A technological acceptance of remote laboratory in chemistry education

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Contents

- Abstract
- Introduction
- Methodology
- Results and discussion
- Conclusion and Educational Implication of Study
- References

Abstract

The purpose of this study is to evaluate the technological acceptance of Chemistry students, and the opinions of Chemistry lecturers and laboratory assistants towards the use of remote laboratory in Chemistry education. The convergent parallel design mixed method was carried out in this study. The instruments involved were questionnaire and interview protocol. A total of 81 Chemistry students, five Chemistry lecturers and two Chemistry laboratory assistants from Universiti Pendidikan Sultan Idris (UPSI) were chosen as respondents in this study. For the quantitative approach, the data from the questionnaire were analysed using

descriptive statistics to evaluate students' technological acceptance of remote laboratory. For the qualitative approach, the responses from the interviews were analysed to evaluate the lecturers and laboratory assistants' opinions towards the use of remote laboratory by using coding and grouping methods. Quantitatively, the student respondents had given the mean scores ranging from 2.97 to 3.30 for the attitude towards use (ATU), perceived ease of use (PEOU), behavioural intention (BI), and perceived usefulness (PU). Qualitatively, the respondents accepted the implementation of remote laboratory in Chemistry education based on its several advantages such as flexibility, cost efficiency, and risk-free environment. However, some disadvantages of remote laboratory such as lack of skills and experience and Internet connection problem were also voiced out by the respondents. Overall, the results from this study showed that the students, lecturers and laboratory assistants had positive responses towards the technological acceptance of remote laboratory in Chemistry education. Thus, remote laboratory could be developed and introduced to Chemistry education in UPSI.

Keywords: Technological acceptance, Remote laboratory, Chemistry education

Introduction

Laboratory is the place where the students can grasp the practical knowledge and experiences (Župerl & Virtič, 2013) to examine a scientific phenomenon (Kurbanoglu & Akin, 2010). By carrying out a laboratory experiment, students can enhance their understanding on the concepts and promote the learning outcomes that have been taught in the classes (Hofstein & Lunetta, 2004; Reid & Shah, 2007).

However, there are several limitations in traditional hands-on laboratory. The first limitation is the time constraint of traditional hands-on laboratory. The insufficient time of the laboratory session (Iskandar, Mahmud, Wahab, Jamil & Basir, 2013) makes the students struggle with the procedures such as unfamiliar laboratory techniques related to the experiments. Some experiments might need a long setup time (Tho & Yeung, 2016). This results in students simply following the procedures word by word. For instance, the students will have a maximum of three hours of a laboratory session for a course in a week (Kelly & Finlayson, 2007). Due to the limited time in the laboratory session, the students would feel that they have to rush in order to complete the experiment. Other than that, some students might need more time to understand or implement the idea than other smarter students (Khattar,

Luthon, Larroque & Dornaika, 2016). Thus, the allocated time is insufficient for them to process the data and information obtained from the experiment (Dey, Hell, Rolf, Stankovski & Ågren, 2010).

In traditional hands-on laboratory, students are usually divided into groups to carry out a laboratory experiment together but sometimes, not every student in the groups has contact with the equipment (Zol & Daud, 2014) and conducts the laboratory experiments together with other group members. For instance, some students are afraid to handle the fragile glass apparatus and chemicals. Such problems will lead to experimental errors resulting in slow mechanism, incorrect result and repetition of procedures which consume a lot of time (Nidup & Yodyingyong, 2015).

Apart from that, in traditional hands-on laboratory, students also often rely on laboratory assistants or lecturers to solve their laboratory problems (Nafalski, Nedić, Teng & Gadzhanov, 2016). This leads to a surface approach to students' learning and not enabling students to operate on a high level of analysis, synthesis and evaluation on the data and information obtained from the experiment (Dey et al., 2010). Besides, resource depletion is also one of the limitations of traditional hands-on laboratory (Tho & Yeung, 2016). Most of the universities are under constant pressure to reduce the expenses of laboratory based education (Župerl & Virtič, 2013). This makes some of the expensive equipment and resources unavailable in some universities and certain experiments cannot be carried out.

As a result of the rapid change and the development of technologies, remote laboratory has been introduced in education. Remote laboratory is a web-based laboratory that allows users to access experimental devices online (Sauter, Uttal, Rapp, Downing & Jona, 2013). It is not a virtual experiment such as simulation but it has a real experimental setup at a distance that enables users to conduct it remotely through the Internet (Ursutiu, Cotfas & Samoila, 2007). Remote laboratory provides remote access for users to conduct the experiments without time and location restrictions (Gomes & Garcia-Zubia, 2007).

Remote laboratories have been used for teaching and learning mostly in science and engineering courses over the last two decades (Cooper & Ferreira, 2009). There are a lot of remote laboratories that have been applied in education especially physics and engineering education (Considine, Teng, Nafalski & Nedić, 2016; Tho, Yeung, Wei, Chan & So, 2016; Velasquez, Ramos & Amaya, 2016). For instance, the PEARL project (Practical Experimentation by Accessible Remote Learning) had developed

and provided teaching experiments in some subject areas including foundation level science, manufacturing engineering, electronic engineering and cell biology (Cooper, Donnelly & Ferreira, 2002). However, there is lack of research regarding remote laboratory and the application of remote laboratory in Chemistry education (Tho et al., 2016). Hence, we are interested to evaluate the technological acceptance of remote laboratory in Chemistry education among students, lecturers and laboratory assistants. The question we can probe for this research is, 'To what extent are they willing to accept the use of technology in carrying out experiments in the remote laboratory? It is important to understand the technological acceptance among them because these groups of people are the users of remote laboratory and the acceptance acts as a key factor associated with the classroom use of technology in the future (Wong, Teo & Russo, 2012).

Objectives of the Study

The purposes of this study are to:

(i) evaluate the technological acceptance of Chemistry students toward the use of remote laboratory.

(ii) study the opinions of Chemistry students, lecturers and laboratory assistants towards the use of remote laboratory.

Methodology

Research Design

The convergent parallel design mixed method was used in this study. Concurrent timing was applied to implement the quantitative and qualitative strands during the same phase of the research procedure, which was done by prioritising the methods equally and keeping the strands independent during analysis and then mixing the results during the overall interpretation (Creswell & Plano Clark, 2017). The quantitative approach consisted of 81 respondents who completed the survey questionnaire, followed by the qualitative approach with seven respondents who took part in the interview. It was the specific aim to attempt to evaluate the technological acceptance of Chemistry students, and the opinions of Chemistry students, lecturers as well as laboratory assistants towards the use of remote laboratory in Chemistry education.

Respondents

Since Universiti Pendidikan Sultan Idris (UPSI) does not implement remote laboratory in Chemistry education, we were interested to study the technological acceptance of remote laboratory among the students. The population for this study involved the students majoring in Chemistry at UPSI. There were 109 students in Semesters 1, 3, 6 and 8. According to Krejcie and Morgan (1970), the sample size of this research was supposed to be 86 respondents. The criterion of choosing the sample was based on the Chemistry students with at least one semester of experience in conducting laboratory session at UPSI. Thus, only 74.31% of the population were chosen as the respondents in this study, excluding researcher and Semester 1 students. Semester 1 students were not chosen because they were new to the Chemistry courses and lack of laboratory experiences at UPSI. In summary, 28 students from Semester 8, 37 students from Semester 6, and 16 students from Semester 3 were chosen as respondents for the survey questionnaire in this study.

On the other hand, five lecturers from different fields of Chemistry (Physical, Analytical, Inorganic, Organic and Polymer) were chosen for the interview session. Each lecturer was chosen based on having at least five years of experience in conducting laboratory sessions in their field. Two laboratory assistants who are experienced in their respective fields were also chosen for the interview to evaluate their opinions towards the use of remote laboratory in Chemistry education.

Instruments

The instruments involved in this study were the questionnaire and the interview protocol. The questionnaire survey had been distributed to the Chemistry students, whereas the interview to the Chemistry lecturers and laboratory assistants had been conducted by the researcher.

Questionnaire

Technology acceptance is a user's willingness to employ technology designed to support tasks (Teo, 2011). In this study, it refers to the Chemistry students' willingness to use remote laboratory in carrying out experiments. A set of questionnaires was used to collect data from the Chemistry students to evaluate the technological acceptance of remote laboratory in Chemistry education. The questionnaire consisted of three sections which included respondents' demographic, opinion on advantages and disadvantages of conducting experiments by using

remote laboratory, and survey items on students' technological acceptance on remote laboratory.

Section A consisted of several items on the demographic information. In section B, an open-ended question was asked in which the respondents needed to give their opinion on the advantages and disadvantages of conducting experiments by using remote laboratory. Section C consisted of four main constructs; perceived of usefulness (PU), perceived ease of use (PEOU), attitude toward use (ATU), and behavioural intention (BI). These four main constructs were based on Technology Acceptance Model (TAM) (Davis, 1989). TAM was originally developed by Davis (1989) to explain the acceptance of using new technologies (Aypay, Çelik, Aypay & Sever, 2012; Wong, Rosma, Goh & Mohd Khairezan, 2013). Remote laboratory is considered as a new technology among Chemistry students at UPSI. Thus, in this study, TAM was used to evaluate the students' technological acceptance of remote laboratory. Since the original items were asked in terms of general technology, the survey items were adapted from previous studies (Davis, 1989; Teo, Wong & Chai, 2008; Willis, 2008; Wong et al., 2013) and some modifications had been done to meet the requirement of the current study. The descriptions for the constructs in the survey items are stated in Table I.

Table I. The Descriptions of Constructs in Survey Items

Construct	Explanation
Perceived of Usefulness (PU) (adapted from Davis 1989; Teo, Wong & Chai, 2008)	The degree to which a student believes that using remote laboratory will enhance his or her performance.
Perceived Ease of Use (PEOU) (adapted from Davis 1989; Wong et al., 2013)	The extent to which a student believes that using remote laboratory would be free of effort.
Attitude toward Use (ATU) (adapted from Davis 1989; Wong et al., 2013)	Students' attitude toward the use of remote laboratory.
Behavioural Intention (BI) (adapted from Davis 1989; Willis, 2008; Wong et al., 2013)	Students' intention to engage in the behaviour to use the remote laboratory.

All of the constructs in section C used a four-point Likert scale ranging from 'Strongly Disagree' to 'Strongly Agree' which is similar to Wong and his colleagues (2013). This section consisted of 12 items and all the items were positive statements. The distribution of items on students' technological acceptance of remote laboratory is shown in Table II. Before carrying out the actual study, a

pilot test was carried out to a group of students who were not the respondents in the actual study. The reliability coefficient obtained was 0.90.

Table II. Distribution of Items for Students' Technological Acceptance of Remote Laboratory

Construct	Item Number in the Questionnaire	Total Items
Perceived of Usefulness (PU)	1,2,3	3
Perceived Ease of Use (PEOU)	4,5,6	3
Attitude toward Use (ATU)	7,8,9	3
Behavioural Intention (BI)	10,11,12	3
Total Items		**12**

Interview Protocol

The second instrument used in this study was the interview protocol. The information collected from the interview session was to evaluate the opinions of Chemistry lecturers and laboratory assistants towards the use of remote laboratory in Chemistry education. Questions asked during the interview session are listed in Table III.

Table III. Semi-Structured Interview Questions

No	Questions
1.	Have you ever heard about remote laboratory?
2.	Will you accept the future implementation of remote laboratory in Chemistry education?
3.	What are the advantages of the remote laboratory that you can imagine?
4.	What are the disadvantages of the remote laboratory that you can imagine?
5.	Do you have any suggestion on the topic of Chemistry experiments that is possible to apply the remote laboratory in the future?

Procedure

This study was aimed to study the technological acceptance of remote laboratory in Chemistry education among Chemistry students, lecturers and laboratory assistants. Data collection mainly depended on questionnaire and interview questions. Pilot study was carried out in order to determine the validity and reliability of the

instruments. In this study, the validity of the instruments was assessed by three experts in the educational field and calculated by using Content Validity Index (CVI). CVI is the degree to which an instrument has an appropriate sample of items for construct being measured (Polit & Beck, 2006). In this study, the I-CVI/Ave (Item-Content Validity Index/Average) for questionnaire and interview protocol were 0.83 and 0.80 respectively. This showed the content validity for both instruments was satisfied (Polit & Beck, 2006). The reliability coefficient was calculated by using Cronbach's alpha in Statistical Package for the Social Science (SPSS) version 20. In this study, the reliability coefficient obtained was satisfied at 0.90 (Chua, 2013). This result indicated that the questionnaire is suitable for conducting such study and the actual study can be proceeded.

Both instruments (questionnaire and interview questions) were modified based on the comments and suggestions given by the experts in the validity forms before conducting the pilot study. Apart from that, the transcriptions for the interview were verified by each of the interviewees to ensure the validity of interview data.

The questionnaire was distributed to the student respondents in the lecture rooms and a short briefing regarding the purpose of the study was given. Two videos regarding remote laboratory were shown to the student respondents in order to enhance their understanding on remote laboratory before answering the questionnaire. A total of fifteen minutes was given to the students to answer the questionnaire items. After that, the questionnaire was immediately collected and then analysed by using percentage (%), frequency (f), mean and standard deviation (SD).

For the interview protocol, five Chemistry lecturers and two laboratory assistants were selected to evaluate their opinions on using remote laboratory in Chemistry education. The interview sessions was carried out by using Malay language, English language or both languages based on the requirements and the convenience of the respondents. Each of the interview session was audio recorded and transcribed. The lecturers and laboratory assistants' answers during the interview session and the students' responses in the questionnaire were analysed using the keywords to interpret the meaning. Then the keywords were coded and then grouped under the same category in terms of advantages and disadvantages of remote laboratory. The categories of advantages and disadvantages of remote laboratory were formed based on literature reviews in the same context. After that, the transcriptions were verified by the respondents to obtain the validity of the

transcriptions. Finally, the responses in the interviews were analysed to answer the research questions.

Results and Discussion

Students' Technological Acceptance of Remote Laboratory

Students' technological acceptance of remote laboratory in Chemistry education was analysed based on the data collected from the questionnaire. In this study, TAM was used to evaluate the students' technological acceptance of remote laboratory. TAM consists of four constructs which are perceived usefulness (PU), perceived ease of use (PEOU), attitude toward use (ATU) and behavioural intention (BI). Table IV shows the distribution of items and the mean for each of the constructs in the questionnaire.

Table IV. Questionnaire Data Analysis Based on TAM constructs

Construct	No. of Item	Mean	SD
Perceived Usefulness (PU)	3	2.97	0.59
Perceived Ease of Use (PEOU)	3	3.14	0.60
Attitude toward Use (ATU)	3	3.30	0.53
Behavioral Intention (BI)	3	3.11	0.58

The mean values for the four constructs ranged from 2.97 to 3.30. According to Wong and his colleagues (2013), a mean value of more than 2.50 indicates a positive response to the scales in the study. The standard deviation (SD) showed a narrow spread around the mean. ATU construct had the highest mean which was 3.30 (SD= 0.53). The mean for PEOU construct and BI construct were 3.14 (SD= 0.60) and 3.11 (SD= 0.58) respectively. PU construct had the lowest mean which was 2.97 (SD= 0.59).

In this study, ATU construct had the highest mean scores (3.30) among the four constructs in the TAM survey. This indicated that students have a positive attitude towards the use of remote laboratory. Users' attitude towards the use of technology is a major predictor for future implementation of technology use (Myers & Halpin, 2002). According to Park (2009), attitude has a significant impact on users' acceptance of technology. Thus, students' positive attitudes indicate their

technological acceptance of remote laboratory in Chemistry education. Overall, the survey on students' technological acceptance of remote laboratory showed a positive response from the respondents.

Besides, PU construct measured the degree to which a student believes that using remote laboratory will enhance his or her performance (Davis 1989; Teo, Wong & Chai, 2008). Previous study showed that remote laboratory can help students to support their learning experiences (Sauter et al., 2013). It helps to enhance the development of students' knowledge and skills related to the experiments and thus enhance their application of the existing knowledge and skills (Maxwell, Orwin, Kist, Maiti, Midgley & Ting, 2013). However, PU construct had the lowest mean scores (2.97) in this study. Student respondents in this study had limited knowledge on remote laboratory due to limited remote laboratory in Chemistry education (Tho et al., 2016). Hence, they were unsure whether the remote laboratory could improve their Chemistry performance, increase their productivity, and enhance their effectiveness in Chemistry.

Technological Acceptance of Remote Laboratory among Chemistry Lecturers and Laboratory Assistants

Technological acceptance of remote laboratory in Chemistry education among Chemistry lecturers and laboratory assistants (pseudo named as THxx) was analysed based on interview questions through coding and grouping method. A total of four (57.10%) respondents had mentioned that they would accept the implementation of the remote laboratory in Chemistry education. The rest (42.90%) of the respondents mentioned that they would consider the implementation of the remote laboratory for particular experiments in Chemistry education. From the interview with respondent TH02, he accepted the future implementation of remote laboratory in Chemistry education and mentioned that students should expose to the latest technology so that they would not face the culture shock wherever they go. The following transcription is a part of the interview with respondent TH02.

> *TH02: ...Of course we have to... so that we **exposed to the students to the latest technology**... Because when you go to, for example industry, where ever they go, there will not be a culture shock in their work.*

However for some of the respondents, they would accept the remote laboratory based on suitability. From the interview with respondent TH03, she accepted the implementation of remote laboratory in Chemistry education only for the

experiments which are difficult or dangerous to carry out in the traditional hands-on laboratory.

> *TH03: ...**melibatkan eksperimen eksperimen yang**..ah..**sangat membahaya**... contohnya macam **melibatkan**.. ah.. chemical **chemical yang membahaya**. Okay, melibatkan ah.. apani..**gas contohnya, pemanasan yang tinggi**, kan? **Melibatkan tekanan yang tinggi**. Ah. Itu kena.. kena.. boleh! **Saya setuju la, guna remote laboratory ini**.*
> (Translation: I agree to use remote laboratory if involves dangerous experiments like dangerous chemical, heating using high temperature, high pressure.)

Overall, none of the respondents rejected the future implementation of remote laboratory in Chemistry education during the interview sessions. All of them gave positive responses on the technological acceptance of remote laboratory in Chemistry education and those qualitative data are consistent with the findings obtained from the TAM survey.

Advantages of Remote Laboratory

The opinions of Chemistry lecturers and laboratory assistants towards the advantages of using remote laboratory were analysed based on interview questions. On the other hand, the opinions of Chemistry students towards the advantages of using remote laboratory were analysed based on the open-ended question in the questionnaire by using coding and grouping method.

Flexibility

Remote laboratory provides flexibility in terms of time and place. From the interview with respondent TH04, he mentioned that remote laboratory is a suitable alternative for schools that have financial constraint on carrying out the experiments in which the students can have the opportunity to conduct the real experiment through the Internet any time and any place (Fallon, 2013). The following transcription is part of the interview with respondent TH04.

> *TH04: ...This remote laboratory could be an alternative in teaching chemistry education and teaching chemistry experiment... I think for such school especially schools with **money constraints**, not able to provide experiments apparatus for example, I think this is a good advantage. This is a good alternative... Students...**although they can't perform the real experiment,***

> ***this remote laboratory could be an alternative…*** *No matter the students are from* ***city or from rural area…*** *I think they would learn this technique…* ***this remote laboratory very fast****…* ***No matter where they are****… They could adapt with the technology. So I think… perhaps with this remote laboratory… they could learn…may be better.*

From the interview with respondent TH01, she mentioned that saving time is one of the advantages of remote laboratory in which students can just control the experiment remotely at home. According to Mokhtar, Mikhail and Joo (2014), students can carry out their learning and conduct laboratory experiments comfortably from home for example during weekends without extra travelling as long as they have a computer with Internet access. The following transcription is part of the interview with respondent TH01.

> *Researcher: So, what are the advantages that you can imagine for the remote lab?*
> *TH01: I can imagine the lab without student... (laughing)*
> *Researcher: Ah?*
> *TH01: I can just imagine the lab without students,* ***everything can control at home****, so they just..* ***Saving time****...and may be save money.*

From the interview with respondent TH03, she mentioned that remote laboratory enables time saving and it would be suitable for long distance learning students. Distance learning students are able to apply the knowledge they gained and carry out experiments in a similar fashion to on-campus students, without the need to be physically located in the laboratory (Alkhaldi, Pranata & Athauda, 2016). The following transcription is part of the interview with respondent TH03.

> *TH03: So advantages ya, kelebihanya. Of course la kelebihannya pertama kalau you buat remote lab ni* ***jimat masa la****…* ***Tenaga mengajar tak perlu ramai*** *la kan? … And then.. ah.. pasal* ***remote laboratory*** *ini* ***sesuai untuk****.…* ***long distance student****... apa ni…*
> (Translation: The first advantage of remote laboratory is it can save time. Less tutor is needed. Remote laboratory is suitable for long-distance learning students.)

Apart from that, from the open-ended question in the questionnaire, most of the student respondents also mentioned several advantages of remote laboratory in terms of flexibility (Table V). They stated that remote laboratory enables time

saving as they do not need to spend time in travelling to the laboratory and they can conduct the experiment anywhere.

Table V. Students' Opinions on the Advantages of Remote Laboratory: Flexibility

No.	Students' Opinions
1	Experiment can do anywhere or anytime
2	Can conduct the experiment in anyplace in the world
3	Do not waste time to go to lab / Save time

Thus, remote laboratory is very convenient and flexible to use in which it offers an opportunity to every student to access the remote laboratory experiment without time and place restriction (Fallon, 2013).

Cost Efficiency

Remote laboratory enables cost saving and is cost effective (Chan & Fok, 2009; Fallon, 2013; Nafalski et al., 2016; Župerl & Virtič, 2013). From the interview with respondent TH01, she mentioned that using remote laboratory would be cost saving, chemical saving and strengthening the bonding between universities and institutions. This is supported by Khattar and his colleagues (2016) in which remote laboratory opens the door to possible collaborations between universities and institutions. By sharing the resources, most of the expensive equipment can be shared among universities and institutions and thus an item of equipment can be utilised more effectively with maximizing the number of students in use of remote laboratory (Cooper & Ferreira, 2009; Župerl & Virtič, 2013). The following transcription is part of the interview with respondent TH01.

> *TH01: I can just imagine the lab without students, everything can control at home, so they just… Saving time...and maybe* ***save money****.*
> *Researcher: Save money?*
> *TH01: Ya. Probably because... if we need to allocate for all students to come here and then we need to prepare for each batch or each group for that. But if we use for this, may be the* ***chemicals will be less, the costs will be less****... It could be* ***save money, save chemicals, save time****... And maybe then we can just* ***close the bond in between two countries, between two universities, between two schools****, so it's more internationally.*

Besides, from the interview with respondent TH06, he mentioned that the way in conducting experiment will be more accurate and the errors such as parallax error can be reduced by using remote laboratory. According to Župerl and Virtič (2013), the expenses of equipment and processing material can be reduced, especially when most of the human errors are eliminated through the remote laboratory. The following transcription is part of the interview with respondent TH06.

> *TH06: ...remote lab... Kalau dibuat... Kelebihan nombor satu ialah, dia mengajar cara yang lebih tepat. Maksudnya students menggunakan camera kan, jadi dia akan tengok, tak ada orang parallax lah, kita boleh* ***avoid parallax*** *tu...*
> (Translation: The advantage of remote laboratory is that it is more accurate. Students use the camera and observe, nobody will have parallax error, so we can avoid the parallax errors.)

Based on the open-ended question in survey questionnaire, some of the student respondents also mentioned several advantages of remote laboratory in terms of cost efficiency (Table VI). They stated that by using remote laboratory, most of the errors in experiment can be avoided for example parallax error when doing the measurement. They also stated that some of the experiments that cannot be carried out in our country can be carried out through remote laboratory.

Table VI. Students' Opinions on the Advantages of Remote Laboratory: Efficiency

No.	Students' Opinions
1	Can avoid human errors in experiment / More accurate
2	Can conduct experiment with other countries / Can go through many experiments that we cannot do in our own country

Thus, remote laboratory enables cost saving and effective in which sharing remote laboratory with other universities or institutions can lead to improved utilization levels, sharing costs and students are able to access a much broader range of laboratory apparatus (Lowe, Yeung, Tawfik, Sancristobal, Castro, Orduña, et al., 2016).

Risk-free Environment

Laboratory can be made safer for students through remote laboratory (Ogot, Elliott

& Glumac, 2002). For the interview part, none of the respondents mentioned that safety is one of the advantages of remote laboratory. However, based on the open-ended question in survey questionnaires, a lot of the student respondents listed the advantages of remote laboratory in terms of safety (Table VII). They stated that it would be safer to students by using remote laboratory as most of the accidents in the laboratory can be prevented. They also stated that they are not exposed to toxic chemicals and it is easier or safer for the students to conduct the experiments which are dangerous.

Table VII. Students' Opinions on the Advantages of Remote Laboratory: Risk-free

No.	Students' Opinions
1	Prevent any accident during the experiment / Safer to students
2	We don't have to face toxic chemicals/ *Tidak terdedah kepada bahan-bahan beracun*
3	*Memudahkan pelajar membuat eksperimen terutamanya eksperimen yang bahaya* (Translation: The students can carry out the experiment easier especially dangerous experiments)

Thus, remote laboratory enables students to avoid injuries that would happen in traditional hands-on laboratory, hence provides a risk-free environment.

Disadvantages of Remote Laboratory

The opinions of Chemistry lecturers and laboratory assistants toward the disadvantages of using remote laboratory were analysed based on interview questions. On the other hand, the opinions of Chemistry students toward the disadvantages of using remote laboratory were analysed based on the open-ended question in the questionnaire survey by using coding and grouping method.

Lack of Skills and Experiences

From the interview sessions with seven respondents, most of the respondents mentioned that lack of skills and experiences are the main disadvantages of remote laboratory. From the interview with respondent TH05, she mentioned that the disadvantage of remote laboratory is students would lack of skill in assembling the apparatus and they would lack of experience for the trouble shooting in laboratory. The following transcription is part of the interview with respondent TH05.

*TH05: ...So means that they lack of skill... yeah **lack of skill in assembling the apparatus.** And then they also like a... **they don't have** the **experience for the trouble shooting.** When you do the experiment, sometimes you learn from your experience right? ...last time I do like this and... I got it wrong... so that's one of the trouble shooting you know. And then they will learn from that. But this one is already set up, everything is already set up and everything is already program like smoothly program, so they just click it to see the.. I mean the result…*

Based on the open-ended question in the questionnaire, student respondents listed several disadvantages of remote laboratory (Table VIII). They also stated that lack of experience in handling real experiments, lack of psychomotor skills and lack of experience in trouble-shooting are the main disadvantages of remote laboratory. Students cannot touch the physical instruments and the real equipment by themselves. They cannot develop their psychomotor skills in laboratory management due to insufficient experiences in handling real apparatus or equipment. According to Ogot, Elliott and Glumac (2002), this leads to insufficient experience of students with typical experimentation tasks such as trouble-shooting experimental apparatus problems.

Table VIII. Students' Opinions on the Disadvantages of Remote Laboratory: Lack of Skills and Experiences

No.	Students' Opinions
1	Less experience in handling real experiment
2	Lack of hands on trouble shooting and debugging experience
3	Students do not know the true techniques to handle equipments/ *Kurangnya kemahiran psikomotor*
4	*Tidak dapat menghidu, menyentuh produk* (Translation: Cannot smell and touch the product)

Internet Connection Problem

Apart from that, based on the open-ended question in the questionnaire, most of the student respondents also mentioned that the problem with the Internet connection is one of the disadvantages of remote laboratory (Table IX). They stated that a strong Internet coverage is required to conduct the experiment through remote laboratory.

They were worried that some of them might not have Internet connection or if they do, it is not possible to conduct experiments through remote laboratory with a weak internet connection.

Table IX. Students' Opinions on the Disadvantages of Remote Laboratory: Internet Connection Problem

No.	Students' Opinions
1	Need strong Internet coverage / Cannot be used if no Internet connection
2	Some students do not have Internet connection

Thus, everything has its pros and cons. Remote laboratory is not a perfect laboratory since the activities through remote laboratory may be affected by certain constraints such as Internet problem (Tho & Yeung, 2016), lack of experiences in handling real experiments and trouble-shooting problems in traditional hands-on laboratory.

Conclusion and Educational Implication of Study

In short, for the quantitative approach, TAM was used to evaluate the students' technological acceptance of remote laboratory in Chemistry education via questionnaire survey. Based on the data analysis, the student respondents had given an overall mean of 3.30 on the attitude towards use (ATU), 3.14 on the perceived ease of use (PEOU), 3.11 on the behavioural intention (BI) and 2.97 on the perceived usefulness (PU). Overall, student respondents gave positive responses on the technological acceptance of remote laboratory in Chemistry education.

For the qualitative approach, the Chemistry lecturers and laboratory assistants also showed positive responses on the technological acceptance of remote laboratory in Chemistry education via interview sessions. These qualitative data are consistent with the findings obtained from survey and previous research studies (Khattar et al., 2016; Mokhtar, Mikhail & Joo, 2014; Župerl & Virtič, 2013). In addition, none of them rejected the implementation or the use of remote laboratory in Chemistry education. They accepted the use of remote laboratory in Chemistry education due to several advantages of remote laboratory. For example, remote laboratory

provides flexibility in terms of time and place, cost efficiency and also risk-free environment. Some lecturers stated that remote laboratory could be applied in instrumentation Chemistry or analytical Chemistry. There was also a lecturer who mentioned that Chemistry students in UPSI should be exposed to the latest technology such as remote laboratory.

Although some disadvantages of remote laboratory had been voiced out by the respondents, overall Chemistry students, lecturers and laboratory assistants had shown positive responses towards the technological acceptance of remote laboratory in Chemistry education. Thus, remote laboratory could be introduced to Chemistry education in UPSI for some feasible experiments as the teaching and learning process is shifting towards a new direction. The suggestions from the respondents could be served as references for the future development of remote laboratory in Chemistry education.

References

Alkhaldi, T., Pranata, I., & Athauda, R. I. (2016). A review of contemporary virtual and remote laboratory implementations: Observations and findings. *Journal of Computers in Education, 3*(3), 329-351.

Aypay, A., Çelik, H. C., Aypay, A., & Sever, M. (2012). Technology acceptance in education: A study of pre-service teachers in Turkey. *The Turkish Online Journal of Educational Technology, 11*(4), 264-272.

Chan, C., & Fok, W. (2009). Evaluating learning experiences in virtual laboratory training through student perceptions: A case study in electrical and electronic engineering at The University of Hong Kong. *Engineering Education, 4*(2), 70-75.

Chua, Y. P. (2013). *Mastering research statistics.* Selangor: McGraw-Hill (Malaysia) Sdn. Bhd.

Considine, H., Teng, M., Nafalski, A., & Nedić, Z. (2016).Recent developments in remote laboratory NetLab. *Global Journal of Engineering Education, 18*(1), 16-21.

Cooper, M., Donnelly, A., & Ferreira, J. (2002). *Remote controlled experiments for teaching over the internet: A comparison of approaches developed in the PEARL project.* Proceedings of the 19th Annual Conference of the Australasian Society for Computers in Learning in Tertiary Education, Auckland, New Zealand: UNITEC Institution of Technology.

Cooper, M., & Ferreira, J. M. M. (2009). Remote laboratories extending access to science and engineering curricular. *IEEE Transactions on Learning Technologies, 2*(4), 342–353.

Creswell, J. W. & Plano Clark, V. L. (2017). *Designing and Conducting Mixed Methods Research.* Los Angeles: SAGE Publications Inc.

Davis, F.D. (1989). Perceived usefulness, perceived ease of use and user acceptance of information technology. *Management Information Systems Quarterly, 13*(3), 983-1003.

Dey, A., Hell, M., Rolf, C. C., Stankovski, P., & Ågren, M. (2010). *Laboratory instructions as a cause of student dissonance.* Paper presented at Lund Institute of Technology

(LTH)'s 6th Pedagogical Inspiration Conference (LTHs 6th Pedagogical Inspirationskonferens), Lund, Sweden.

Fallon, T. (2013). *Survey of existing remote laboratories used to conduct laboratory exercises for distance learning courses.* Paper presented at the 120th Annual Conference & Exposition (ASEE), Atlanta, GA.

Gomes, L., & Garcia-Zubia, J. (2007). *Advances on remote laboratories and e-learning experiences.* Bilbao: University of Deusto.

Hofstein, A., & Lunetta, V. N. (2004). The laboratory in science education: Foundations for the twenty-first century. *Science Education, 88*(1), 28-54.

Iskandar, Y. H. P., Mahmud, N. E., Wahab, W. N. A. W. A., Jamil, N. I. N., & Basir, N. (2013). The development of teaching and learning in bright-field microscopy technique. *Malaysian Online Journal of Educational Technology, 1*(4), 31-43.

Kelly, O. C., & Finlayson, E. (2007). Providing solutions through problem-based learning for the undergraduate 1st year chemistry laboratory. *Chemistry Education Research and Practice, 8*(3), 347-361.

Khattar, F., Luthon, F., Larroque, B., & Dornaika, F. (2016, July). *Using computer vision for student-centred remote lab in electronics.* Paper presented at 8th International Conference on Education and New Learning Technologies, Barcelona, Spain.

Krejcie, R. V., & Morgan, D. W. (1970). Determining sample size for research activities. *Educational and Psychological Measurement, 30*(3), 607-610.

Kurbanoglu, N., & Akin, A. (2010). The relationships between university students' chemistry laboratory anxiety, attitudes, and self-efficacy beliefs. *Australian Journal of Teacher Education, 35*(8), 48-59.

Lowe, D., Yeung, H., Tawfik, M., Sancristobal, E., Castro, M., Orduña, P., et al. (2016). Interoperating remote laboratory management systems (RLMSs) for more efficient sharing of laboratory resources. *Computer Standards and Interfaces, 43*(C), 21-29.

Maxwell, A. D., Orwin, L., Kist, A. A., Maiti, A., Midgley, W., & Ting, W. (2013). *An inverted remote laboratory - makers and gamers.* Paper presented at the Proceedings of the 24th Annual Conference of the Australasian Association for Engineering Education (AAEE 2013), Toowoomba, Australia.

Mokhtar, A., Mikhail, G. R., & Joo, C. S. (2014). A survey on remote laboratories for e-learning and remote experimentation. *Contemporary Engineering Sciences, 7*(29), 1617-1624.

Myers, J. M., & Halpin, R. (2002) Teachers' attitudes and use of multimedia technology in the classroom: Constructivist-based professional development training for school districts. *Journal of Computing in Teacher Education, 18*(4), 133-140.

Nafalski, A., Nedić, Z., Teng, M., & Gadzhanov, S. (2016). A remote measurement laboratory using NetLab. *World Transactions on Engineering and Technology Education, 14*(1), 45-50.

Nidup, T., & Yodyingyong, S. (2015). I*nexperience students' perception, difficulties and challenges towards implementation of lab-based inquiry approach: A case study in Bhutan.* Proceeding of the 3rd Global Summit on Education GSE 2015, (pp. 390-399). Kuala Lumpur, Malaysia.

Ogot, M., Elliott, G., & Glumac, N. (2002). *Hands-on laboratory experience via remote control: Jet thrust laboratory.* Proceedings of the 2002 American Society for Engineering Education (ASEE) Annual Conference & Exposition, (pp. 7.603.1-7.603.18). Montreal, Canada.

Park, S. Y. (2009). An analysis of the Technology Acceptance Model in understanding university students' behavioral intention to use e-learning. *Educational Technology & Society, 12*(3), 150-162.

Polit, D. F., & Beck, C. T. (2006). The content validity index: Are you sure you know what's being reported? Critique and recommendations. *Research in Nursing & Health, 29*(5), 489-497.

Reid, N., & Shah, I. (2007). The role of laboratory work in university chemistry. *Chemistry Education Research and Practice, 8*(2), 172-185.

Sauter, M., Uttal, D. H., Rapp, D. N., Downing, M., & Jona, K. (2013). Getting real: The authenticity of remote labs and simulations for science learning. *Distance Education, 34*(1), 37-47.

Teo, T. (2011). *Technology acceptance in education.* The Netherlands: Sense Publishers.

Teo, T., Wong, S. L., & Chai, C. S. (2008). A cross-cultural examination of the intention to use technology between Singaporean and Malaysian pre-service teachers: An application of the Technology Acceptance Model (TAM). *Educational Technology & Society, 11*(4), 265-280.

Tho, S. W., & Yeung, Y. Y. (2016). Technology-enhanced science learning through remote laboratory: System design and pilot implementation in tertiary education. *Australasian Journal of Educational Technology, 32*(3), 96-111.

Tho, S. W., Yeung, Y. Y., Wei, R., Chan, K. W., & So, W. W. M. (2016). *A systematic review of remote laboratory work in science education with the support of visualizing its structure through the Hist Cite and Cite Space software.* International Journal of Science and Mathematics Education, Advanced online publication. doi.org/10.1007/s10763-016-9740-z

Ursutiu, D., Cotfas, P., & Samoila, C. (2007). *Graphical programming and remote controlled laboratories.* In L. Gomes, & J. Garcia-Zubia (Eds.), Advances on remote laboratories and e-learning experiences, (pp. 151-186). Bilbao: University of Deusto.

Velasquez, Y., Ramos, O., & Amaya, D. (2016). Technology used for the implementation of remote laboratories. *International Journal of Applied Engineering Research, 11*(6), 7456-7461.

Willis, T. J. (2008). *An evaluation of the Technology Acceptance Model as a means of understanding online social networking behaviour (Doctoral Dissertations, University of South Florida).* Retrieved from http://scholarcommons.usf.edu/etd/568

Wong, K. T., Rosma, O., Goh, P. S. C., & Mohd Khairezan, R. (2013). Understanding student teachers' behavioural intention to use technology: Technology Acceptance Model (TAM) validation and testing. *International Journal of Instruction, 6*(1), 89-104.

Wong, K. T., Teo, T., & Russo, S. (2012). Influence of gender and computer teaching efficacy on computer acceptance among Malaysian student teachers: An extended technology acceptance model. *Australasian Journal of Educational Technology, 28*(7), 1190–1207.

Zol, B. R., & Daud, M. H. (2014, November). *Approach of assessing 'hands-on' in laboratory exercises in engineering technology courses.* Paper presented at 8th MUCET 2014, Melaka, Malaysia.

Župerl, U., & Virtič, M. P. (2013). Remote controlled laboratory as a modern form of engineering education. *Journal of Elementary Education, 6*(1), 27-42.