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Using lesson study to enhance meaningful understanding on the topic of pressure

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ABSTRACT

This paper aims to explore how the use of lesson study approach with a constructivist framework could enhance Year 9 students' conceptions of pressure specifically on the topic of manometer reading in determining gas pressure. A diagnostic test was first administered to three Year 10 classes to help teachers identify student difficulties in learning the topic. Four cycles of lesson study was carried out on four classes, three from one school and an additional confirmatory cycle conducted in a class from a different school. Four tests of pre-, post, delayed and confirmatory were conducted in order to identify students' misconceptions and their conceptual understanding. The results of the study showed that with the use of the improved lesson design positive progress were achieved on the understanding of pressure to assist the reading of manometers to determine gas pressure.

KEYWORDS
Pressure Concept, Lesson Study, Students' Misconceptions

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Introduction

Brunei Darussalam has introduced an educational curriculum reform known as the *Sistem Pendidikan Negara Abad ke-21*, commonly referred to by the abbreviation SPN21 (Ministry of Education, 2013). Fundamentally, the goal of SPN21 is to equip students with 21st century skills which focus on critical thinking, collaboration, creativity and communication skills within the contexts of the various subjects. One of the main aims included is also to provide Bruneian students with the opportunity to construct knowledge through

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meaningful learning. With the ongoing reform of SPN21, the curriculum is poised to enhance the quality of students' learning and improve the teachers' pedagogical content knowledge. It was also stipulated in the SPN21 curriculum that science education is one of the eight key learning areas, whereby physics was listed as one of the core subjects that is offered to Year 9 to Year 10/11 students.

Most concepts in physics are considered difficult and hard to imagine (Ornek et al., 2008). One of the difficult concepts in physics to be taught and learned is pressure. This concept is important to be understood clearly as it is related to other fields: in chemistry, biology or medicine such as in physical changes in the rate of changes of reactions and also in blood pressure.

There is extensive literature that indicate students' learning challenges in trying to conceptually understand the concept of pressure (deBerg, 1995; Clough & Driver, 1985; McClelland, 1987; Rollnick & Rutherford, 1993; Shepardson & Moje, 1994). However, as far as is known, there is no existing local study that has been done on this particular topic. Although this topic is known to be a challenging topic in most school curriculums, it is only addressed at a minimal level. The concept of pressure is important, not only in Physics, but also in other disciplines and a full and better understanding to its concepts is important for students to grasp and to allow teachers to feel at ease when teaching it.

Rationale and Significance of the Study

This present study aims to explore the effect and impact of teaching and learning of pressure with the use of lesson study. It is hoped issues in relation to students' difficulty in learning the concept of pressure can be tackled during the study. Lesson study is taken to be as an intervention to not only improve the teaching and learning of pressure but also to make students' learning more meaningful. Lesson study approach can be very useful for improving teacher pedagogy. Teacher practice knowledge can be summed up as a combination of teachers' knowledge of subjects or curriculum they are teaching, teaching or pedagogic methods they use to teach as well as students and their learning needs. A study of teacher learning in lesson study (Dudley, 2008) shows that teachers tend to develop all three and focus on a combination of the first two which Shulman (1986) calls 'pedagogical content knowledge'. This includes knowledge of how the aspect of the subject being taught relates to prior learning in the subject itself and knowledge of the stage the students' prior knowledge has reached.

Theoretical Framework of the Study

Lesson study was chosen to be the research method of this study because it aims to create structured occasions for teachers to examine teaching and learning (Haithcock, 2010). Dudley (2011) indicated that lesson study is a systematic attempt to achieve an educational objective that involves repeated opportunities to plan, observe, evaluate and discuss student learning in close detail. Lesson study was initially used in Japan and benefits from this approach have contributed to the strong record of achievement level in students (Schmidt et al., 1997). In addition, Dudley (2011) stated that having goal of becoming more effective, Japanese teachers used lesson study as their professional development in order to be engaged and able to examine their practices systematically. Nowadays, lesson study is used in East Asia such as in Singapore, Hong Kong and China. It has been developed mainly in school settings, but its use has now begun to extend successfully to Higher Education (Cerbin & Kopp, 2006). Lesson study is also listed in the Strategic Plan 2012-2017 as one of the various initiatives implemented by the Ministry of Education of Brunei Darussalam. Hence, due to its obvious success for professional and educational development (Matussin et al., 2015; Suhaili et al., 2016), this approach was employed in this study.

Lesson Study involves not only lesson planning and teaching a lesson but also observing and critiquing the lesson being observed by a number of teachers working collaboratively. The teachers involved will select an overarching goal and related research question that they want to investigate and this will provide as their focus and direction to their work. The teachers will jointly work on a detailed lesson plan and one of the teachers will teach the lesson while others will observe the lesson. After the lesson, all the teachers will discuss about their observation and this often lead to a better revision of plans where another teacher will then implement into a second lesson while the rest observe the lesson. Then, discussion will take place and this cycle can repeat up to 3 or 4 lessons and eventually the teachers will make a report on this professional development process in particular in answering their chosen research question.

Figure 1 shows a lesson study cycle that intended to enable learning to take place in order to benefit students. In turn, the teachers, researchers and subject specialist involved learn from one another, from the students and from the literature. Hence it acts as a collaborative effort that will allow those involved to have greater success of improving pedagogical practice. It also seeks out and incorporates the perspectives of learners themselves and expect teachers to find ways of passing on the knowledge they have gained in ways that enable other teachers to utilise this knowledge in their own practice.

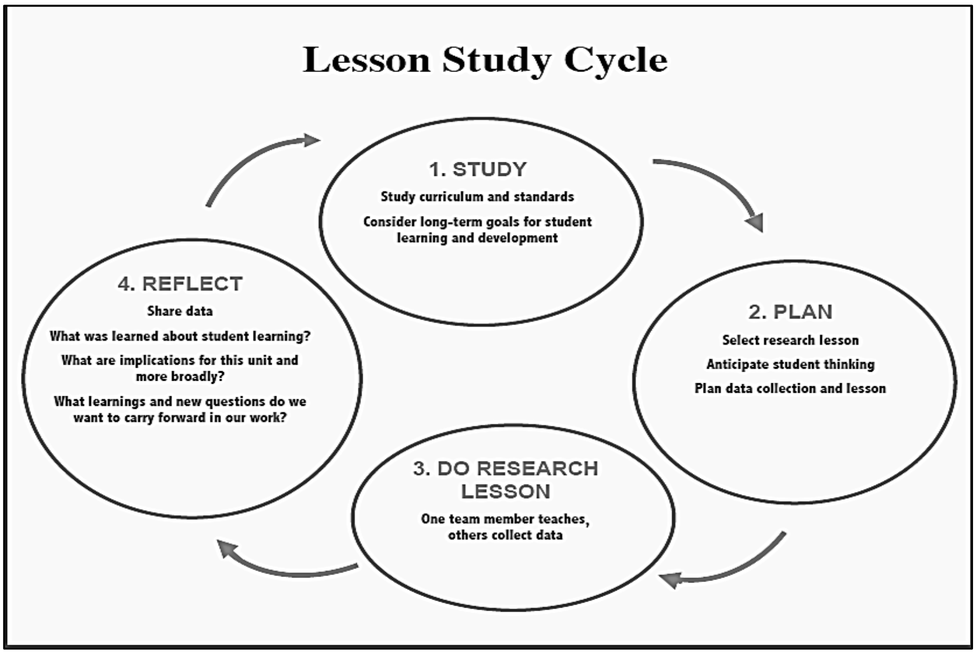


Figure 1. Lesson study cycle adapted from Lewis (2008)

In lesson study, a prevailing learning theory in education of constructivism theoretical framework is applied when designing a lesson (Powel & Kalina, 2009). Teaching and learning can be seen to be improved with the used of constructivism and hence why educators around the world are using it. Constructivism has been widely embraced by educators because of its implications on the improvement of teaching and learning (e.g., Klein, 1999; Staples, 2008; Steffe & Gale, 1995). Constructivist teaching highlights that learning should occur through active involvement of the learners in the process of knowledge construction as opposed to passively receiving information. Moreover, it emphasises the importance of the learners' cognitive processes individually and socially (Glasersfeld, 1995; Wood, 1995). A constructivist classroom differs from a traditional classroom in several ways. In this case, the lessons are student-centered and interactive, and the teacher acts as a facilitator rather than a 'deliverer' of information in the process of learning. Students are more accountable to their own learning and becomes more independent.

The main research question guiding this study is thus "How can the lesson study approach be used to develop lessons to enhance meaningful understanding of pressure to assist the reading of manometers to determine gas pressure?" It is hoped that the study will help physics teachers see the significance of taking cognisance common learning/teaching difficulties of this important topic in designing effective learning experience and provide them with an approach to handle this topic, or any other topic, more effectively to support the students' meaningful learning.

Students' Understanding of Pressure

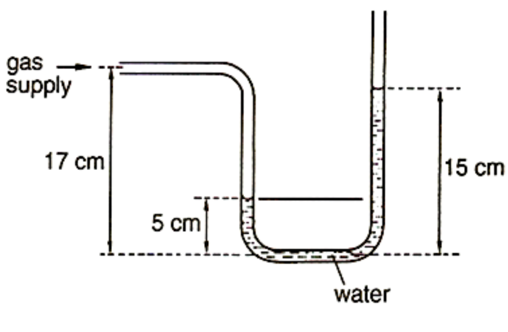
Pressure was chosen as a topic to be explored in this present lesson study for the reason that students encounter problems in learning its concept. Students often takes pressure as force and understand the concept as forceful and one-dimensional instead of a state that is ambient and multidirectional (deBerg, 1995; Leong et al., 2015; Pathare & Pradhan, 2011; Smith et al., 1985; Smith et al., 1992; Smith et al., 1997). However, it was not found to be the case for this present study. Instead it was found students perceive atmospheric pressure as non-existent or as vacuum as it cannot physically be seen. This leads to students' difficulty on manometer reading because of the 'nonobvious causes and effects' of pressure. This in turn, led to the tendency of students to substitute active causal agents for passive ones which was found by other studies (Chi, 2000; Grotzer, 2004; Perkins & Grotzer, 2000; Resnick, 1996).

Basca and Grotzer (2001) described a more complex model in explaining the pressure related non-scientific concepts, "the nonobvious agents in play require appropriate recognition" (p. 5). According to Tyler (1998), students in a variety of age group fail to recognise air pressure in science related activities which involved air pressure. Hence, the aim of this study is to employ a different approach and teaching strategy through lesson study that can address this difficulty faced by the students. Ultimately, to prevent students' inadequate conceptualisation from engaging deeply in more advanced science topics including weather patterns, plate tectonics, and ocean, air and convection currents, as these are all based on concepts of pressure.

Identifying Students' Misconception

Prior to the commencement of the lesson study, a diagnostic test was first instigated to identify any prior knowledge of the students as well as explore the possible misconceptions or difficulties the students possess. Nine two-tier multiple choice questions were used to enable us in identifying the wrong concepts the students possess as well as any reasons behind their misconceptions. The objectives of the diagnostic questions covered the students' knowledge of concepts relating to pressure exerted by a column of fluid, shapes of vessels that contain the fluid has no effect on the pressure exerted by the fluid, measurement of pressure using barometer and manometer. A sample question from the diagnostic instrument is given below in Figure 2 for illustrative purposes.

4a) The diagram shows the water levels in a water manometer used to measure the pressure of a gas supply.



How much greater than the atmospheric pressure is the pressure of the gas supply?

A. 2 cm of water

B. 5 cm of water

C. 10cm of water

D. 12 cm of water

b) Explain the reason for your answer:

____

____

Figure 2. A sample question from the diagnostic instrument

Students' responses to the multiple choice portion of the diagnostic instrument were analysed quantitatively and percentage responses for each multiple choice option for each question was tabulated to identify the most prevalent incorrect answers. In addition the open ended second tier responses which required the students to explain their choice were qualitatively analysed to gain a detailed view of students' conceptual understanding of the topic.

Detecting students' conceptions of a topic is necessary as many studies have indicated that what students learn can actually be different to what their teachers taught them (Leong et al., 2015; Maier, 2004; Martin et al., 2002; Mazur, 2003; Thompson, 2006). Although students are able to solve advanced problems in science, they often fail to grasp basic concepts and still hold on to same misconceptions that they had prior to their learning to the concepts. Zirbel (2006) stated that misconception or 'alternate conception' is part of the "student's private knowledge that is strictly speaking not completely consensual by scientific standards, though it may make sense to the student himself" (p. 5).

Sample of the Study

The collection of data was solely done in the Brunei-Muara district. This district is the most populated amongst the four districts in Brunei Darussalam and thus, have the largest concentration of secondary schools in the nation. School A, chosen as the site of the main study, is a highly reputable school for its high standards in academic performance and achievements in extra-curricular activities. School A was chosen as it has adequate number of classes of Year 9 for the commencement of the 3 cycles.

The sampled students followed a 2-year upper secondary programme which require them to sit for GCE O Level examinations at the end of their Year 10. The three classes of Year 10 students from School A were involved in the collection of the diagnostic data with 64 students of age range between 13 to 16 years old. In addition, one Year 9 class, 9X of an express class (a new generation of classes in Brunei where the students start their upper secondary education in their third year of secondary school instead of the usual fourth year) was involved in the pilot study and was taught by the class physics teachers. All the other three classes of Year 9: 9A, 9B and 9C were engaged in the actual study and were taught by the first author. The total number of students involved in the present study was 71 students with 37 boys and 34 girls with their age ranging between 12 to 14 years old. A confirmatory cycle was conducted in a second school, School B. This was to trial the reliability of the results obtained in School A. School B is a respectable, all girls institution which has obtained the top five ranking in the 2012 O levels result in Brunei Darussalam. The confirmatory cycle was done in School B with one group of 17 students of Year 9P and they were assumed to have similar academic abilities as the students from School A.

The three teachers who participated in this study, with the inclusion of the first author, will hereinafter referred to as the 'lesson study team'. The Year 9 physics teacher, teaching the three classes was recruited as part of the lesson study team, along with the head of the physics department and a sixth form (or college level) teacher. The three teachers recruited possessed an undergraduate with physics as a major, and all of them had more than 10 years of experience in teaching O level physics. Based on the student responses to the diagnostic instrument the content that cover three questions was made the focus of the research lesson designed during the lesson study. A detailed master lesson plan for the lesson study with the inclusion of the lesson development was devised during preparatory meeting by the main author with assistance from the three members of the lesson study group. Before the lesson design was finalised the team of teachers considered the conceptions held by the students, who have already been taught the topic and reflected on the methods they have previously used to teach the topic. Teachers collectively discussed the ways of overcoming the students' learning difficulties and arrived on a constructivist model of teaching to design the master plan for the research lessons. This master lesson plan, which involved a series of hands on activities followed by questioning, was used in the teachings of all the cycles taught by the first author except the pilot lesson was taught by the Year 9 teacher. After every cycle, a post-test was administered and the student responses were carefully analysed to detect any misconceptions still held by the students in the class. The lesson design was then further modified, mainly by changing the hands-on tasks to provide students opportunities to discern the critical features of the concepts that were not grasped by the students in the previous cycle. The scaffolding provided to help the students make the necessary connections were also varied. During the study cycle 2 involved the most modifications. The research lessons were taught by the first author throughout all the interventions to ensure reliability of the findings. Members of the lesson study were invited to make observation where all lessons were video recorded. All the team members for all the three classes, was always present during the interventions.

Limitations to the Study

The study was affected by a few limitations. Taking into consideration the nature of the study and the limited time frame caused by events such as teachers' and students' commitments, school functions, school holidays and so on. This present study was also limited to two secondary schools in Brunei Darussalam. It is also worth to remark that each class only consisted of small number of students. This would therefore influence the statistical analysis and affect the generalization of the findings.

Another limitation faced during the course of conducting the present study was regarding the willingness of teachers to be involved. Some difficulties were encountered in trying to convince the physics teachers to participate and allowing them to be observed. These kinds of complications were highlighted by Tillman (2002), whereby the reasons for this could be "fear of penetration of personal defenses, fear of scrutiny and exposure or due to intrusive threat which means fear of probing into areas which are private, stressful or sacred" (p. 8).

Discussion of the Results

In all cycles the same instrument was used as the pre- and post-tests. The instrument comprised 8 questions that were used in the diagnostic instrument including the three questions that were the focus of the research lessons. In each cycle the pre- and post-test scores were compared using a paired t-test for the three focal questions. In scoring the answers each correct answer was scored 1 and wrong or incomplete answers were scored 0. Table 1 summarises the pre- and post-test comparison for the first three cycles.

Table 1. Paired sample statistics between pre-, post- and delayed post-test scores of three focal questions for cycles 1, 2 and 3

					Paired Differences					
						95% Confidence Interval of the Difference				
		Mean	N	Std. Dev.	Mean	Lower	Upper	t	df	Sig. (2-tailed)
Cycle 1	pre	.75	16	.775	-1.313	-1.919	-.706	-4.612	15	.000
	post	2.06	16	.854						
Cycle 2	pre	1.42	19	1.017	-1.368	-1.930	-.807	-5.121	18	.000
	post	2.79	19	.419						

Cycle 3	pre	1.00	20	.795	-1.250	-1.702	-.798	-5.784	19	.000
	post	2.25	20	.851						

Note: Maximum mark awarded for the three questions was 3.

A comparison of the mean score differences between the different cycles taking in to account all eight questions was also done and graphically depicted by Figure 3, where an encouraging general pattern of an increase in the mean scores for Year 9A, 9B and 9C can be observed.

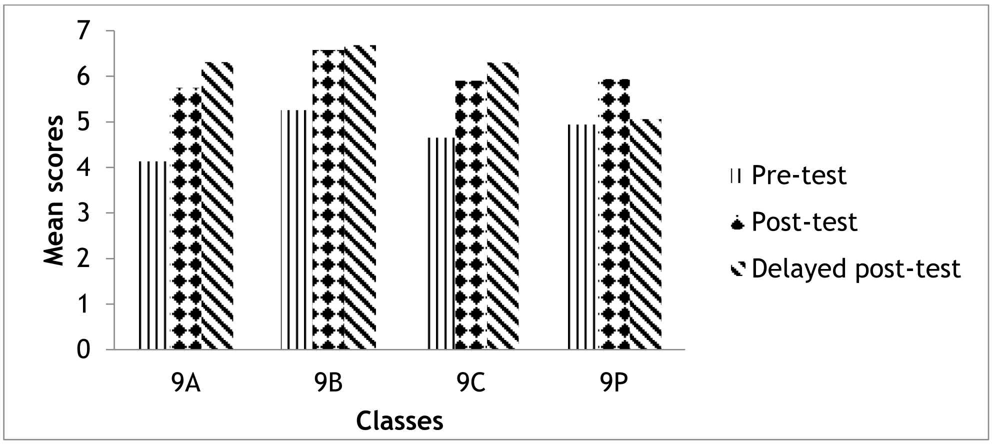


Figure 3. Mean scores of the items in the pre-, post- and delayed-post-test

It was clear that improvements were certainly achieved and the lesson intervention that made the best impact was from the second cycle. This was further confirmed by the one-wat ANOVA and the Tukey post-hoc post test results of the different cycles. It was also established good knowledge base coupled with an effective intervention was important factors to ensure the success of this present study. Thus, the lesson study approach can be viewed as not only managed to enhance the learning of a specific concept, such as manometer reading, but it also improves a broader understanding of the topic, in this case the concept of pressure.

Overall, the lesson study can be seen to have met the expectations of Brunei's SPN21 for enhancement of pedagogical content knowledge, where students actively engaged in constructing the requisite knowledge and skills. Teachers seemed to have been able to design more effective learning experiences, mainly due to the professional development opportunities afforded to the teachers by the lesson study approach (Ball & Cohen 1999; Suhaili et al., 2014; Matussin et al., 2015; Suhaili et al., 2016). All members of the lesson study team agreed that participation in and experience from the lesson study was educational and beneficial for both teachers and students. The collaborative act of lesson study had enabled the teachers to act as a learning community and gain new pedagogical skills in a more systematic and consistent way to improve teaching and learning (Takahashi & Yoshida, 2004). Throughout the process, the study conducted has enabled teachers to work collaboratively in exchanging thoughts, ideas and solution towards realising a common goal.

This study also found that lesson study allow for development of lessons that can enhance learning experiences for the students. Thus, the learning objectives and outcomes for the teaching of the manometer reading can be predefined and hence, an effective teaching sequence was better developed. With the addition of strategic questioning and incorporation of practical demonstrations, long-term conceptual changes in the teaching of manometer reading was made possible.

Conclusions and Recommendations

This study reconfirms that lesson study is very useful for improving teacher practice knowledge of subjects or curriculum they are teaching, pedagogic methods they use to teach, as well as students and their learning need. The lesson study cycles combined with collaboration with the lesson study group gives opportunities to pass on valuable knowledge to other educators. With encouraging results obtained from the adaptation of this study, it is recommended that other difficult topics in physics, such as radioactivity and electromagnetism, be subjected to this kind of research investigation.

However, further improvements could be made in order to solve students' misconceptions such as changes to scheme of work by the curriculum department. It is recommended that experienced teachers to share their expertise in teaching the pressure topic, or any other topic, with teachers from different schools. This will ensure similar, if not better, approaches to teaching within the school system being developed for the benefit of the students learning.

Another reason for the success of the lessons developed, the researchers believe, is that the lessons focussed on instances where the concept of pressure was experienced in the real life of students, which afforded more concrete learning situations. It is, therefore, recommended that teachers incorporate as many of the real life experiences in physics in classroom teaching and learning of the subject. This is to get the students interested in a particular topic and for them to realise that physics is a part of their daily lives. The concept of pressure many students will experience in such situations as pressure of their car tyres, choice of comfortable shoes to wear, water flow and supply in their homes, as well as in the careers they may be pursuing, such as taking blood pressure for nurses and doctors and the importance of air pressure in weather forecasting.

Disclosure statement

No potential conflict of interest was reported by the authors.

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