from energy topic.

METHOD

Design and Treatment

This study used qualitative research methods (Denzin & Lincoln, 2011; Mutlu, 2020) to collect data in accordance with the principles of classroom natural setting. Classroom natural setting in question is a science learning activity in physics with the topic of energy. The energy topic was chosen because it is one of the cross-cutting concepts in science and is also relatively familiar to students because it has been studied since elementary school. In this study, three scientific experimental activities in physics on the topic of energy were designed and developed. The first experiment was about potential and kinetic energy, the second experiment was conserving energy, and the third experiment was about the transfer and transformation of energy forms. All experimental activities were carried out in small groups.

The three experimental activities validated by three subject matter experts with a screening method according to the requirements stated by Nieveen & Folmer (2013). The validation method used is a rating given by subject matter experts in the validation measurement instrument. The suitability of the rating given by the subject matter expert was analyzed using the validity and reliability index as stated by Aiken (1985). Based on the results of the validity and reliability index calculations, it is concluded that the experimental activity worksheets were valid and reliable. Furthermore, the research team coordinated with the physics subject teacher to implement the three experimental worksheets on this energy in the learning process according to the semester program that had been made previously. The level of scientific inquiry used is an open level with several scaffolding in the form of questions or guiding instructions as stated by Wheeler & Bell (2012).

Participants

This study involved thirty Senior High School students enrolled in 11th grade (aged 17-18 years). This group of students consisted of eleven male students and nineteen female students. The Senior High School used as the place for this study to be conducted is one of the public schools in the Bulungan Regency, North Kalimantan Province.

All students involved in this study have given their consent voluntarily to participate. In addition, all participant data will be kept confidential and submitted anonymously in accordance with the research code of ethics.

Collecting and Analyzing Data

The data collected in this study were data related to the students' scientific inquiry skills. The data was obtained based on the experimental worksheets that the students had filled in during practicum/experimenting activities. In addition, data were also obtained from notes on observations during learning activities. The real data is then compared with indicators in the proposing action and interpreting results categories according to Gutwill & Allen (2012). Indicators of scientific inquiry skills in proposing action and interpreting results are presented in Table 1.

Table 1. Description of scientific inquiry skills indicators

No.	Indicator	Description/Attribute
1	Proposing Action	Skills in association with planning or designing experiment, defining the problem/research question, operational definitions, and formulating hypothesis and operational definition from scientific investigations.
2	Interpreting Results	Skills in association with conducting experiment, observing, collecting data, analyzing, and interpreting experiment results.

For the reliability of the measurement to be guaranteed, an assessment rubric is made that makes it easy to analyze the data from the experimental worksheet entries. The rating scale used is a three-point scale (0-2). A score of 0 indicates that the student did not fill in or was wrong from the concept/key, while a score of 2 indicated that the student's response was in accordance with the indicators and attributes in scientific inquiry skills.

RESULT AND DISCUSSION

The context of this study emphasizes the written responses in the experimental worksheets filled out by each participant. The responses are then codified and grouped based on two types of scientific inquiry skills, namely proposing action, and interpreting results. The discussion on the data is as follows:

Proposing Action

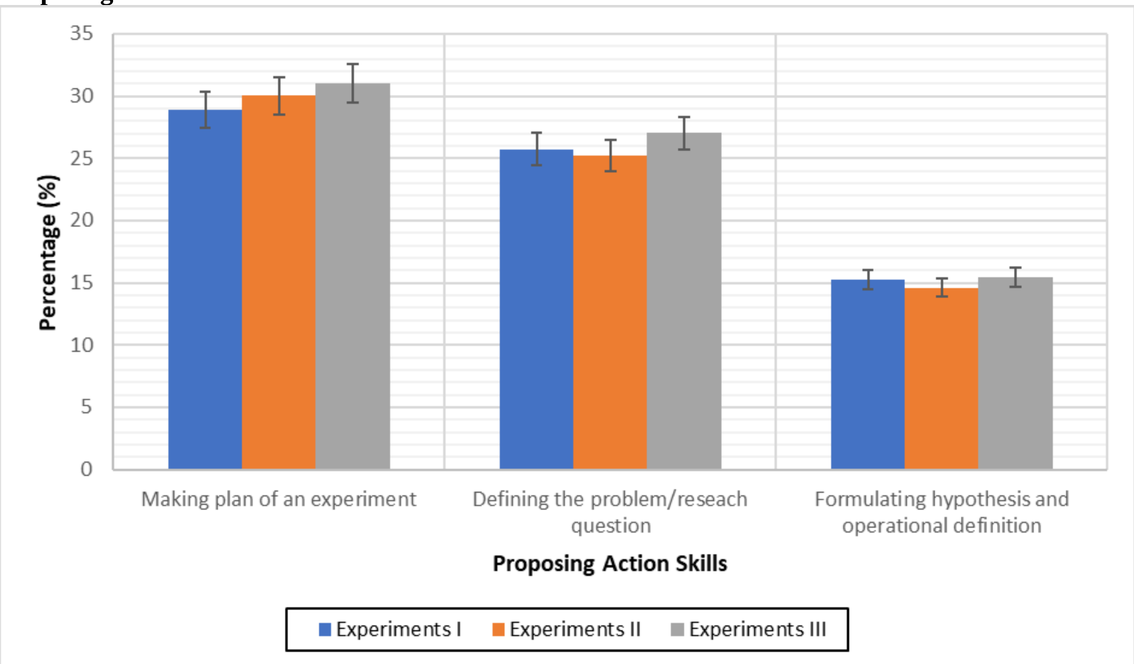

Figure 1. Students' performance on proposing action (error bar: 5%)

There are three types of proposing action in this study, namely: (1) planning of an experiment; (2) defining the problem/research question; and (3) formulating hypothesis and operational definition. Based on the data in Figure 1, all three skills in the proposing action category are at a low level (mean percentage 23.70%). The lowest ability is that students still experience problems in formulating hypotheses and operational definitions (mean percentage 10.74%). The hypothesis itself is a scientific conjecture in the form of a cause-and-effect statement based on scientific knowledge. The results of this study indicate that the students' lack of skills in procedural concepts are due to mastery of low substantive concepts and a lack of emphasis on inquiry learning in science subjects in secondary schools. The process of making hypotheses is the most difficult for students (Kuang et al., 2020). This difficulty is because the formulation of hypotheses requires reliable thinking, reasoning, calculation, and planning creativity (Osborne, 2015). In the future, it is necessary to provide scaffolding in the form of assistance in the formulation of hypotheses and operational definitions partially according to the zone of proximal development of the students.

The ability to plan experiments and define problems or create research questions also shows low results, although it is still better than the ability to formulate hypotheses. The average percentage of the ability to make plans was 29.98%, while the ability to define research problems / questions was 26.00%). The low ability to plan experiments and define problems or research questions has strengthened the findings so far that science learning at the secondary school level is still not inquiry based. Planning experiments that lead to the formation of research questions is the most important part of successful inquiry-based learning. Research questions are the first step in developing research-based science education (Herranen & Aksela, 2019). In addition, the term of inquiry is an understanding of content and skills (Bybee, 2000). The results of this study on proposing action skills indicate that the practice of science learning, especially in pre-inquiry abilities, needs to be improved along with understanding content according to substantive concepts.

Interpreting Results

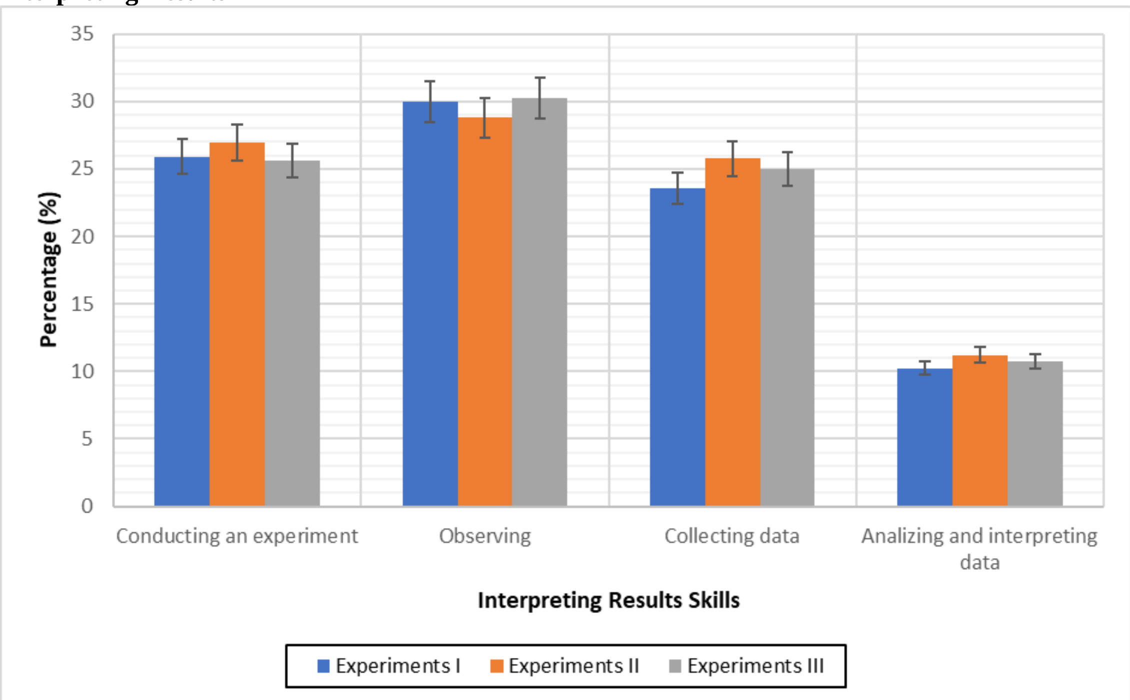

Figure 2. Students' performance on interpreting results (Error bar: 5%)

Interpreting results is a skill while doing experimentation and post-inquiry (conducting experiment, observing, collecting data, and analyzing and interpreting data). The process of interpreting the results is the key to completing laboratory-based inquiry activities (Mutlu, 2020). Of all the abilities in the cluster interpreting results presented in Figure 2, the ability to analyze and interpret data is the lowest (mean percentage 10.74%). The process of analyzing and translating experimental data is not easy. This process requires a good understanding of the concept and mastery of content according to substantive concepts. The process of reasoning through data is a crucial point in science learning (Morris et al., 2015). Examples of student responses in analyzing gravitational potential energy from the experiment I,

"… PE is getting bigger; distance is getting bigger…" (Student #7)
"The data shows that potential energy is obtained from values of mass, gravity, and height ..." (Student #16)
"... Potential energy changes due to the difference in height." (Student #23)

The ability to conduct the experiment activities is closely related to the ability to collect data based on observations. The average percentage of the conducting experiment ability was 26.14%, the ability to collect data was 24.76%, and the ability to observe was 29.68%. The students' low mastery of these three abilities is because the skills in the action proposing cluster are also low. Mutlu (2020) reports in his research that the pre-inquiry stage, such as the experimental planning aspect, is very decisive in the laboratory-based inquiry stage. Osborne (2015) also suggests that the process of collecting data and testing solutions requires the ability to observe, experiment, measure, and test.

The students' mistakes are due to incomplete mastery of content and concepts. lack of content knowledge acquisition resulted in faulty experimental design made during the pre-inquiry stage. Proficiency in content knowledge and inquiry abilities influence each other (Fang et al., 2016). In addition, because of limited resources, students rarely or even never did practicum or experiment activities before, so that many students are wrong or even not skilled in using tools and materials to support experimental activities. Student observation ability is also still low, although it shows better performance when compared to the ability to carry out experiments and collect data. On the other hand, experimental activities in groups tend to share the dominant role, especially during the preparation of equipment and observation and data recording. Equivalent results were reported by Mutlu (2020) and Puntambekar, Gnesdilow, Dornfeld Tissenbaum, Narayanan, & Rebello (2020).

CONCLUSION

Based on data on scientific inquiry skills (proposing action and interpreting results), it appears that it is necessary to change the experimental-based inquiry learning approach. This experimental process should not only be viewed as a process to induce experimental activities in the laboratory as is done by scientists. Scientific inquiry skills must be viewed as a form of scientific practice and involve the performance of students' scientific inquiry (Kruit et al., 2018; Scalise & Clarke-Midura, 2018). The idea of scientific practice in the science learning process must be a multifaceted approach that involves conceptual, procedural, epistemological, security, temporal, material, and social aspects (Wei & Li, 2017). In detail, the grouping of scientific or science practice is divided into three, namely investigating, sensemaking, and critiquing (Cherbow et al., 2020).

The clusters of scientific inquiry skills, namely proposing actions and interpreting results, are in line with the scientific practice approach in the science learning process in secondary schools. In addition, scientific inquiry skills are closely related to mastery of content knowledge. The results of this study indicate that scientific inquiry skills can be divided into several clusters and each cluster consists of several indicators of ability or subskills. Measuring each indicator through student performance can add insight to the teacher in the form of diagnostic data to fix the curriculum so that it is compatible with inquiry-based learning with the scientific practice approach. This approach can increase knowledge and introduce and bring science closer to students. This study also indicates how the teaching and learning process of science family subjects is sustainable to form a scientific classroom culture, so that it can erode the habit of using traditional methods of teaching science that are only knowledge-oriented and form a community of philosophical inquiry in the classroom. However, it is necessary to replicate it in other schools, so that they can produce more comprehensive data in the context of science education in Indonesia.

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