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SCIENTIFIC EPISTEMOLOGY IN LEARNING PHYSICS THROUGH PRACTICAL WORK

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Experience in conducting physics practical work provides an opportunity for students to engage in hands-on science activities and enhance the understanding and mastery of physics. Practical work that based on inquiry approach would be essential in generating student constructive thinking and scientific epistemology. By improving scientific epistemology students would form scientific views as scientists. The aim of this paper is to determine the common activities that students engage during physic practical work which can describe cultural student's practice. An unstructured observation is conducted on a group of students in one science school for an hour 15 minutes. All students' activities are recorded in the field notes at every five minutes interval to understand how science students perform the experiment during their regular practical work. The observation is also recorded by audio and video record. The data is being interpreted using thematic analysis to find the themes that represent the science school practice. The result shows that students are less practicing inquiry during practical work. There are four themes that obtained to describe the common activities of students in the science school; teacher's guide, applying scientific skills, interaction and emotion response. A science activity that students usually carry out during practical work is applying scientific skills, which is the highest percentage of the themes. The findings suggested that the practical work based on inquiry should be applied consistently in science school for students to gain real experience on how scientists should act and think.

Keywords: Scientific Epistemology, Practical Work, Physics.

1. INTRODUCTION

Physics is one of the important subjects that is a prerequisite to scientific and technological progress which is reflected in its studies closely linked to national development (Celik *et al.*, 2011). But the number of nation proficient in science, technology, computer and scientific skills to meet the challenges of the 21st century is lacking (Tuan Mastura *et al.*, 2010). Thus, physics is a study that provides scientific skills, such as exploring, identifying, investigating and solving problems (Zanaton *et al.*, 2006; Kamisah *et al.*, 2007). Therefore, learning physics is in line with the national requirements for experts to cultivate scientific skills as well as that support the development of science and education of physics in the country (Celik *et al.*, 2011; Tuan Mastura, *et al.*, 2010.). However, the decline student enrollment in science has led to a decrease in industrial experts, scientists and technology certified trainers to the detriment of development and economic position (Onn and Subramaniam, 2011). As reported by Fatin *et al.* (2014), student

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participation and achievement in science stream are declining due to few factors. One of the factors related to this issue is the students' scientific epistemological beliefs (Ogan-Bekiroglu and Sengul-Turgut, 2011; Schommer-Aikins and Duell, 2013; Sharma *et al.*, 2013; Yong and Fatin, 2015). This is because there is a gap between student's practical work learning with student's epistemological beliefs about science (Sandoval, 2005). Students's view about scientific epistemology is affected by students' performance in practical work as the students may understand that they are not discovering new theory in physics but they should learn how to discover physic in real scientific inquiry (discovering like scientific communities) (Hirvonen and Virri, 2002). Thus, practical work learning based on scientific inquiry approach may expose students to gain experience on how students can master and understand knowledge on physics adequately.

1.1 The Importance of Scientific Epistemology in Learning Physics

Epistemology in science or scientific epistemology is known as a nature of scientific knowledge (Abd El-Khalick *et al.*, 1998; Lederman *et al.*, 2002). The nature of scientific knowledge - nature of science (NOS) is a description of how students can learn, assess and build confidence in the development of scientific knowledge (Abd El- Khalick *et al.*, 1998). Sandoval (2005) emphasizes that scientific epistemology should be based on logic and philosophy of science which form a scientific statement which is advanced and can be justified. The description of the nature of scientific knowledge is based on the source of knowledge, its legitimacy, proven scientifically and others (Sandoval, 2005).

According to Sandoval (2005), there is a gap that exists between the knowledge of science (belief in knowledge) and practice. Students who are well versed in the facts, principles, laws and theories of science do not necessarily mean they understand the process and the underlying philosophy of science (Wenning, 2009). Sandoval (2005) pointed out that the beliefs and practices of scientific inquiry can enhance students' scientific epistemology and form a scientific view, as scientists. Thus the development of scientific ideas of physics students can be viewed individually through the exploration and findings of the inquiry undertaken during practical work in schools. There are seven steps that referring inquiry in this research context; asking questions, generating and pursuing strategies to investigate the questions by generating data, analyzing and interpreting the data, drawing conclusion, communicating the conclusions, applying the conclusions back to the original question, and follow up on new questions (if any) (Sandoval, 2005).

As reported by Lidar *et al.* (2005) the presence of the scientific epistemology can be identified and described through the behavior of students. Student behavior can be observed while performing practical work (Duncan and Arthurs, 2008).

Scientific practice, such as, a practical work should be exposed to students to enable them to know the difference between observation and inference while conducting experiments. Lederman *et al.* (2002) states that observation and inference are the fundamental theoretical concepts and entities in the world of science. Therefore, mastering the skills of observation and inference makes it an important aspect of scientific epistemology (Abd El-Khalick *et al.*, 1998).

In line with the objectives of the study, *i.e.* to see how practical work can foster students' scientific epistemology, Ogan-Bekiroglu and Sengul-Turgut (2011) has found that students need to use a discovery-inquiry method to develop their scientific epistemological beliefs. Figure 1 shows four elements in the inquiry-based physics practical work learning to develop scientific epistemological beliefs. These elements are intergrated ideas from Sandoval (2005), Duncan and Arthurs (2008) and Lederman *et al.* (2002).

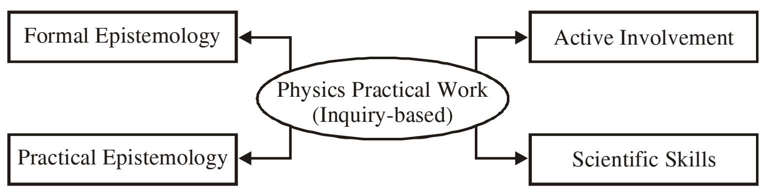

Figure 1: Inquiry-Based Practical Work Learning to Promote Scientific Epistemology

Formal epistemology can be found from the view of students to the physics knowledge by stating the understanding of the concept, theory and explanation on how the knowledge of physics is constructed (Ogan-Bekiroglu and Sengul-Turgut, 2011; Schommer-Aikins and Duell, 2013; Sharma *et al.*, 2013). While the practical epistemology is the development of scientific knowledge through practical work in schools. At schools, the practical work and its activities are carried out in the laboratory through hands-on learning and active involvement among students. The activities encourage them to think and discuss on how to complete the experiment. Practical work learning is a medium to expose students on how scientists act and think (Duncan and Arthurs, 2008). Through the integrated and manipulative scientific skills applied during physics practical work, students would be able to improve their knowledge by thinking constructively (Sharifah and Rohaida, 2005; Abrahams *et al.*, 2015).

Hence, the objective of this research is to explore in what way that practical work in science school influence students learning and lead to generate scientific epistemology. According to Sandoval (2005) inquiry approach is the process of doing science. This preliminary study is to determine the common activities in the practical work at science school that culturally practice among students and how they discover physics like scientist.

2. METHODOLOGY

In exploring the common activities that physics students involve during practical work, the qualitative research method through unstructured observations has been used. Based on Lidar *et al.* (2006), the qualitative approach is used to understand the factor that students' view of science influenced students learning physics in practical work. Thus, in this study, the aims of using the unstructured observation are to determine the activities of students in conducting experiments and to explain how the activities in practical work learning can help to generate students' scientific epistemological beliefs. For this preliminary study, purposive sampling is used to a group of form four physics students from a science school in Johor, Malaysia. The group of students was observed during physic practical work that lasted for 1 hour 15 minutes. The students were selected based on their active participation in physics lesson. The students' age is about 16 years old and all of them are male.

The researcher observed the students from the beginning of setting up the experiment until the completion. Data was collected using field notes. All of the students' activities during the experiments were recorded via audio and video for every 5 minutes, and finally 12 activities were obtained, and labeled as A. In the data, the first 10 minutes was for class management, teacher explanation, followed by demonstration. In the last 5 minutes, students returned all equipment and cleaned up the laboratory. Although the data is for one time observation, researcher had observed the participant for two months (from April until May) to understand the character and students' behaviour.

The data was analyzed and interpreted using thematic analysis method proposed by Braun and Clarke (2006) to obtain the activities that lead students complete the experiment. To get familiarized with the data, the data were read and reviewed repeatedly. Next, initial codes were generated. The coding generation was made line by line to obtain the sense of inquiry that students should practice. The coding is referring to the element in Figure 1; inquiry-based practical work learning to promote scientific epistemology. After repeating few methods and interpretation, the codes definition is made. Based on the interpretation of the activities in the practical work learning, the resulting themes was obtained.

3. RESULT AND DISCUSSION

Physics practical work in science school is shown in Table 1. Through the interpretation of the data, several codes are identified and collected during the practical work learning. The coding forms four themes that represent how student doing practical work in school.

From the analysis, four themes are found namely; teacher's guidance; apply scientific skills; interaction; and emotion response. In this study, the researcher

TABLE 1: THEMES AND CODING IN PRACTICAL WORK LEARNING

Theme	*Code*	*Example Activities*
Teacher's Guide	Instruction	[A1a] Students are waiting for the teacher's instructions to set up the equipment before starting the experiment
	Alarm	[A5b] Teacher notifies wrong cable installation
	Presence	[A5a] Teacher asks the progress
Apply Scientific Skills	Handling equipment	[A5f] Student C puts the trolley, sensor and track same as the worksheet (manual) and correcting the position.
	Data interpretation	[A9d]Students have difficulties to relate the graph with the data and concept.
	Solving problem	[A11b] Student D explains the mechanism of momentum by pointing out the equipment and trolley.
	Testing	[A3e] Student C repeatedly moves the trolley on the track without purpose.
Interaction	Discussion	[A12d] Students discuss to answer the reflection (worsheet)
	Questioning	[A2d] Student A asks in group about the computer battery can last how long.
Emotion Response	Confuse	[A8b]Members of the group are in confusion and continued to discuss.
	Dubious	[A7d] Students are less confident by the data after questioning by teacher
	Excited	[A5i] The students expressed excitement during the experiment.

Note: [A] - activity, [Number] - labelled every 5 mins, [small letter] - sequence of sentences.

defines the teacher's guidance is like the existing of teacher near to the students in any students' activities. Students need a teacher to assist during the practical work and help them to complete the experiment performed. The teacher is seen as an important knowledge resource for students that influence the acquisition of knowledge in practical work learning. This claim is made based on three sub-theme that potray the significant present teacher's carried during the activities. According to Schommer (1994) students believe the absolute nature of knowledge is presented by teachers. Therefore, teacher's guidance; such as instructions, alarms, and their presence; influenced in generating the epistemological beliefs of students.

Applying scientific skills means students conduct the experiment used integrated and manipulative scientific skills. It is obtained from this study are the skills of handling equipment, interpreting data, conducting experiments and solving problems. Appropriate scientific skills should be able to translate knowledge into understanding concepts and thus enhance students thinking (Hofer, 2004). Scientific skills also help students to be more independent to carry out their own experiments. These skills are forming meaningful experience and encourage positive perception toward physics. Students can explore the phenomena studied and tend to construct their own understanding through the experiments. Hence, students can improve physics learning through scientific skills.

Besides, there is a theme of interaction during practical work learning. In line with Lidar *et al.* (2006), learning interaction is a communication used by students to obtain information, construct meaning and relate to real life. The interaction found in this research are discussion and questioning. Students' inquiry approach during practical work can be seen in this interaction. Most of the time, students prompt questions during experiment to the teacher. The inquiry approach is fragile when students are seen to use less inquiry approach in accomplish the experiment as they faced difficulties to articulate conclusion. As interaction in practical work learning can be observed through communications between students and teachers and classmates, and during conducting experiments. By referring to Lidar *et al.* (2006), interaction through experience also can be observed from the application of what the students have read in books. The existence of this interaction is measured to identify on how someone builds a knowledge and understand the meaning of the knowledge built (Lidar *et al.*, 2006).

As reported by Hofer and Pintrich (2002), epistemological beliefs reflect the perspective of the students' cognitive and affective domains. The description is through behavior that eventually forms the value of the formation of an emotion response towards physics (Metallidou, 2012). When one's emotion works against something negative, the knowledge acquisition becomes retardation and can be seen in behavior and that affects the beliefs against knowledge (Sharma *et al.*, 2013). Table1 shows that students are experiencing confusion during the experiments and have doubts about their answers. However, students still feel excited to conduct experiments that provide a meaningful experience for them. That is the reason the experiment is completely done in the practical work learning.

Table 2 shows the themes percentage in learning practical work physics. During physics practical work, 50% of students apply scientific skills and 19% for interaction and emotion response, while only 12% requires teacher's guide.

TABLE 2: THEMES PERCENTAGE

Theme	*Frequency*	*Percentage (%)*
Teacher's guide	12	12
Scientific skills	49	50
Interaction	18	19
Emotion Response	18	19

The development of scientific ideas of physics among students can be seen through the exploration and discovery-inquiry during practical work. Table 2 shows that the highest percentage (50%) of students is applying scientific skills during practical work. Handling experiment, solving problem, data interpretation and testing are the sub-theme that show students have scientific experience. Sandoval (2005) stated that by approaching inquiry-based in practical work encourage students to gain the exposure and experience similar to scientists. Students can apply not only their scientific skills learned in theory but generate constructivist thinking, as the epistemological beliefs is related to the intellect and mastery of knowledge of students (Hofer, 2004). However, students need to improve scientific skills as it seem quite limited in the data. Students should be skillful to make decisions and make inference in observation. As suggested by Abd El-Khalick *et al.* (1998) mastering the skills of observation and inference are an important aspect of scientific epistemology.

Emotion response like confuse and dubios require a special attention from teachers. These two emotion seem to overpowering their excitement as students can easily caught in entangle with their incompetency to run the experiment. This argument is supported by Sandoval (2005) which agreed about the challenge faced link between knowledge learned in theory with practice knowledge gained (Sandoval, 2005), especially if the findings are different with information obtained from teachers. Since this analysis is limited to explore the relationship, however the present of unwell emotion during experiment might be the reason why student feel less confident with themselves. This provides the consequences that students would face a conflict, dilemma or difficulties in learning (Schommer, 1994). Although only 12% of students requires teacher's guidance in carrying out experiment, most of the students are actually relies on the instructions given by the teacher (Mihladiz *et al.*, 2011). As stated in Rahman and Phang (2016), teacher also has difficulties in connecting their scientific experience with scientific knowledge acquisition. Thus, widespread implications, such as, not being able to learn and to explore the physics knowledge would occur, furthermore, for those who are influenced by answers given by teachers, instead of their own experimental findings.

Despite, an active student involvement during the practical work could elaborate on the question related to acquisition of knowledge; what is being done by the students, what students know and how students construct and do it (Merriam, 2002). It shows the link between students' acquisition of knowledge and its relationship with practical work learning. Practical work learning is vital in providing meaningful experiences for students in order to form scientific line of thought similar to scientists. The meaningful practical work learning requires continuity between scientific skills, epistemology and inquiry approach (Duncan and Arthurs, 2008). In the same view with Sandoval (2005) stress that scientific epistemological beliefs of students are also influenced by the activities in practical work in school. Therefore, this study shows that common activities in practical work lead to generate students' scientific epistemology. The activity that students usually carry out during practical work is applying scientific skills, which is the highest percentage of the themes. Hence, the practical work based on inquiry should be applied consistently in science school for students to gain real experience on how scientists should act and think.

4. SUMMARY

Through a constructivist point of view, epistemological beliefs of students should reject the nature of knowledge that is fixed, certain and absolute. Students should have the belief that knowledge is attainable on its own (exploration) and can be built through experience, such as conducting an experiment (Hofer and Pintrich, 2002). However, students are often faced with the cultural science approach, such as memorizing, summarizing and reasoning to produce a belief that knowledge of science is very simple and easy (Schommer, 1990). School science practices would highly affect the views of students to the actual science culture (Sandoval, 2005). Therefore, by realizing the purpose of doing practical work, it affects students' epistemology on physics. Students should use a constructivist approach to understand the phenomenon of science through practical work. In line with the purpose of science subject taught, *i.e.* to find out what and how (Hirvonen and Virri, 2002), students should place a mindset that doing practical work is learning on 'how to do' and not memorizing it (Dopico *et al.*, 2014).

Students with naïve thinking would consider that doing practical work is to prove the theory (Ryder and Leach, 2008; Hirvonen and Virri, 2002). Verily, scientific epistemology helps the students to enhance their understanding of scientific concepts and mastery of scientific skills, as practical work learning is to promote students' thought through scientific methods and to apply skills during experiments (Ryder and Leach, 2008). As reported by Hirvonen and Virri (2002), practical work implementation is not to make new theoretical findings but to help students learn the knowledge of physics with the discovery similar to earlier scientists. Even though a culture of constructivist is not being practiced among students or even teachers (Ogan-Bekiroglu and Sengul-Turgut, 2011), the development of epistemological beliefs is vital to be improved, and a belief is always changing each day, over time and situation (Schommer, 2004). Hence, students should be clear as to why practical work should be done through exploration and discovery-inquiry directly to gain the experience similar to scientists.

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