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Constructivist Learning Environment During Virtual and Real Laboratory Activities

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Abstract

Laboratory activities and constructivism are two notions that have been playing significant roles in science education. Despite common beliefs about the importance of laboratory activities, reviews reported inconsistent results about the effectiveness of laboratory activities. Since laboratory activities can be expensive and take more time, there is an effort to introduce virtual laboratory activities. This study aims at exploring the learning environment created by a virtual laboratory and a real laboratory. A quasi experimental study was conducted at two grade ten classes at a state high school in Bandung, Indonesia. Data were collected using a questionnaire called Constructivist Learning Environment Survey (CLES) before and after the laboratory activities. The results show that both types of laboratories can create constructivist learning environments. Each type of laboratory activity, however, may be stronger in improving certain aspects compared to the other. While a virtual laboratory is stronger in improving critical voice and personal relevance, real laboratory activities promote aspects of personal relevance, uncertainty and student negotiation. This study suggests that instead of setting one type of laboratory against the other, lessons and follow up studies should focus on how to combine both types of laboratories to support better learning.

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INTRODUCTION

In a typical science textbook, such as Campbell Biology (Reece et al., 2011) "Plant growth and development" covers plant tissues, primary and secondary growth, morphogenesis, and cell differentiation. In most Indonesian school books, however, the content is limited to germination and factors that influence plant growth (Kistinah & Lestari, 2009; Subardi, Nuryani, & Pramono, 2008). In addition, the term "growth" is limited to the growth of a whole plant and does not cover "growth" in terms of tissues culture, such as the growth of plantlet or callus (Hasanah, Suwarsi, & Sumadi, 2014; Nurchayati, Santosa, Nugroho, & Indrianto, 2016). Since the content consists of concrete and abstract concepts, real laboratory activities are insufficient to deliver the full content.

Although traditionally laboratory activities have been regarded as important for science lessons, laboratory activities are not well-represented in the curriculums (Ferreira & Morais, 2014). Research on the effectiveness of laboratory activities also reports variable results (Abrahams & Millar, 2008; Harlen, 1999). A study conducted by Abrahams and Millar (2008) suggested that laboratory activities help students to memorise practical aspects of the experiments related to natural phenomena. A review of the roles of laboratory activities for the Indonesian setting conducted three decades ago (Thair & Teagust, 1977) reported that laboratory activities promoted students' achievement in cognitive, problem solving as process skills. More recent review unfortunately are not available.

Compared to other teaching strategies, laboratory activities are relatively high cost. Computer technology offers a solution for conducting laboratory activities at a lower cost in the form of virtual laboratory (Flowers, 2011). In virtual laboratory settings students conduct laboratory activities, but the activities are undertaken through computer software. According to Scheckler (2003), virtual laboratories offer a number of advantages, like allowing students to repeat the activities, omitting the risk of dangerous experiments, and reducing the time and costs.

Since real and virtual laboratories are two different activities they may create different learning environments. As constructivism is becoming more popular in science education, a number of educators have proposed an instrument to measure the learning environment called the Constructivist Learning Environment Survey or CLES (Aldridge, Fraser, Taylor, & Chen, 2000; Taylor & Fraser, 1991; Taylor, Fraser, & Fisher, 1997). CLES is widely used in many countries, including the US (Partin & Haney, 2012), Hong Kong (Kwan & Wong, 2014), Iran (Ebrahimi, 2015), Turkey (Anagun & Anilan, 2013), South Africa (Luckay & Laugksch, 2015), and Indonesia (Widodo, et al., 2010). These studies report that CLES is reliable and can be used to measure a constructivist learning environment based on five aspects: personal relevance, uncertainty critical voice, shared control, and student negotiation.

Studies on constructivist learning environment have reported different results. Some studies found that lessons met the criteria of constructivist learning environments (Zeidan, 2015), while others report the opposite results (Ozkal, et al., 2009). Studies conducted in Indonesia have also revealed inconsistencies. While a study conducted by Yulianti (2006) reported that lessons did not meet indicators of a constructivist learning environment, others reported that the use of e-books promote lessons to be more constructivist (Fitriana, 2010; Nurbaety, 2010).

The main aims of this research are: First, to analyse the learning environment during virtual laboratory and real laboratory activities, and secondly, to identify the criteria of a constructivist learning environment promoted by each type of laboratory activity.

METHODS

The study was conducted at a state high school in Bandung that has nine grade 10 classes. For the purpose of this study two classes were chosen using the cluster sampling technique. One class was assigned as the treatment class while the other class was assigned as the control class. The number of the students in the treatment class was 27 while the number of students in the control class was 26.

The study employed a pre and post-test design of quasi-experimental research. The treatment class worked with a virtual laboratory while the control class worked in a real laboratory. Data was collected using the CLES administered before and after the laboratory activities. Detailed activities of both classes are presented in Table 1.

A descriptive data analysis was conducted on the student responses to the questionnaire. Average scores of student responses were calculated based on individual student scores. In addition, a more detailed analysis was also conducted to identify the criteria of the constructivist learning environment (personal relevance, uncertainty critical voice, shared control, and student nego-

Table 1. Activities conducted by students in the virtual laboratory and real laboratory settings

Students activities in the virtual laboratory		Students activities in real the laboratory	
0	Reading instruction guide on how to use the software	0	-
1	Reading a case presented in the software	1	Reading a case presented in a student worksheet
2	Formulating a hypothesis and identifying variables that influence the situation	2	Formulating a hypothesis and identifying variables that influence the situation
3	Identifying equipment needed for the experiment	3	Identifying equipment needed for the experiment
4	Conducting virtual experiments	4	Conducting real experiments
5	Recording data with the software	5	Recording data in notes
6	Analysing data	6	Analysing data
7	Answering guiding questions	7	Answering guiding questions
8	Drawing conclusions	8	Drawing conclusions
9	Reflecting on the activities	9	Reflecting on the activities

tiation) promoted by virtual laboratory activities and real laboratory activities. Average scores for each criterion are calculated based on students' responses to five statements that represent each criterion.

RESULTS AND DISCUSSION

In general, students in this study gave a positive impression about the laboratory activities. A comparison between the two types of laboratories using CLES shows that real laboratory learning environment is slightly more constructivist than virtual laboratory (Figure 1). This result is quite similar to a previous study reported by Fraser & Lee (2009) that students preferred to have real laboratory activities. Opportunities to have hands on experience and to do things of their interest are factors that contribute to students' positive views on laboratory activities (Toplis, 2012).

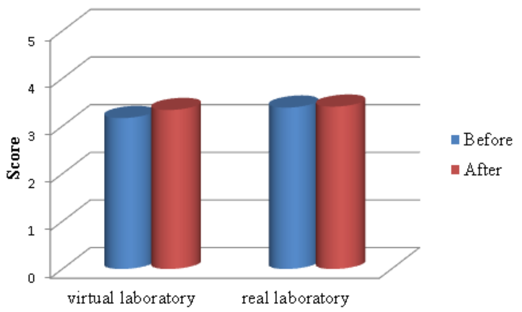

Figure 1. Constructivist learning environments in both types of laboratory settings before and after the lessons

Analysis of the scores before and after the laboratory activities, however, show that the virtual laboratory promotes a constructivist learning environment slightly better than the real laboratory (Figure 1). While virtual laboratory activities showed improvement, real laboratory activities did not.

The CLES scores reported in this study are higher than a previous study conducted with junior high school students (Yulianti, 2006) as well as studies conducted in Turkey (Ozkal et al., 2009) and Vietnam (Thao-Do, et al., 2016). The scores are, however, lower than found in Palestine (Zeidan, 2015). In general, studies on constructivist learning environments suggest that students' active involvement in hands on activities may lead to better constructivist learning environments. In addition, in a cultural context where students have a high respect to the teachers, they also tend to perceive their learning environment as more constructivist (Aldridge et al., 2000). These results suggest that constructivist learning environments are shaped by physical factors, such as the use of hands on material as well as psychological factors, such as respect for the teacher.

A more detailed analysis for each criterion of the learning environment shows that real laboratory activities score higher on all criteria, except for "Student Negotiation" (Figure 2). The aspect of student negotiation scored higher in the virtual laboratory since that environment allows students to make decisions on their own and to be independent learners (Donnelly, O'Reilly, & McGarr, 2013; Scheckler, 2003). Unlike their fellow students in the real laboratory class who have to follow the instruction in the worksheet, students in the virtual laboratory have the opportunities to explore and to make "trial and error" guesses without worrying about the consequences.

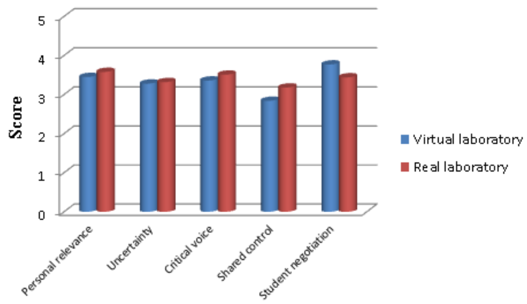

Figure 2. Comparison of each criterion of the learning environment in the virtual laboratory and the real laboratory settings

The study reported here also found that 'Shared Control' is the lowest scored CLES criterion. This was also observed by Thao-Do et al. (2016) in their study in Vietnam and Aldridge et al. (2000) who conducted a study in Taiwan. Traditional views on the roles of teachers and students, where teachers are considered more knowledgeable and students are expected to follow them, may contribute to these results. In many cases teachers give too much directions to the students to do the laboratory activities and give few opportunities to the students to explore and try out their ideas. As a result, students are given less control over their own learning. Some of the teachers' reasons for such tight control during laboratory activities is to avoid experimental failure. It is one of the reasons why extended time is usually spent on pre-laboratory activities (Widodo & Ramdhaningsih, 2006).

The pattern of distribution of students' responses shows that students in both classes predominantly answered "Sometime" and "Often" (Figure 3). This suggests that students at both classes gave similar responses.

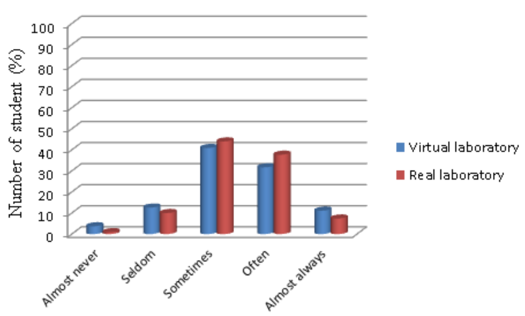

Figure 3. Distribution of students' responses in both classes

Personal relevance

As presented in Figure 4, there is an observable difference in the pattern of students' responses between virtual and real laboratory classes. While the students in the real laboratory setting frequently choose "often", their cohorts using the virtual laboratory tended to choose "sometimes".

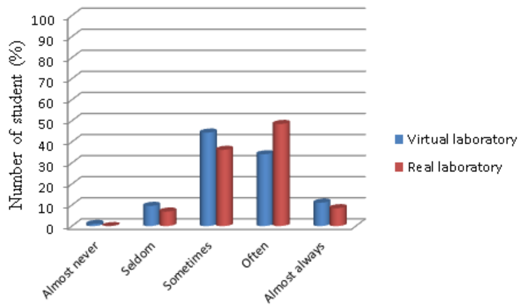

Figure 4. Pattern of students' responses on CLES criterion of "Personal relevance"

Different responses on this criteria indicate that real laboratory activities provide more opportunities to the students to relate the laboratory activities to their daily life experiences. As reported in the previous study (Widodo et al., 2010), doing real experiments using resources available in daily life helps students to generate more meaningful learning.

Uncertainty

Figure 5 shows that students' responses on 'Uncertainty' are similar regardless of the laboratory settings they experienced. Students from both groups most frequently choose "sometimes" on questions of the extent to which the laboratory activities promoted uncertainty.

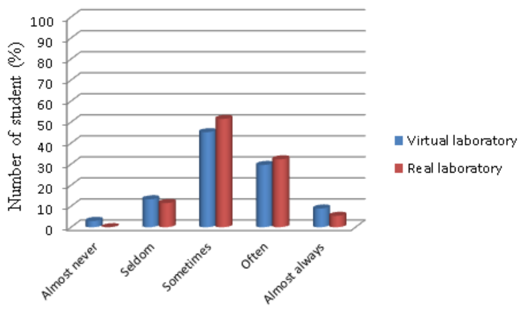

Figure 5. Pattern of students' responses on the CLES criterion of "Uncertainty"

This result indicates that both real and virtual laboratories could not present the activities in a way that helped students perceive scientific knowledge as arising from inquiry, and that the results of their experiments may contribute to science. Although the laboratory activities in this study were designed to facilitate students to do inquiry, the implementation was very much content-oriented and gave little opportunity for students to experience "uncertainty". In line with the notion that science is tentative, teachers should present lab activities in ways that value students' ideas and findings. It is worth considering Abrahams & Millar's (2008) suggestions that laboratory activities should not only aim at developing students' substantive scientific knowledge, but also develop students' understanding of the processes scientific enquiry so that laboratory activities can develop students scientific knowledge, skills and attitudes.

As documented in previous studies (Hofstein & Lunetta, 2004), one of the weaknesses of school laboratory activities is that most of the activities are simply verification and cook-book exercises. Lab activities designed to verify existing theories and evidence put students in an "incompetence" position when they are unable to prove the theory with their own results. As Abrahams & Millar (2008) said, cook-book recipe laboratory activities are likely to be used in schools. To improve the benefit of such laboratory activities, teachers should give a greater proportion of the time to help students make use of the ideas they discover in the laboratory activities rather than just focus on the successful completion of the activities.

Critical Voice

As shown in Figure 6, there is a different pattern of student responses on 'Critical Voice' criterion. While students working in the real laboratory tended to say "often" and "sometimes', students in the virtual laboratory setting gave somewhat more diffuse responses. This suggests that the virtual laboratory setting is perceived differently by different students.

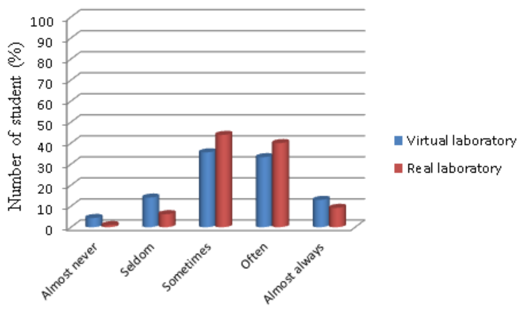

Figure 6. Pattern of students' responses on the CLES criterion of "Critical Voice"

Shared control

Figure 7 shows that there is variability in students' responses on the 'Shared Control' criterion. In the virtual laboratory setting students' responses tended toward "almost never" and "seldom" while students in the real laboratory setting responses with "sometimes" and "often". Although students in both groups used similar worksheets, students in the real laboratory perceived that they were given opportunities to control their own learning more than students using a virtual laboratory. As reported by Toplis (2012), students saw real laboratory activities as learning experiences that promote participation, autonomy and interest. Therefore it is reasonable that students in the real laboratory setting perceived that the teacher shared more control.

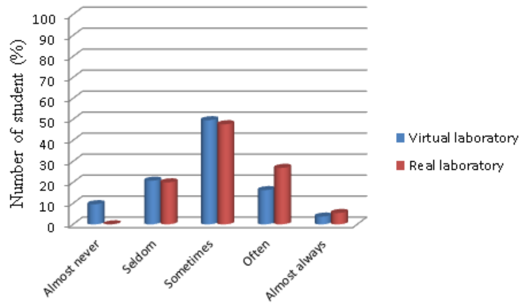

Figure 7. Pattern of students' responses on CLES criterion of "Shared Control"

The different patterns of student responses indicate that virtual laboratory activities and real laboratory activities create different learning environments in terms of giving opportunities for students to share the control of the lessons with their teacher. Articulating learning goals, design and management of learning activities and assessment criteria are important aspects of lessons that may be shared.

Student Negotiation

In contrast to the criterion of 'Shared Control', students in the virtual laboratory settings gave more positive responses on the criterion of 'Student Negotiation' (Figure 8).

Results on this criterion indicate that virtual laboratory activities can create opportunities for students to explain and justify their newly developing ideas, and to reflect on the viability of other students' ideas. This result may relate to the opportunities provided for students to explore different ideas without worrying about the time and the consequences since the exploration only involves a few clicks of the mouse. During the lessons, students were eagerly trying different things and challenging each other's ideas. This result fits a finding reported by Donnelly, et al. (2013) that virtual laboratory activities give more emphasis on the "minds on" part of the laboratory activities. In the virtual laboratory setting students have the opportunity to design and test their ideas in very quick ways.

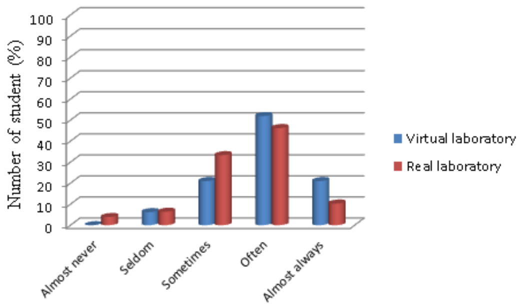

Figure 8. Pattern of students' responses on CLES criterion of "Student Negotiation"

In general, this study finds that virtual laboratory and real laboratory activities can create constructivist learning environments. It suggests that both types of laboratories can provide a learning environment that supports students in constructing new knowledge. Since the national curriculum (Kurikulum 2013) is also based on constructivism (Kementerian Pendidikan dan Kebudayaan, 2014) teachers may use either virtual laboratory or real laboratory activities, or a combination of both. The results of this study also support previous studies on constructivist learning environments as contributing to an improvement in student learning. Two separate studies conducted by Alt (2015) and Partin & Haney (2012) show that constructivist learning environments contribute to the improvement of students' academic self-efficacy. Other studies have also reported improvement in students' critical thinking skills (Kwan & Wong, 2014) and students' conceptual understanding (Widodo et al., 2010).

Each type of laboratory activity however, has unique strengths and weaknesses. While virtual laboratory activities are more powerful in creating opportunities for student negotiation, real laboratory settings are stronger at creating personal relevance, uncertainty, critical voice and shared control. This result suggests that virtual and real laboratory activities are not best set up in competition, but rather complement each other. Therefore, lessons should focus on finding the best strategies to combine the two types of laboratories so that students get maximum benefits (Olympiou, et al., 2003). Taghavi & Colen (2009) suggest that the best alternative is to start a lesson with real laboratory activities and follow it with virtual laboratory activities. In such a sequence, students have opportunities to explore and interact with the real situation before exploring more possibilities virtually.

The recognition of the importance of laboratory activities in the Indonesian curriculum is clearly reflected in the teaching approach recommended by the government, i.e. the scientific approach (Kementerian Pendidikan dan Kebudayaan Republik Indonesia, 2013). The implementation of the scientific approach in teaching requires a teacher to provide a certain level of laboratory exposure to the students. Previous studies however, have reported that real laboratory activities are rarely conducted due to reasons such as unavailable of equipment, limited school budget, and prolonged time needed in the class (Yenita, et al., 2013). Virtual laboratory activities may offer a good alternative for laboratory activities that demand observation at an analytical level such as measuring the absorption of metal ions by a certain plant callus (Nurchayati et al., 2016) or exploring different composition of growth media (Hasanah et al., 2014). Virtual laboratory activities are worth considering in schools either as an alternative to real laboratory activities or as a complement to the real laboratory activities.

The result of this study shows that both types of laboratory activities can create a constructivist learning environment and therefore biology teachers may choose either type of laboratory activity in the lessons. However, since each type of laboratory activity has particular strengths and weaknesses, in planning the activities biology teachers should bear in mind strategies to reduce the weaknesses and improve the strengths of the chosen laboratory activities. In the context of the implementation of the new curriculum (Kurikulum 3013) that requires teachers to implement scientific approach in their teaching, teachers can perform demonstration to raise students' questions followed by virtual laboratory or vice versa. For the future research, this study suggests that researchers should focus on finding the best combination of virtual and real laboratory activities and how they may facilitate students' learning progression and conceptual change.

CONCLUSION

Both virtual laboratory and real laboratory activities can improve the learning environment to become more constructivist. Each type of laboratory, however, contribute differently to each aspect of the constructivist learning environments. While a virtual laboratory is powerful in improving critical voice and personal relevance, real laboratory activities promote aspects of personal relevance, uncertainty and student negotiation. The current study suggests that each type of laboratory activity has weaknesses and strengths and for this reason, lessons should combine both virtual laboratory and real laboratory activities in order to maximise the opportunity to create a constructivist learning environments.

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