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THE EFFECTIVENESS OF VIRTUAL LAB COMPARED TO PHYSICAL LAB IN THE MASTERY OF SCIENCE PROCESS SKILLS FOR CHEMISTRY EXPERIMENT

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Abstract

The aim of the research is to assess the effectiveness of Virtual Lab (experimental group) compared to Physical Lab (control group) in the level of Science Process Skill mastery of topic salt experiment. This research also was done to compare the students' level of Science Process Skill mastery by gender and to find interaction effect between groups and gender on the level of Science Process Skill mastery. The instrument that used to evaluate the effectiveness is "Science Process Skill mastery test (SPST)". A quasi-experimental research design with nonequivalent control group pre-test and post-test was used in this research. The participants of this research were chosen by purposive sampling from Malaysian 4th grade science stream students. This research involved a total of 147 participants, which is 64 male and 83 female. The two-way ANCOVA analysis showed that the effectiveness of group (VLab and PLab) on the mean score of SPST post-test was significant. The SPST post-test mean score of PLab is higher than the post-test mean score of Virtual Lab. It concluded that the students' level of Science Process Skill mastery in experiments for confirmatory tests for anions and cations is better when Physical Lab is used. The effectiveness of gender on the mean score of SPST was not significant. The analysis also showed that the interaction effectiveness between group and gender in SPST was not significant. This means the group's influence on the mean score of SPST is not caused by the gender as well as the gender influence on the mean score of SPST is not caused by groups.
Keywords: *SPS mastery, virtual lab, physical lab, gender effectiveness, salt topic.*

Introduction

Chemistry is a unique and interesting subject. However, chemistry is considered as a difficult subject among Malaysian students (Chu & Hong, 2010). This is due to a misunderstanding of content derived from various sources. As a result, curriculum for the chemistry of secondary school was designed to give students the opportunity to be actively involved in the process of learning knowledge, scientific skills, and technology literacy. This enables students to solve and decide their daily life problems based on scientific attitudes and noble values. It is also intended to develop a dynamic and viable community in line with the latest scientific information and technologies. Thus, the chemistry curriculum has been developed with the emphasis on the acquisition of knowledge and mastering of science process skills (SPS) through practical learning approaches. Practical work is a fun activity carried out in chemistry lessons to help students to develop scientific skills (SS) besides it promotes creative thinking and scientific attitude.

Practical work is used to develop scientific attitude among students. It can also provide important information regarding SPS and increase student interest in chemistry subject. Besides, chemistry practical will help students to improve their problem-solving method in learning chemistry. Practical activities in laboratories can increase interest and change students' attitudes towards chemistry as well as assisting the teachers to teach (Tüysüz, 2010). Practical work gives

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students the opportunity to interact directly with the material world using tools, data collection techniques, models, and science theories (National Research Council, 2005). Experimental activity in laboratories can attract students to pure science subjects such as chemistry. This further enhanced by the emergence of Information and Communication Technology (ICT) that accommodates new teaching method which further enhances the existence of the current Malaysian Education System into a smart education system. Experiments carried out in a physical laboratory (PLab) can be done virtually using ICT technology, e.g., the use of ICT in experiments is the virtual lab (VLab). VLab is the center of creativity that meets every thought. Such systems need to be trusted in education and technical aspects (Drigas, Vrettaros, Koukianakis, & Glentzes, 2005). VLab differs from the PLab by giving an advantage to computer-controlled teaching and experimental pedagogy. VLab is able to enhance teacher-student interaction during the experiment and it could be less costly compared to PLab (Ibrahim, 2011). Most current teachers have a high level of awareness about the importance of ICT integration in the teaching and learning process of science. However, teachers practicing ICT in the process of teaching and learning science are still at a moderate level (Surif, Ibrahim, & Hassan, 2014). School teachers need to understand the need of ICT usage in enhancing the effectiveness of teaching and learning practices. Conducting experiments using VLab is one of the way teachers can practice ICT in the lessons.

According to Burns, Okey, and Wise (1985), practical work in the teaching and learning activity confined to developing students SS in many subjects. It is used to prove a theory and help students to discover new knowledge either individually or in groups (Tatli & Ayas, 2012). The aim of the chemistry experiment is to provide students with detailed information on SPS. It also improves the mastery of science concepts and SS. However, in Malaysia, the priorities for these skills in science teaching are highly ignored. Most teachers who teach science do not master the SPS and they just require the students to copy a practical report from a reference book or from a senior student's practical report. They feel that the practical class is not important in training to prepare them as a skilled science teacher. Studies conducted in Malaysia stated that the mastery of SPS is at a less satisfactory level and this will cause students to have low achievement in chemistry (Shaharom Noordin & Nur Laili Lockman, 2011). The studies also showed that the teaching and learning process is an important factor in determining the achievement of SS among students. So, the conducive teaching and learning environment should be sought so that students have the opportunity to learn, master and apply SS to face the flow of globalization in education. Cheun (2012) found that the opportunity for students to handle experiments and determine the types of experiments to be made are very limited. This would be solved using VLab which enables students to understand the chemical concept and to increase experimentation opportunities for students to determine the type of experiment they want to do (Herga, 2016).

Millar (2004) quoted by saying that practice in laboratories requires high cost and most schools lack of laboratory materials and apparatus. This cost factor can be accommodated through these teaching methods. Most experts agree to change the chemical curriculum by adapting to using ICT, internet and other 21st century technologies to make teaching and learning effective. They have a positive view on ICT and quoted that these changes can improve the learning environment by using VLab which can allow various experiments to be conducted at a reasonable cost. This further was supported by Allerhand & Dobie Galuska (2000) by saying that, VLab is one of the good methods of implementing the latest chemical practices, because it has the advantage to increase SPS during the experiment. Apart from this, students' proficiency in SPS also increased after using the VLab (Yang & Heh, 2007). This experiment in the chemistry learning is expected to encourage the participation of students in their learning activities by working cautiously and systematically in handling laboratory activities (Sapriati, Rahayu, & Kurniawati, 2013). However, most teachers do not apply this experiment in the lab due to many students in one particular class, add-on to lack of quality time and their inability and inappropriateness in using the effective methodology in the laboratory, not forgetting students negative attitude in using the practical activities in laboratories (Walton, 2002). Apart from this, there are also students who are not interested in conducting group experiments because of insufficient apparatus in the lab (Sonte, 2006). Effective teaching in the laboratory depends on the skills of teachers in using various teaching methods by utilizing new teaching materials.

Background

According to Reid and Shah (2007) chemistry experiments are an effective way of learning to develop SS among students. Experiments conducted in laboratories can help develop SS among students as well as assist in the learning of chemistry subjects. During chemistry experiments, students are trained to handle apparatus and they can observe experimental results. This enhances students gaining of detailed information on the process of science and help to increase their interest in the learning of chemistry (Patricia, 1990). Experiments give students the opportunity to conduct systematic investigations through planning, execution and discussion (Nurzatulshima Kamarudin, Lilia Halim, Kamisah Osman, & Subahan, 2009). Through experimental teaching methods, various learning objectives can be achieved in one lesson. Experiments can also strengthen three key elements in the curriculum namely knowledge, SS and noble values that can be obtained directly through laboratory use. PLab is generally recognized as a good way of learning science or chemistry subjects. But, the importance and value of VLab or alternative simulations to replace the PLab may still be disputed (Yunus & Ali, 2013).

In the chemistry labs, students can link visible process to symbolic and phenomenal equations. Lab activities also will encourage students to make abstract understanding through different representations (Kollöffel & Jong, 2013; McElhaney & Linn, 2011). Even though the physical experiments take a long time to complete a test, yet it encourage more careful planning and provide suggestions and reflections for subsequent investigations (Renken & Nunez, 2013). The 21st century skills are the starting point for inquiry learning. The learning of inquiries depends largely on learning through experiments or practices. According to Hofstein (2004), adequate data exist to prove that the experimental activity in laboratories plays a very important role in learning. Experiments also can provide students with authentic and practical learning experiences that have the potential to change the learning environment in the classroom, besides encourage their motivation to learn. Practical activities are used to validate and illustrate theories and present experiences for future teaching (Sapriati et al., 2013). Additionally, the experiment activities will also help students actively engage in practical work, write good practical reports and create positive attitudes towards chemistry practice.

Knowledge needs to be updated continuously to deal with this modern world. Today's modern technology has given many advantages to the teaching and learning process. ICT plays an important role in teaching and learning process. The use of technology in teaching and learning can help students to improve the cognitive level and effective outcomes in learning (Lee, Waxman, Wu, Michko, & Lin, 2013). Such use of technology can become an effective aid for student-centered learning if the program is capable to fit the special needs of the students in supporting the knowledge acquisition and emphasizing technology capabilities of creating a new learning experience (Pedersen & Liu, 2003). This is due to the fact that; Technology cannot be separated from education. It helps to overcome various problems in teaching and learning, especially in the experimental teaching in laboratories, which has become increasingly popular. According to Zwickl, Finkelstein, & Lewandowski (2012) it's use in conducting experiments in the advanced laboratories can create a comprehensive laboratory transformation process which supports the latest teaching goals and contributes to an effective assessment of the experiments carried out.

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PLab Learning Method with SPS Mastery

SPS is a skill that scientists use to gain information about the world (Bulent, 2015). SPS mastery will only be achieved if the teacher takes into account the type of laboratory they want to use in teaching so that students can focus on SPS in each of their learning activities. The use of SPS in an activity which will contribute to a better understanding among students as well as students also will understand each skill and learn how to master the skills. This creates critical-minded students so that they will always try to find solutions for a problem (Ambross, Meiring, & Blignaut, 2014). The study on the use of PLab inquiry-oriented learning has an impact on SPS and creative thinking skills, which concludes that PLab activities can help students to master SPS and improve the level of creative thinking skills. This study involved 36 trainee teachers who had enrolled in the science lab course. Experiments conducted in PLab can provide students with confidence about SPS and help students to think creatively and critically (Yakar & Baykara, 2014; Sodikun, Prayitno, & Sugiyarto, 2016). According to research, the high school chemical curriculum framework reports that students should directly be involved in investigative activities in order to demonstrate their ability in science practice. Research also quoted by saying that the laboratory activities are difficult to be implemented in schools because of various challenges (Levy, Thomas, Drago, & Rex, 2013). Although the goals and standard experiments in the lab have been well documented in various countries, the opportunity to carry out these activities is still limited (Huang, Chiu, Liu, & Chen, 2011). Among the challenges and constraints faced by students in conducting investigative inquiries in laboratories are that students cannot analyze the issue of an investigation. It is difficult for students to write in words about the procedure of an experiment because students are not familiar with measurement tools and do not understand the lesson content that is required for the investigation (Girault, d'Ham, Ney, Sanchez, & Wajeman, 2012).

VLab with an inquiry-based learning plays a very important role in enhancing the mastery of SPS among students (Prajoko, Amin, Rohman, & Gipayana, 2016); (Yildirim, Çalik, & Özmen, 2016; Germann, Aram, & Burke, 1996; Koksal & Berberoglu, 2014; Roth & Roychoudhury, 1993). The effectiveness between the experiments that have been carried out in the VLab with the mastery of SPS is very significant in many studies. This relationship has been illustrated in a study conducted by Feyzioglu (2009). According to this study, positive relationships exist between the effective use of laboratories and SPS mastery. Studies show that SPS cannot be improved if the VLab is not used effectively (Hofstein & Mamlok-Naaman, 2007). The study also shows there is a significant, consistent and high correlation between laboratory use and SPS mastery in science subjects. Factors affecting the efficiency of laboratory use include the use of laboratory methods that can expose SPS, teacher readiness to apply laboratories, use of technological innovation in laboratory environments, and establish relationships between laboratory work, everyday life, and conceptual knowledge. Myers (2004) examined the effects of research laboratories on student SPS and found that students using learning based on research laboratory approach have higher SPS and content knowledge level compared to students taught by traditional methods but there is also a study that explains that students are confused between SPS with Bloom taxonomy and problem-solving stage. As such, the VLab always plays a very important role in understanding and mastering SPS in an experiment (Simsek, 2010). As such, the VLab always plays a very important role in understanding and mastering SPS in an experiment (Simsek, 2010).

VLab Learning Method with SPS Mastery

Chemistry is a subject that has many abstract concepts. Thus, make students think that chemistry has a lot of difficult concepts to learn. Students experience problems in chemistry because of abstract concepts (Nakhleh, 1992). For that reason, students are forced to learn the concept of scientific chemical knowledge. The place where students can learn this scientific

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knowledge is in the laboratories. The laboratory activities contribute to students about ideal exercises using constructivist approaches, investigative approaches, tests, a problem-solving method, thinking like scientists and give a logical explanation of a chemical concept. However, the education system at this point did not include laboratory activity in their studies because of various problems. Therefore, VLab is an alternative solution for the problem of laboratory activity. Students conducting experiments using VLab, can produce better experiment results compared to students conducting experiments with PLab (Tatli & Ayas, 2010).

Computer-assisted learning including the use of simulation laboratories has enormous potential in solving problems through complex activities. The learning requires a structured approach to use simulation laboratories as teaching tools. The teaching tools need to emphasize SPS assessment. The importance of SPS assessment was discussed by Harlen (1999) stating that SPS should be used in the context of science. While, SPS is a way to understand and to develop the mastery of science. In addition, SPS is also the ultimate goal of science education because this skill is not only required by scientists but is needed by scientifically literate societies because science plays a major role and affects the students' life. The study on effect of using a simulation laboratory on SPS achievements carried out by Huppert, Lomask, and Lazarowitz (2002) found that the use of this simulation laboratory did not show a significant change in the mastery of SPS for microbiological subjects although students' score in experimental groups (simulation laboratory) is higher than students' score in the control group (traditional laboratory). This outcome is also supported by Beichner (1990) whereby the use of a computer-based simulation laboratory cannot help students in mastery of SPS. While in the study carried out by Yang and Heh (2007) on 150 students from a private high school in Taiwan on physics subjects found that students from the experimental group (virtual lab) achieved better in the mastery of SPS compared to the students from the control group (traditional lab). This study shows that VLab can help students to master the SPS among level 10 students in Taiwan. Further studies needed to find the relationship between VLab and the mastery of SPS in chemistry subjects to contribute to the literature as there is not much literature available about the mastery of SPS in VLab.

Aim of Research

The aim of this research is to assess the effectiveness of VLab (experimental group) compared to PLab (control group) in the level of SPS mastery of topic salt experiment among 4th grade students. This research also was done to compare the students' level of SPS mastery by the gender. Other than that, the aim of this research is also to find the interaction effectiveness between groups and gender on the level of SPS mastery.

Research Methodology

Virtual Lab (VLab)

VLab is developed using interactive elements, multimedia elements and actual experimental scenarios. To develop a learning experience that can improve the mastery of SPS among students, the design of VLab is based on Constructivism theory and two approaches that is contextual and collaborative. The Cognitive Theory of Multimedia Learning (CTML) (Mayer, 2001) was used to design and built the VLab. This is because VLab is based on multimedia learning material. The main concept in the development of VLab is an interactive multimedia composed of texts, graphics, simulations and animations. The development of this laboratory involves three stages namely identifying problems, VLab development and VLab assessment. The problems were identified based on the analysis of Malaysian Certificate of Education (SPM) report, teacher and student interviews and analysis data from questionnaires. VLab development is based on instructional design Model Kemp (Morrison, Ross, & Jerold

E. Kemp, 2007) to include elements such as interface, interactivity, user-friendly, teaching and learning objectives, environment and targeting groups and the development of multimedia courseware prototypes. VLab assessment involves formative and summative evaluations.

VLab is also developed based on cognitive domain from Bloom's Taxonomy to reinforce the cognitive skills of the students. VLab was developed based on the Malaysian 4th grade chemistry syllabus that involves three experiments. Those experiments are Confirmatory Tests for Anions in Aqueous solution, Confirmatory Tests Cation in Aqueous solution and Confirmatory Test for Ammonium ion, Ferum (II) ion, Ferum (III) ion and Lead (II) ion. Important factors in developing VLab are the content that meets the learning outcomes, measurable learning outcomes, the best content delivery strategy, the students' ability to evaluate their achievement and the students' ability to apply knowledge gained through VLab activities. Figure 1 shows the example of experiment procedure flow chart used in VLab.

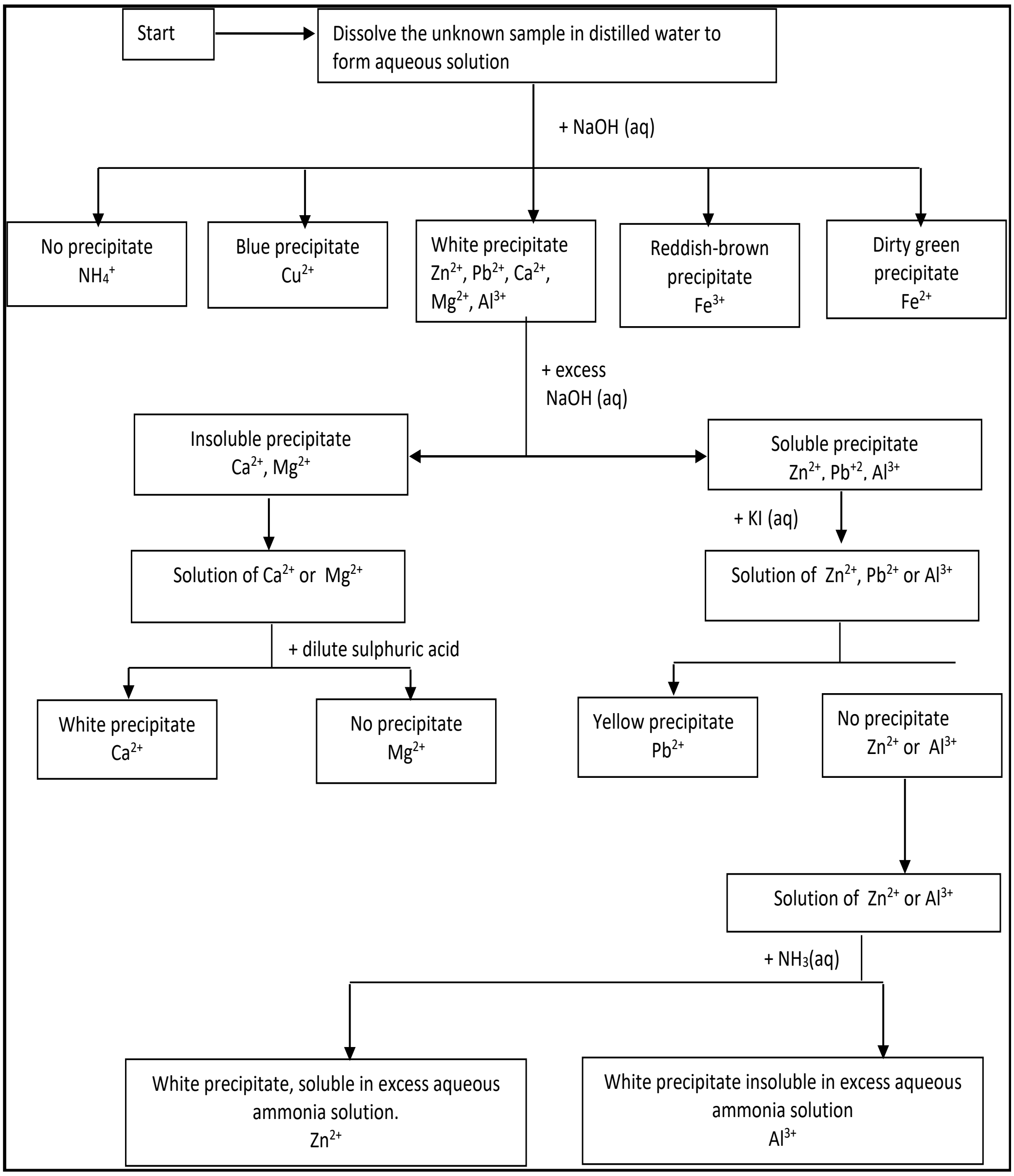

Figure 1. Example of experiment procedure flow chart to identify cations.

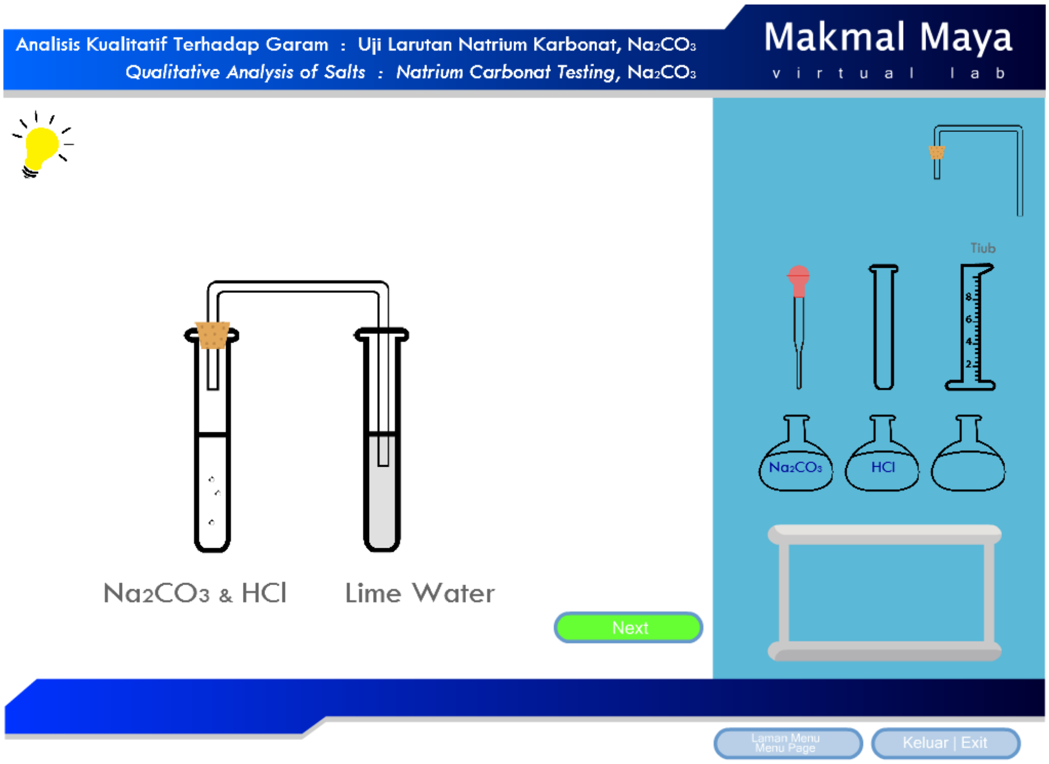

Figure 2. An example of experiment in vlab.

Research Design

The research uses a quasi-experimental design to compare the effectiveness of VLab and PLab. This design is used because a random distribution of participants cannot be implemented between the control group (CG) and the experimental group (EG). The random distribution cannot be implemented because the research is conducted on existing classes. The existing classes mean the original classroom of students set by school management. That means all participants were maintained in their original classroom. The researcher did not form a new class with a random distribution concept to avoid interference. However, random selection was conducted on existing classes to choose CG and EG. The type of quasi-experimental design used is a nonequivalent control group pre-test and post-test design. On salt topic, there are two sub-topics that have multiple experiments. As for this research, it only involves experiments from a sub-topic, qualitative analysis of salt. From the sub-topics, only experiments of confirmatory tests for anions and cations are selected. This research started in August 2017 and the design of this research is shown in table 1.

Table 1. Research design.

	Confirmations the Anion and Cation		
		Treatment	
Class 1	Pre-test	X1(VLab-EG)	Pre-test
Class 2	Post-test	X2(PLab-CG)	Post-test

Sample of Research

The participants of this research were selected by purposive sampling because the participants are students in National Secondary School (NSS) from 4th grade science stream around the Kuching city, Sarawak Malaysia. Three schools were randomly selected to participate in this research. Researcher finds a school that has two science steam classes from the State Education Department. From the list of school given by State Education Department, the researcher randomly selected the schools. Two schools were randomly selected to engage in real studies while one school was engaged for pilot studies. This research was conducted for eight weeks and involved two science stream classes in each school. Overall, this research involved a total of 147 participants. Table 2 shows the number of participants involved in the research. The informed-consent rules and ethical procedures were followed. All participants are voluntarily involved in the research. They have been informed about knowledge of relevant benefit, risk, the purpose of research, expected duration and procedures.

Table 2. The number of participants involved in the actual study.

Group	School	Gender		Total
		Male	Female	
Class 1	NSS A	12	18	30
	NSS B	21	25	46
Class 2	NSS A	11	17	28
	NSS B	20	23	43
Total		64	83	147

Instrument

Assessment test named “SPS mastery test (SPST)” was used as the instrument in this research. The aim of this test is to find students' SPS mastery level when they are doing the experiment in salt topics. Two sets of equal SPST were prepared as a pre-test and post-test. The question division in SPST is based on two things; First, Test Specification Table (TST) according to Bloom's Taxonomy (revised) cognitive level, which is categorized into six main categories namely remembering, understanding, applying, analyzing, evaluating and creating (Krathwohl, 2002) and Second, the descriptions of 4th grade Chemistry Syllabus. The SPS testing after the experiment consists of 13 structural questions (maximum 56 points). The questions were designed with the help of two experienced chemistry teachers and validated by two experts from the local university. Data from the pilot study shows that the correlations between average score for SPST pre-test and SPST post-test are; $r = .907$, $p < .001$. Other than that, the students answer sheets were assessed by two examiners and the result was, the correlation-coefficients between the scores provided by both SPST pre-test examiners are strong; $r = .836$, $p < .001$ and the correlation-coefficient between the scores provided by both post-test examiners is also strong; $r = .998$, $p < .001$.

Table 3. Matrix diagram of the SPST

No	Learning Objective	Remember	Understand	Apply	Analyze	Evaluate	Create
1.	Test of anion	3(b)	1(b), 1(d), 2(d), 3(d), 4(c)	1(c), 2(c), 3(c),	2(b), 5, 6	2(b), 4(b)	1(a), 2(a), 3(a)
2.	State the obser-vation between cation with NaOH (aq) and NH_3 (aq)			7a.b.c 8a.b.c 9a.b.c			
3.	Test of cation Fe^{2+}, Fe^{3+}, Pb^{2+}, NH_4^+	10(a),12a	10(b)	10(c), 10(c)	13	12b	11a
	Total Point	6	12	12	8	8	10

Data Analysis

All data are analyzed using descriptive and inference statistics. The descriptive statistics was used to discuss descriptive data in form of mean, standard deviation and frequency, while inferential statistics was used to discuss data by using two-way ANCOVA. Before the treatment began, the participants were tested in terms of homogeneity of SPS mastery. The descriptive statistical analysis showed that the SPST pre-test mean score for the CG was higher ($M = 23.70$, $SD = 5.44$) compared to the EG ($M = 22.42$, $SD = 4.47$). While t-test analysis showed that there was no significant difference between SPS Pre-test mean score for EG and CG; ($t = -1.55$, $dk = 145$, $p = .123$). This shows that EG and CG are homogeneous in terms of SPS mastery before the intervention is implemented.

Research Result

The data analysis of this research was conducted on the sub-topic of qualitative analysis of salt in topic salt. This sub-topic consists of experiments with confirmations of anions and cations. Descriptive statistics for 147 participants involved in pre and posttests is as in Table 4.

Table 4. Descriptive statistics: Pre-test and post-test SPST mean score for group and gender.

SPST	Group	Gender	M	SD	N
Pre-test	CG	Male	5.83	3.24	37
		Female	5.06	2.75	34
		Total	5.46	3.02	71
	EG	Male	5.26	2.01	27
		Female	5.41	2.77	49
		Total	5.35	2.51	76
	Total	Male	5.59	2.79	64
		Female	5.26	2.75	83
		Total	5.41	2.76	147
Post-test	CG	Male	48.49	11.18	37
		Female	50.79	12.81	34
		Total	49.59	11.96	71
	EG	Male	46.70	12.27	27
		Female	43.71	13.08	49
		Total	44.78	12.80	76
	Total	Male	47.73	11.59	64
		Female	46.61	13.36	83
		Total	47.10	12.59	147

Table 4 shows that the SPST mean score of students increased from pre-test (M = 5.41, SD = 2.76) to posttest (M = 47.10, SD = 12.59). The descriptive statistics of post-test CG (M = 49.59, SD = 11.96) is higher than EG (M = 44.78, SD = 12.80). While in terms of gender, mean score post-test SPST male participants (M = 47.73, SD= 11.59) outperformed compared to female participants (M = 46.61, SD = 13.36). Mean score post-test SPST of female participants (M = 50.79, SD = 12.81) in CG is higher than male participants (M = 48.49, SD = 11.18. Meanwhile the mean score post-test SPST of male participants (M = 46.70, SD= 12.27) in EG was higher than female participants (M = 43.71, SD= 13.08). Figure 1 shows the post-test mean score comparison of SPST followed by group and gender. The achievement gap between male and female participants in both groups was small that is 2.31 (2.31%) for the CG and 2.99 (3.30%) for the EG with the achievement gap between male and female participants in the EG greater than the CG.

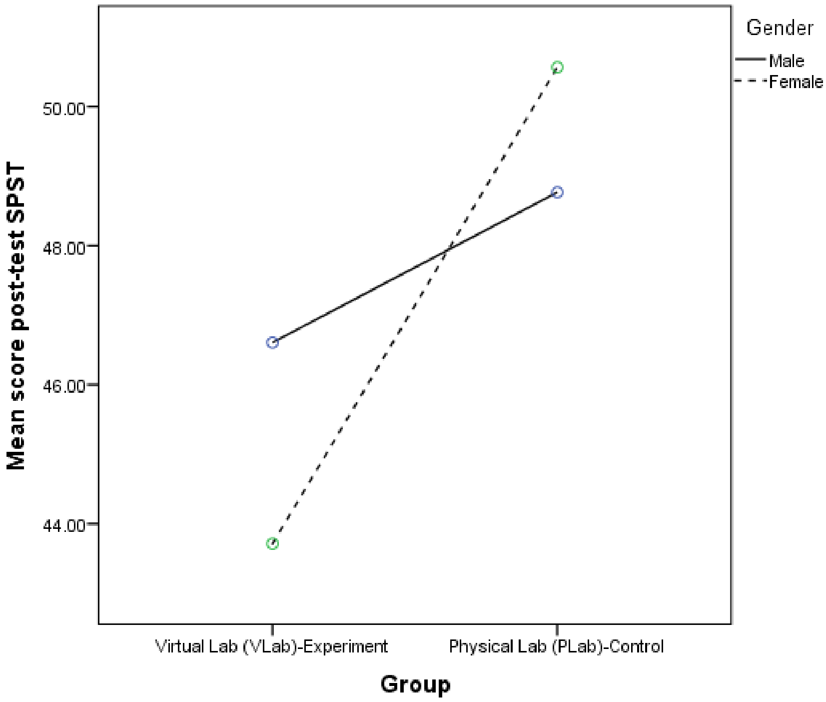

Figure 3. SPST post-test mean score comparison by group and gender.

The two-way ANCOVA analysis was used to test the main effects and interaction effects of group and gender. Table 5 shows the results of ANCOVA analysis of the main effects and interaction effects on students SPS mastery in the experiments for confirmatory tests for anions and cations.

Table 5. Two-way ANCOVA analysis for the main effect and interaction effect of group and gender.

Resources	Sum of Squares	df	Mean Square	F	p	Partial eta squared
Group	712.932	1	712.932	4.692	.032	.072
Gender	10.473	1	10.473	.069	.793	.001
Group*Gender	191.853	1	191.853	1.263	.263	.009

Significance level = .05

The results showed that the main effect of the group on the mean score of SPST was significant, F (1,142) = 4.692, p= .032. Based on descriptive statistics, the SPST post-test mean score of PLab is higher than a post-test mean score of VLab. It can be concluded that the students' level of SPS mastery in experiments for confirmatory tests for anions and cations is better when PLab is used. This shows that the PLab method is more effective than the VLab to improve students' SPS mastery. The main effect of gender on SPST mean score was not significant, F (1,142) = .069, p = .549. Based on descriptive statistics, mean score post-test SPST for male participants was higher than female participants. It can be concluded that the level of mastery of male participants in anion and cation confirmation experiment is better than female participants. The results of the ANCOVA analysis also used to obtain interaction effects between the group and the gender against the mean score SPST. Interaction results obtained were also not significant, F (1, 142) = 1.263, p = .263. This means the group's influence on the mean score of SPST is not caused by gender as well as the gender influence on the mean score of SPST is not caused by groups.

Discussion

The findings of STST showed that the SPST mean score of the CG was higher than the mean score of EG. There was a significant difference in mean score of SPS between CG and EG. The level of SPS mastery among students who conducted experiments using PLab was better than students who conducted experiments using the VLab. The effectiveness of PLab on the student's SPS mastery for the confirmations of anion and cation experiments is better than the VLab. Although the VLab can increase the student's SPS mastery level, this improvement is not as good as the use of PLab. Although the experiment in PLab is generally bound to conventional methods based on learning materials such as textbooks and practical books provided by Ministry of Education Malaysia (MOE), but chemistry experiments in PLab are still effective in developing students SPS in chemistry subject. During chemistry experiments in PLab, students can be trained to handle apparatus and they can observe experimental results. This will help students to get detailed information on the process of science and help increase their' interest in chemistry (Patricia, 1990). Generally, the importance of PLab is recognized as a good way of learning science or chemistry subjects but the importance and value of using VLab to replace PLab is still questionable (Yunus & Ali, 2013).

In addition, in chemistry labs, especially PLab students can relate the learning content that can be observed to symbolic equations or to visible phenomena. This will encourage students to develop an abstract understanding of various representations (Jong, Linn, & Zacharia, 2013; McElhaney & Linn, 2011). Although experiments in the PLab take a long time to carry out a test, physical experiments encourage more careful planning and provide suggestions and reflection on subsequent investigations (Renken & Nunez, 2013). This is in contrast with the use of VLab which allows experiments implemented quickly but virtual experiments do not provide broad opportunities for students to do careful planning. This is because all activities in VLab have been programmed and this limits the planning process that those students can do. The use of VLab still comprises some deficiencies compared to PLab. Dalgarno, Bishop, Adlong, and Bedgood (2009) stated that the use of VLab will cause students' uncertainty in the process of conducting experiments. This is because students do not get manipulative skills while conducting experiments in laboratories. They cannot handle the apparatus and laboratory materials well during actual experiments. The study also showed that VLab can explain the concept clearly and its prototype is inconsistent where the concept is expressed in the form of general (May, Skriver, & Dandanell, 2013).

When students are conducting experiments using the VLab they are rarely involved in idea sharing activities. This is because, during the experiments in VLab, students only focus on their computers. The process of sharing ideas between group partners is less. This situation is different in PLab whereby students have more opportunities to share and relate ideas to each other during the experiment. Although VLab integrates a collaborative learning approach, the collaborative levels in the VLab and PLab are different. Researchers found that the collaborative level of students in PLab was higher and more efficient than the VLab. Another weakness that causes students to not master the SPS from the VLab is that students cannot practice hands-on skills. Students never pay attention when they are engaged with the experiment in the VLab and they tend to use the computer for other purposes. Teachers found that students were too quick to give up on problem-solving when using VLab instead of using PLab. Students do not want to find solutions through discussions with peers but they want the teacher to provide the solution to them. This finding is in line with the findings conducted by Donnelly, O'Reilly, and McGarr (2013).

While the students' SPS mastery in VLab experiments is less satisfactory but the VLab still helps the students to improve the level of SPS mastery. This is because learning using the VLab has the potential to carry out complex and dangerous experiments. Therefore, VLab developed usage of a very structured approach to help students understand the importance of simulation tools as learning aid materials. In the context of this study, the VLab development needs to be structured to produce a simulation material that prioritizes SPS interest in chemistry learning. SPS is important because it caters for assessment for understanding and mastery of science. VLab is also a future learning tool to help students to do experiments. This is because the cost of doing experiments using PLab is high. VLab can help students to carry out difficult experiments in an easier way. This will help students master the SPS to do a complex and difficult experiment (Dalgarno, 2002; Ibrahim, 2011). The VLab can also be programmed so that it promotes an important SPS that can make teaching and learning process become more meaningful besides enhance the mastery of SPS (Trundle & Bell, 2010; Koretsky, Kelly, Gummer, & Northwest, 2011). The level of SPS mastery is not only dependent on the process of experimenting and problem solving but it also depends on the potential content and activities found in VLab. This content and activities must help to improve the mastery of SPS (Yang & Heh, 2007).

Based on the data analysis conducted on the students' level of SPS mastery on gender, there was no significant difference between male and female students. The findings of this study are same with the findings of many other studies in Malaysia which state that gender factors do not show significant differences with the SPS mastery (Yew & Tajuddin, 2015; Ong & Shamalah, 2014; Ong & Johairi Abdul Rahim, 2012). However, descriptive analysis shows that the mean score of male students is higher than that of female students. The findings of this study support the study of Rahmani and Abbas (2014) which conclude that male students have a higher level of SPS mastery than female students but it is contrary to the study of Ong and Bibi Hazliana (2013). Results of the two-way ANCOVA showed that the interaction effect between the group and the gender against the SPST score was not significant. This indicates that group and gender variables affect SPST scores individually, where the mean score of the group is not based on the gender and otherwise. The findings also show that male students get higher score than female students if the experiment is conducted in VLab, and the female students get higher mean score than male students if the experiment is conducted using PLab. This is in line with the study conducted by Kondrat (2015) which states that female students are better in various tasks while male students are visually oriented and outperforming compared to female students in spatial abilities.

Descriptive statistics also shows that the SPS mastery between male and female students in the CG is smaller than the EG. The VLab that integrates a variety of learning approaches still does not cater to the learning styles of male and female students. VLab is less beneficial for both gender in SPS mastery among students compared to PLab. The mean score between male and female students of the EG was greater than the CG. This showed that the approach used in the VLab was less likely to help students in reducing the SPS mastery gap between male and female students compared with the use of PLab. Thus, a new learning approach should be introduced during the VLab development so these new approaches can help to reduce the gap between the SPS mastery among male and female students. This is because the gender gap in the mastery of SPS in the context of science education in Malaysia is wider when students move up from primary to secondary schools (Ong & Bibi Hazliana, 2013).

Conclusions

Results of this research were found that the VLab did not show a significant effectiveness on the student SPS compared to PLab. Even though PLab has a better effectiveness on the student's SPS mastery, the mean score of the students SPS mastery is still increasing as the experiments carried out using the VLab. This shows that the VLab is still able to increase the level of SPS mastery. Experimental activity conducted in VLab is a student-centered activity. It was also noted that, students were actively involved in conducting experiments using the VLab. This will help students to improve the level of SS and SPS when they are doing experiment in laboratory. VLab becomes as a teaching aid for the teacher that can motivate students to learn chemistry. VLab has the tendency to become a teaching aid for teachers which can motivate students to learn chemistry. In summing this, VLab would be a good choice to help chemistry teachers in providing guidance to implement experimental sessions in a laboratory in a more systematic manner without creating any room for mistakes and problems. Undoubtedly, improvements still need to be made on the VLab to help students improve their SPS mastery. Students gender does not affect SPS mastery in chemistry experiments. There are no any significant differences between male and female mean score of SPST. However, descriptive analysis shows that the mean score of male students is higher than female students. The interaction effectiveness between the group and gender on the SPST is also not significant whereby the SPST mean score difference of group is not due to gender and SPST mean score difference of gender is not due to group.

Note

This paper is part of PhD thesis. Title of the thesis is “The development and effectiveness of a virtual lab compared to a physical lab in learning salt topic experiments in 4th grade chemistry”. The research was conducted at Malaysia secondary school and the participant is only from 4th grade. The PhD candidate study at the National University of Malaysia. This thesis is not yet available in the repository. The PhD thesis was examined on oral examination and accepted with minor correction on 29 June 2018.

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