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SCIENCE AND ENGINEERING PRACTICES (SEPs): STUDENT'S PROFILE OF PLANNING AND CARRYING OUT INVESTIGATIONS (PCOI)

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Abstract

Purpose of the study: The purpose of this study is to analyze the students' profiles of planning and carrying out investigations (PCOI).

Methodology: This research is used as a descriptive method involving 40 students of 10th grade from two senior high schools in Boyolali regency, Central Java, Indonesia. The instrument is five questions based on the indicators of science and engineering practices by California Science Test Practices.

Main Findings: The average student's correct answer is 42%. The result of the study represented that planning and carrying out investigations ability students categorized into a low level.

Applications of this study: The involvement of this research is to improve students' science and engineering practices, especially in the aspects of planning and carrying out investigations, that can facilitate students in learning physics.

The Originality of this study: This research has an innovation that aims to determine student's profiles of planning and carrying out investigations in work and energy materials using a two-level test adapted from the California science test practice.

Keywords: *Science and Engineering Practices, Science Process Skill, PCOI, Physics, Education.*

INTRODUCTION

The world in the 21st century is a place to innovate to keep changing and developing (Whittington, 2017). An important agenda in facing globalization in the 21st century is to produce a high-quality generation (Rusdin, 2018). Facing the industrial revolution 4.0 in terms of disruption of education requires curriculum and learning models development. One of the educational developments that need attention is physics education (Lazzaro, 2015). The most basic science is physics and it has profound philosophical implications (Kabil, 2015). The physics learning process in schools basically aims to develop students' thinking skills to provide knowledge (Depdiknas, 2006; Gane, Zaidi & Pellegrino, 2018).

Physics lessons have a special use in terms of discovery. However, most students consider that physics is a difficult subject to learn (Astalini, Kurniawan, Perdana & Kurniasari, 2018). So, they need encouragement to make them interested in physics, such as practicum activities in learning so that the theories can be learned in an everyday life context. One way is to insert practicum activities in learning so that the theories that have been taught can be learned in real life (Maison, Budiarti, Christine Samosir, & Nasih, 2020). Therefore, it takes an alternative to make physics lessons more fun.

Physics learning has a new framework called NGSS which stands for Next Generation Science Standard. It is intended to increase students' involvement in STEM learning **(**Barakos, Lujan & Strang, 2010; NGSS Lead States, 2013**).** The new standard regarding students' ability is expected to alter the basic skills and knowledge of the past, not only in the US (NGSS Lead States, 2013) but also in Indonesia, because it has similar characteristics to the current 2013 curriculum, which used today. The curriculum change is designed not only for cognitive learning, but also for the effective or psychomotor domains and the balancing competencies achievement between attitudes and skills with holistic and fun learning (Depdiknas, 2016).

NGSS requires the development of three scientific skills dimensions, there is an application of science (science and engineering practices), science content (students' understanding of disciplinary core ideas), and ideas that connect the disciplines in science (constructing concepts) (Bybee, 2014; National Research Council [NRC], 2011; NGSS Lead States, 2013). The three dimensions of NGSS were built to develop scientific dispositions so that students could find out the right time and way to seek and build knowledge (Krajcik et al., 2014). SEP is a repetition of the so-called science process skills or science inquiry skills in the previous standard version of science. (Atwood-Blaine, 2017; National Research Council, 1996). The NGSS identified eight SEPs, collectively referred to as practices. NGSS practice encourages students to be 1) able to give questions and identify problems [SEP-1], 2) able to develop models and use them [SEP-2], 3) able to plan investigations and carry them out [SEP-3], 4) able to analyze data and interpret them [SEP-4], 5) able to use computational mathematics and thinking [SEP-5], 6) making explanations and designing a solution [SEP-6], 7) participating in arguing from existing evidence [SEP-7], 8) and being able to draw information, evaluate, and communicate it [SEP-8] (Hynes & Berry, 2014; NGSS Lead States, 2013).

This study employs one of the practices in NGSS, namely planning and carrying out investigations (PCOI) on work and energy materials. PCOI is designed to involve students in deciding the steps from question to action or in other words designing investigations to compile experiments (Duschl & Bybee, 2014). Scientific investigations can be carried out to test a theory or represent a phenomenon and become a model for how the world works (NGSS Lead States, 2013). Specifically, work and energy materials are materials studied from primary to secondary education. Physics lessons on the concept of work and energy in high schools have a broad scope and are widely utilized in everyday life (Lindsey, Heron & Shaffer, 2009).

Meacham (2019) provided a clear description of PCOI as a systematic investigation that produces data that substantiate scientific questions. This investigation determines the goal of the investigation, develops predictions or hypothesis, and designs procedures. Besides, students also controlled and investigated the method to be used, as well as identified and analyzed experimental variables. They carried out investigations to collect data using appropriate tools and methods, and the last one was to compile experimental work steps.

Physics teachers have attempted to make students like physics. However, students still have difficulty learning physics, so there is a need for a practice that makes learning more meaningful. (Hombouger et al., 2019). These problems motivate the writer to conduct research aimed at identifying the initial abilities of students in the PCOI aspect so that later the teacher can develop the skills that the student already has.

Therefore, this study aimed to analyze the students' initial planning and carrying out investigation (PCOI) skills.

LITERATURE REVIEW

Science and engineering practices (SEPs) are part of the dimensions of the next generation science standards framework (Malkawi & Rababah, 2018). SEPs consist of the skills needed for involved in engineering design and scientific inquiry (Brand, 2020). Practices in science and engineering describe actions in science learning (Tomovic, McKinney & Berube, 2017). There are several assumptions about SEPs: Practice gives students the skills needed to participate in analytical thinking, Practice grows in complexity and sophistication in the whole class, Practice represents what teachers expect students to do (National Research Council, 2012). So, teachers need to give lessons to students, to improve understanding and facilities with practices that are appropriate to the context of the material.

Science and engineering practices are commonly called science process skills. Science and engineering practices replace and enhance one's view of previous science views (Nollmeyer & Bangert, 2017). Practice in science enriches students' understanding of learning processes, such as how to do and get things (Michaels, Shouse, & Schweingruber, 2008). It is used to solve problems and construct knowledge (Karadan& Hameed, 2016; Maison, Budiarti, Christine Samosir, & Nasih, 2020), so it can be used to develop students' process skills (Arantika, Saputro&Mulyani, 2019; Ernawati, Damris, & Asrial, 2019). SEPs in NGSS are used as a means for students to conduct experiments or demonstrations. So they can apply knowledge for further and meaningful experience (Stephenson, 2020). Duschl & Bybee, 2014 hypothesized that the review of planning and carrying out investigations (PCOI) was an attempt made to inform students in building knowledge through scientific Practice. Planning and carrying out investigations in psychological research and science education discusses investigations, such as creating and interpreting the evidence obtained (Manz, Lehrer, & Schauble, 2020). This Practice requires individual planning and collaboration between several individuals and the need to provide an evaluation and investigative plan revision (Alonzo, 2013; NGSS Lead States, 2013). Several PCOI indicators are part of the primary abilities of process skills, including identifying variables, identifying relationships between variables, making hypotheses, designing experiments, arranging experimental steps, and others (Rezba, Mcdonnough, Matkins & Sprague, 2007; Meacham, 2019).

The students' process skills are in a low category as well as the Student Planning and carrying out investigations are still in a weak category (Windriyana, Prodjosantoso, Wilujeng, & Suryadharma, 2018). One of the best ways that used to measure the abilities of SEPS students with practicum programs (Feyzioğlu, Demirdağ, Akyildiz, & Altun, 2012). The Science and engineering practices aspects that developed using Practice are planning and carrying out investigations. Because with practicum activities students can plan and conduct investigations such as determining practicum goals, predicting hypotheses, using tools in the laboratory (Darmaji, et al, 2019; Meacham, 2019).

The use of experiments in improving students'PCOI skills is appropriate when it is applied in physics because experimentation is one of the needed learning methods in science education to achieve students' psychomotor knowledge and skills. Besides, it can also help students receive lessons, make students more active, develop a sense of responsibility to students, make learning more meaningful (Karamustafaoğlu, 2016).

METHODOLOGY

This research employed the descriptive method. It was conducted with 40 students in grade 10th from two senior high schools in Boyolali regency, Central Java, Indonesia in the academic year of 2019/2020. The school was chosen by using random sampling techniques.

This research used the multiple-choice test to collect data. Students' planning and carrying out data were obtained from student tests using the Two-Tier Multiple Choice (TTMC) assessment instrument. This instrument is divided into two

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levels. The first level is the main answer to the question called the first tier. The next level is the choice of reasons to choose answers at the first level its called the second tier (Treagust, 1998). TTMC is like an ordinary multiple-choice but emphasizes high-level thinking and skills in giving reasons (Adodo, 2013). The number of instruments used in this study is five items developed based on the indicators of PCOI from the California science test Practices. Examples of questions on the TTMC instrument adapted from California Science Test Practices (Caaspp, 2019).

Assessment of the TTMC instrument uses the Graded Response Model (GRM) method. GRM was developed in the assessment of polytomous items (De Ayala, 1993). This method can help teachers knowing and correcting students' answers, then detecting and indicating students' skills (Wardani, Yamtinah & Mulyani, 2015). The rules of the TTMC instrument assessment presented in table 1 (Ratnasari, Sukarmin, Suparmi & Aminah, 2017).

Table 1: PCOI Skills Assessment Guidelines with the GRM Assessment Model

No	Assessment Aspects		Score
	First Tier	Second Tier	
1	Do not answer the question or wrong	Do not choose the reason or wrong	0
2	Wrong answer or False	True reason	1
3	True answer	Wrong reason or False	2
4	True answer	True reason	3

Source: Ratnasari,et al., 2017

The score from TTMC were converted into four categories (Sugiyono, 2010) are shown in table 2.

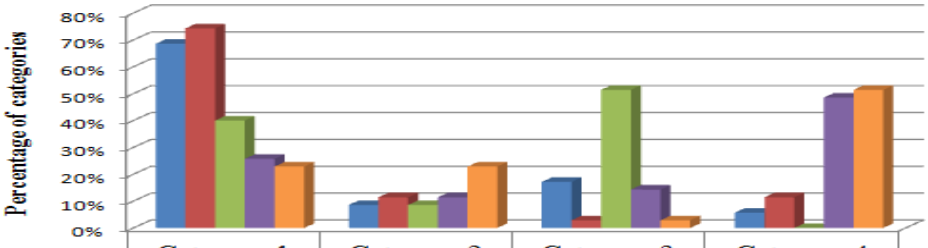
Table 2: The Students' Achievement Criteria of PCOI

Percentage	Categories
$0\% < P \leq 25\%$	Very Low
$25\% < P \leq 50\%$	Low
$50\% < P \leq 75\%$	Medium
$75\% < P \leq 100\%$	High

Source: Sugiyono, 2010

RESULTS AND DISCUSSION

This section describes and discusses the research findings. The researchers obtained these findings using the TTMC instrument to analyze students' planning and carrying out investigation skills. The initial skills analysis from PCOI skills employed Microsoft Excel application. The students' answer results were then analyzed using the GRM model assessment's four categories, as shown in Figure 1.



	Category 1	Category 2	Category 3	Category 4
Item 1	69%	9%	17%	6%
Item 2	74%	11%	3%	11%
Item 3	40%	9%	51%	0%
Item 4	26%	11%	14%	49%
Item 5	23%	23%	3%	51%

Figure 1: Percentage of planning carrying out investigations

Source: Author, 2020

The results of the study based on Figure 1. reveal that the item 1 and 2 get the most results in the first category, this indicates that the students have difficulty in answering the questions correctly and it indicates that the questions are complicated (Putri, Istiyono, &Nurcahyanto, 2016). The item 3 describes that most of the students answer the third category; 51% of students have been able to answer the first level correctly, but they have not been able to choose the right reason. Meanwhile, items 4 and 5 explain that most of the students choose the answer in the fourth category. It means that they have already understood because the questions are easy (Putri, Istiyono, &Nurcahyanto, 2016). In addition to categorizing each aspect of students 'answers using the GRM assessment model, the researchers also classified students' answers into four categories: very low, low, medium, and high. Achievement results for each item are

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shown in Figure 2.

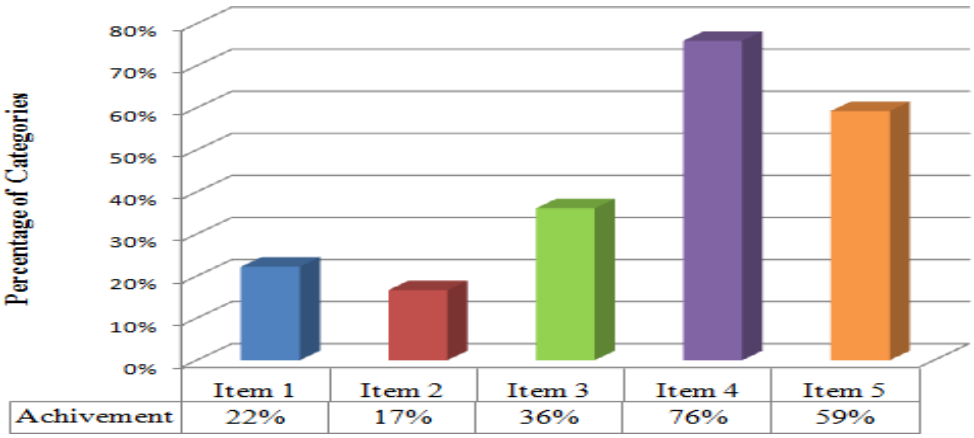

Figure 2: Result of Planning and Carrying Out Investigations Skill Analysis

Source: Author, 2020

Based on Figure 2, shows that the indicator which has the lowest percentage is to identify the tools and materials used in the experiment (item 2). The second indicator that has few achievements is identifying the variables used (item 1). The average result of students' achievement is 42%. This shows that the achievement of planning and carrying out investigations (PCOI) skills of the students is in a low category. That indicates that the achievement of planning and carrying out an investigation (PCOI) skills based on the criteria in table 2 (Sugiyono,2010) is in a low category.

This 21st century requires an individual to master various skills; thereby, education becomes one way to prepare for mastery (Zubaidah, 2016). One learning method that can improve student skills is practicum (Astuti, Putra, & Bhakti, 2018). Practicum can change something that allows us to develop knowledge, which in turn enriches the learning process (Zhaidary, Zhibek, Rauza & Zhuldyz, 2015). Researchers in the science world have agreed that practical work carried out by students is essential in learning science (Abrahams & Millar, 2008) (Hodson, 2009) (Millar, 2004). Johnson (2016) expressed his opinion that effective science learning must involve students in doing science practices, such as getting used to thinking, which leads to modern science practice and meaningful learning. This aspect of SEP still needs to be improved by using NGSS-based learning, similar to existing research that NGSS-based learning improves planning and carrying out investigations skills (Nollmeyer&Bangert, 2017) Learning models that are suitable for increasing student's SEP skills include experiments or projects both in the laboratory. Since with practicum activities, students can plan and carry out investigations, such as determining practicum objectives, predicting hypotheses, employing tools in the laboratory, identifying variables, identifying relationships between variables, making hypotheses, designing experiments, compiling experimental steps, and others (Bradley, 2005) (Darmaji, et al, 2019) (Lunneta, Hofstein, & Clough, 2007)(Meacham, 2019) (Rezba, Mcdonnough, Matkins& Sprague, 2007)(Wong, Hodson, Kwan, & Yung, 2008). This is supported by research conducted by (Maison, Budiarti, Christine Samosir, &Nasih, 2020), namely student's science or science process skills and students' engineering practice which is carried out with practicum. The use of practical activities causes students to learn in a different way than usual.

CONCLUSION

Planning and carrying out an investigation (PCOI) is one aspect of skill science and engineering practices. The PCOI aspect is essential because students in the 21st century are required to master the knowledge and have skills. Nevertheless, the results obtained from the study showed that the students' PCOI skills were still low. The data analysis results of students' initial PCOI skills obtained a percentage of 42%. The lowest indicator in this study was to identify the tools and materials used in the experiment. It was due to a lack of learning that helped students hone their skills. Therefore, it is necessary to develop a learning model that can improve the students' SEPs skills, especially in the PCOI aspect.

LIMITATION AND STUDY FORWARD

This study has several limitations. The number of participants was relatively small, its only 40 students. This study was also only examined at the school of the research subject, not to several other subjects and schools. Researchers hope that there will be more research on the science and engineering practice skills, especially on the aspects of planning and carrying out investigation because besides being equipped with the knowledge, students must also be equipped with skills to face the industrial revolution 4.0. Besides that, hopefully, in the future, there will be many question instruments that are adapted to the material being taught so that it will be easier for teachers to see the students' skills.

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AUTHORS CONTRIBUTION

In research, Yushinta Amalia acted as an article writer, theme chooser, data collector and analyzed it. Sukarmin and Suharno as mentors who provide ideas and comment on articles with deep discussion.

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