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TRANSFORMATION OF DYNAMICAL PRACTICAL LAB FOR INTERACTIVE VIRTUAL LEARNING EXPERIENCE

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Abstract

Starting from the year 2020, the pandemic situation has forced a shift of most learning into the online mode. Making it much more challenging to exercise the physical lab work. Various approaches such as lab demo video and live discussion session were introduced as the immediate alternatives. However, these alternative models have a limitation where learners are still disconnected from the actual hardware for the hands-on learning experience. Available virtual lab modules in the market are costly and do not necessarily fit the required learning outcomes of courses. In this research, an initiative was taken to convert an engineering physical lab through commonly used software. The PowerPoint-Lab (PPT-Lab) is a low-cost lab tool that enhances the interface and interactive element in practical activities while engaging multiple learning domains within learners. Using the available functions in PowerPoint, a slide is designed and embedded with the 3D computer-aided design models to allow a virtual touch experience of the experimental hardware which is not possible with the 2D images in the lab manual. The PPT-Lab was implemented across Malaysia and Edinburgh campuses for the 'Wheel and Axle Acceleration' experiment. The PPT-Lab enables students to practically run the experiment virtually and collect individual distinct data which prevented plagiarism. The quality of students' reports is comparable with the reports during physical lab time. A survey with first-timers and experienced students to the physical lab received positive feedback. A high number of students agreed that the PPT-Lab enabled them to run the same lab work off-campus.

Keywords: CAD, learning styles, laboratory, psychomotor, virtual

1.0 INTRODUCTION

Aligning to the Quality Education (SDG 4) of the United Nation's Sustainable Goal Development vision, the community is exploring to establish a good and sustainable education level across countries. With the outcome-based education framework, knowledge growth follows closely with the Bloom Taxonomy. Learning develops from the understanding and recall stage (low level) to the application and analysis (medium level) and finally extends to the higher level's capability of evaluating and creating knowledge (Rao 2020). Emphasising holistic learning, the curriculum design closely mapped to the cognitive, psychomotor, and affective learning domains. This is to ensure effective knowledge development through mind, hands, and heart. Even with the physical workspace for learning and teaching, effective engagement with learners through different multiple-intelligence styles was never been easy. Many studies focus on its effectiveness and improvement (Nasri et al. 2021). Now the task has gotten much more challenging with the recent transformation in education due to the pandemic. A conventional simple immediate approach during this new normal might be adopting video recording of lab demonstration and distributing of raw lab data to support students in lab report writing. Many misconduct cases arise from this practice, especially in big class sizes. Having similar sets of lab data increase plagiarism opportunity in report writing. The virtual lab approach has been introduced in various engineering lab work (Jarka & Fernão D. 2020) to ensure the effectiveness of practical learning and development, as recommended by the professional accreditation bodies.

Virtual laboratories serve as an alternative especially when physical facilities and workshops are non-accessible. Supported by Babateen (2011), computer simulation improves and helps in learning science-related experiments. This is supported in a study to investigate the effectiveness and growth of concepts understanding and student self-paced learning (Rajendran et al. 2010). The findings indicate students' preference for computer-assisted tools in learning over textbooks, for it can enable thinking outside the box. Aljuhani et al. (2018) created a Virtual Science Lab (VSL) for middle school students in Saudi Arabia. VSL is a web-based platform to enhance the learning approaches through an interactive lab environment and allowed users to conduct experiments individually with unlimited attempts. It has been proven that a virtual laboratory provides equivalent conventional face-to-face instruction and saves time when accessible from home (Hamed & Aljanazrah 2020). However, the research raised the limitation to scale the same approach to all physics experiments. In addition, virtual lab tools may incur a high cost of development and to users.

Despite the rapid advancement of technology having brought a vast variation in digital learning, the observation signifies the importance to integrate both virtual and physical lab practice. Knowing there is a strong correlation between multiple intelligences and learning styles (Xhomara & Shkembi 2020). This provides an in-depth engagement to the different learning styles and supports multiple intelligence learners. The graphics and usability appear to be the most important features especially for primary and secondary school learners (Mircik & Saka 2018). In-depth learning has always been the topic of discussion. The question lies on how to ensure deep learning and not only touch a surface level of understanding in digital learning. Vogt et al. (2021) introduced a mental model in the attempt of prompting in-depth learning prior to entering the virtual reality learning setting to boost its effectiveness.

Compiling the observations, this study intends to design a cost-effective virtual lab module framework and tool to enhance the practical learning experience. The approach aims to connect and improve the engagement and interaction in conventional practical activities with learners through readily available user-friendly software while engaging multiple learning skills.

2.0 METHODOLOGY

The sudden shift of teaching and learning mode has introduced many new skill training requirements for educators. For a non-technology savvy individual, this has created much pressure in focusing to perform effective teaching. Taking this into consideration, an all-in-one Lab module is designed via PowerPoint. Understanding that PowerPoint is more user-friendly software to many educators and students, the initiative intends to reduce the need to learn new software when operating the PPT-Lab. Figure 1 illustrates the corresponding transformation from the conventional physical lab instruction into the PPT-Lab. Each conversation step is mapped to its corresponding activated learning styles.

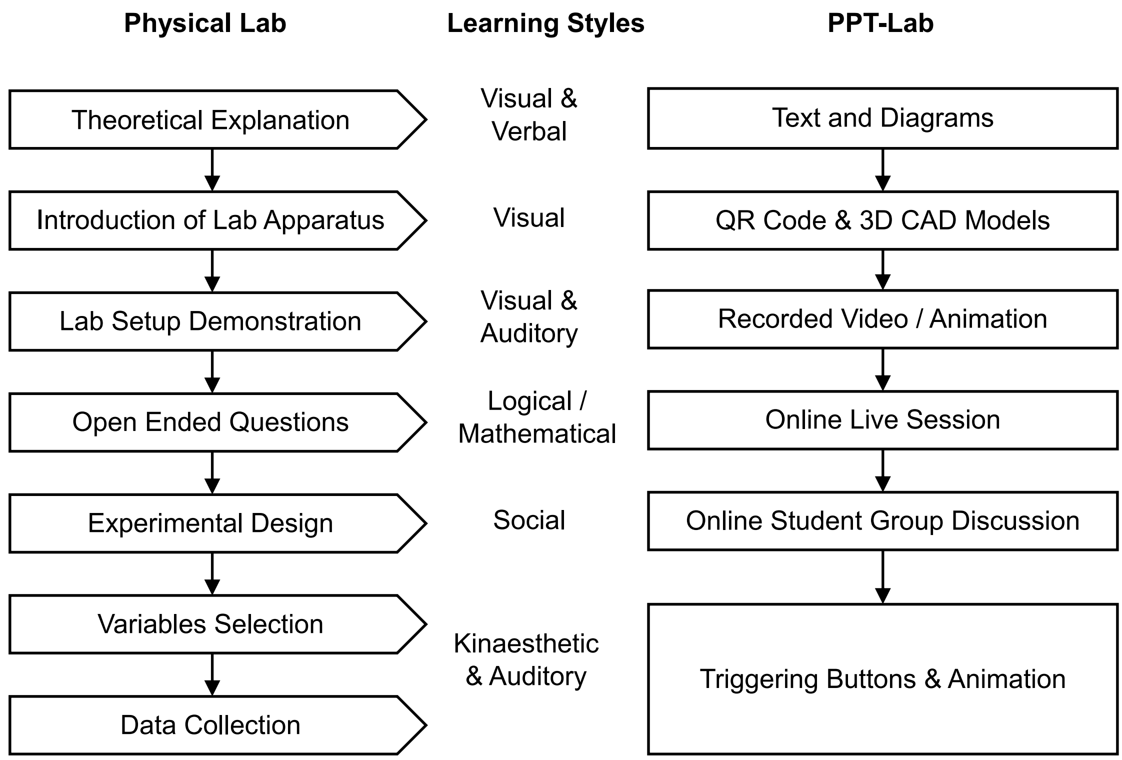

Figure 1: Transformation of physical lab to PPT-Lab with learning styles mapping

The PPT-Lab begins with the theoretical explanation (cognitive) with open-ended context to prompt discussion between students. Integrated with the 3D computer-aided design

(CAD) models of experimental hardware allows a virtual touch (visual) to students. The 3D model orientation can be adjusted by students through a navigation feature to view and inspect for hardware details. After understanding the theoretical and hardware setup, students can now initiate a group discussion (teamwork) on the desired testing variables. They can practically run the experiments via the animated feature in PPT-Lab to collect the responding data. The individual group can obtain their distinct set of data for further analysis.

The first PPT-Lab was developed for one of the undergraduate engineering courses implemented across two campuses (Malaysia and Edinburgh). The engineering experiment, 'Wheel and Axle Acceleration experiment' caters to 155 local and international students for their long or short report writing. Students are assigned into 4-5 students per group. An online session with the assigned groups of students was conducted to discuss the theoretical framework of the experiment and walk-through of the demo, followed by a question-and-answer session to stimulate critical thinking and in-depth learning. Group discussion shall continue to finalise the experimental design and the desired parameters for investigation. Finally, students can run the experiment in PPT-Lab to collect the necessary data for analysis and report writing. Figure 2 shows the features in Wheel and Axle Acceleration PPT-Lab which maps to the different learning deliverables.

3.0 Results and Discussion

The PPT-Lab was used by 155 local and international students within their respective groups. Since this is a virtual tool, students at different locations due to local movement control can perform the experiment without the need to worry about the time zone differences.

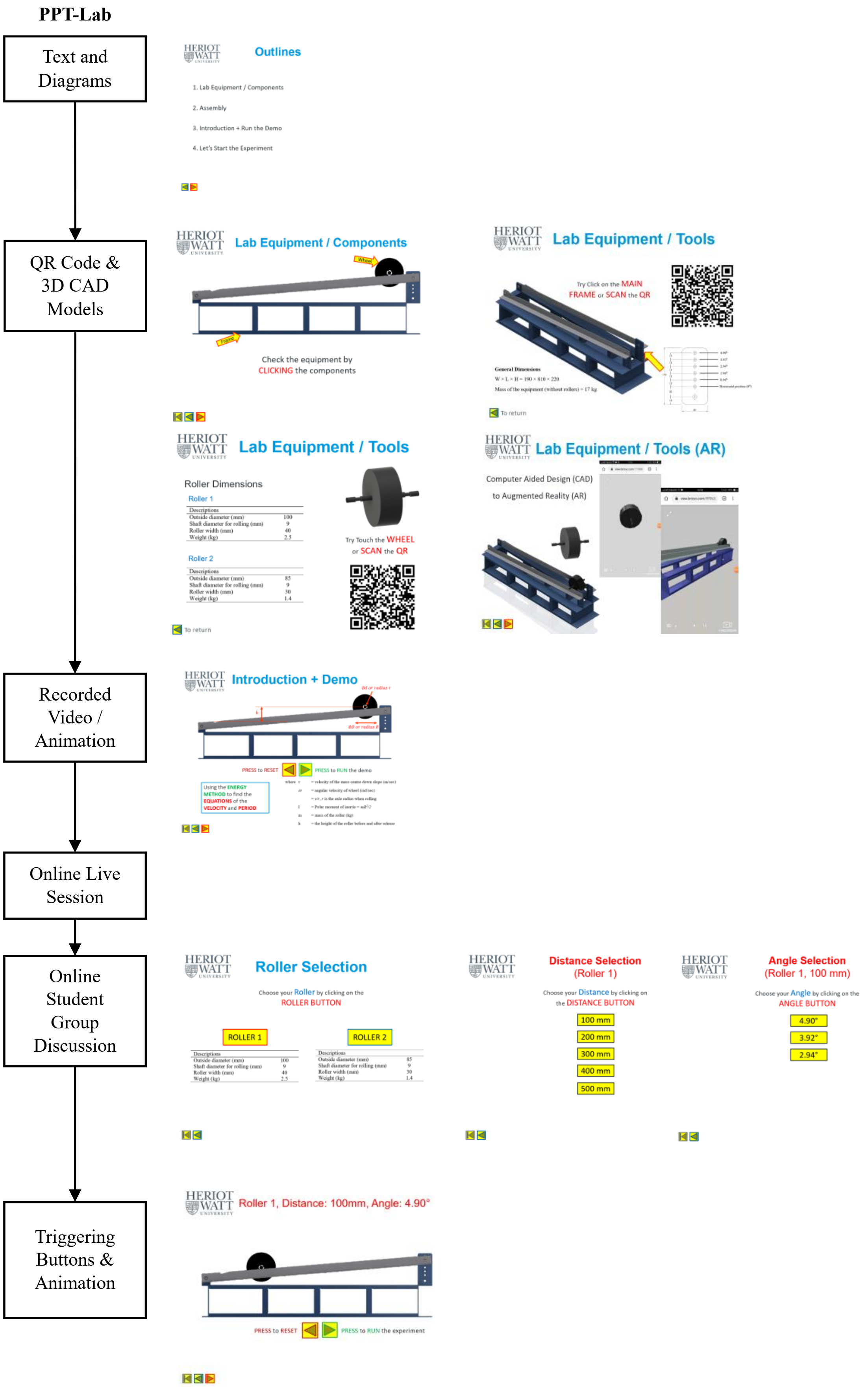

Figure 2: PPT-Lab for engineering lab

A survey was conducted with students who used the PPT-Lab. For better comparison, the respondents are categorised into two groups based on their prior experiences. Group 1 consists of students who have not performed the actual physical lab on campus before, while Group 2 contains students who had the opportunity to conduct the actual physical lab with hardware on campus before the pandemic. The PPT-Lab was shared and attempted by the Group 2 students as well. The rationale is to compare the experience of first-timer and hardware-experienced students. A total of 43 respondents (Malaysia and Edinburgh students) has been collected from this survey. Table 1 listed the questions asked in the survey.

Table 1: *Questions posted in the survey*

No	Question	Type of question
1	You can understand very well about the practical "Wheels and Acceleration" Lab with the PowerPoint Lab?	Yes/No
2	I can perform exactly the same practical lab work even with this PowerPoint Lab.	Yes/No
3	Using the PowerPoint Lab is BETTER than just taking raw data and do the lab report without conducting physical lab during the off-campus period.	Yes/No
4	Using the PowerPoint Lab is BETTER than just taking raw data + LAB DEMO VIDEO and do the lab report without conducting physical lab during the off-campus period.	Yes/No
5	Please kindly share your feedback on the PowerPoint Lab for its potential as an alternative physical lab. You can comment as reasons for the option you chose in Question 3 & 4.	Open-ended

Figure 3 shows the collective response from 43 students in answering the yes/no questions 1 to 4. Group 1 consists of 24 students while 19 students are in group 2. Overall, more than 90% shared that they can understand the lab work and perform the same practical lab through the PPT-Lab. 100% of respondents who conducted the practical lab on campus before, said that running the experiment with PPT-Lab is similar to how they perform the actual experiment with hardware. More than 70% in both groups agreed that the PPT-Lab is better than just learning through demo video with raw data sharing. The approach received a positive response in terms of the excellent experience when using the PPT-Lab and found the 3D CAD models were very helpful in understanding the hardware setup. Even though they are from different prior experiences, the trend is rather similar. Group 2 agreement on question 2 gave a significant implication that the PPT-Lab does perform similarly to the actual setting as they can make a direct comparison.

Tables 2 and 3 summarise some of the comments from Group 1 and 2 respectively while Figure 4 shows the rating based on the responses. Various comments highlighted its innovative feature, easy to use, and the data collected is reliable compared to the real data. In terms of academic performance, students can still produce high-quality technical reports without deteriorating the learning efficiency as compared to the previous years where the lab was conducted physically. From the collected feedback, no doubt physical lab experience is irreplaceable, however, the PPT-Lab serves as an alternative to provide a different practical learning experience. This corresponds to the ‘rather positive’ shown in Figure 4 which took the second highest in both groups. Yet this should be visited as future improvement where both physical and virtual labs do need to complement each other with their respective strengths (Puntambekar et al. 2021). The virtual lab improves conceptual understanding while the physical lab is still important for practical activities and different learning aspects (Sharma & Ahluwalia 2018). Through this experience, students were able to run the virtual experience and own their lab data for post-processing and report writing. Resolving much of the plagiarism possibilities especially through this full online learning and teaching mechanic. With the high number of ‘very positive’ ratings by group 2 students who were able to compare with their past hardware self-experience, it significantly shows the impact brought by PPT-Lab as an alternative virtual lab tool.

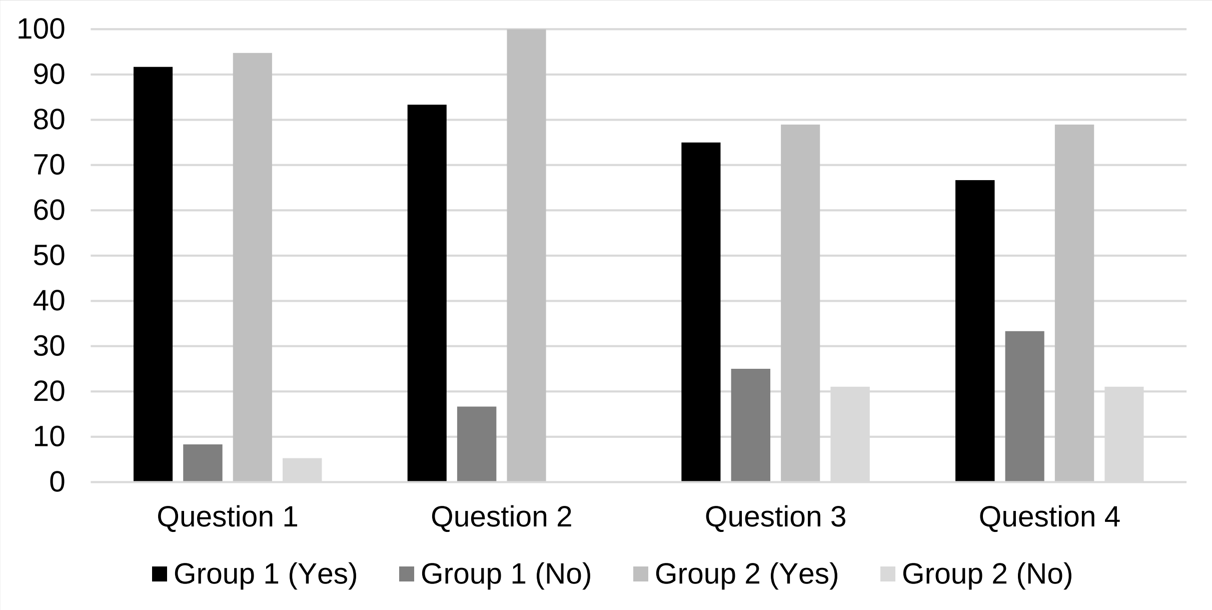

Figure 3: Chart of 43 responses for individual survey question

Table 2: *Feedback from some students (Group 1) who did the experiment for the first time*

Respondent	Feedback
A	PowerPoint Lab might be a good alternative for physical lab, however the lab experience from physical is irreplaceable. However, it is much better comparing to just taking raw data and lab demo video which we don't know what we are doing.
B	I have not conducted this lab in real life, but as it seems like a simple experiment the PowerPoint lab should be as effective at teaching the relevant theory. I believe that conducting a real experiment is more engaging however and makes a more lasting memory. That being said, the PowerPoint should serve as an effective substitute.
C	it just like a real lab

D	Although physical lab would be the best hands-on experience.... I think the physical lab is the next best option during the pandemic
E	Could incorporate a demo video so we can know it would have been done in real life
F	The UI kept glitching out which made the lab very hard to conduct.
G	The PowerPoint Lab was very helpful and very simple to use simulator.
H	Using the PowerPoint is very good because it gives me a full understanding on the experiment, and it allows me to do my report without having any doubts.
I	It is much better for students to see and actually experience the experiment instead of watching someone else do it, would love to see more of this as well as additional models/apparatus/materials that will also be used in the physical experiment to be included

Table 3: *Feedback from some students (Group 2) who experienced the same on-campus lab session with hardware before pandemic*

Respondent	Feedback
A	It is better than physical lab because it can minimize the parallax error that made in real life.
B	Overall structure and content are clear. Maybe can improve graphic more like at different angle the bar will set at the correct hole.
C	I think this is very cool and helpful especially during this pandemic. However, if there wasn't a pandemic, I advise them to do it in real life as it allows them to make mistakes (even though minor) and allow them to improve better in my opinion
D	It's doable as long as there is a video representation of the experiment for better understanding

E	The navigation of the experiment could be better as for me I need some time to understand the whole PPT-Lab work, but I believe it's just a software restriction.
F	Time saving, as we don't need to go to the university just to do the physical which could be done online

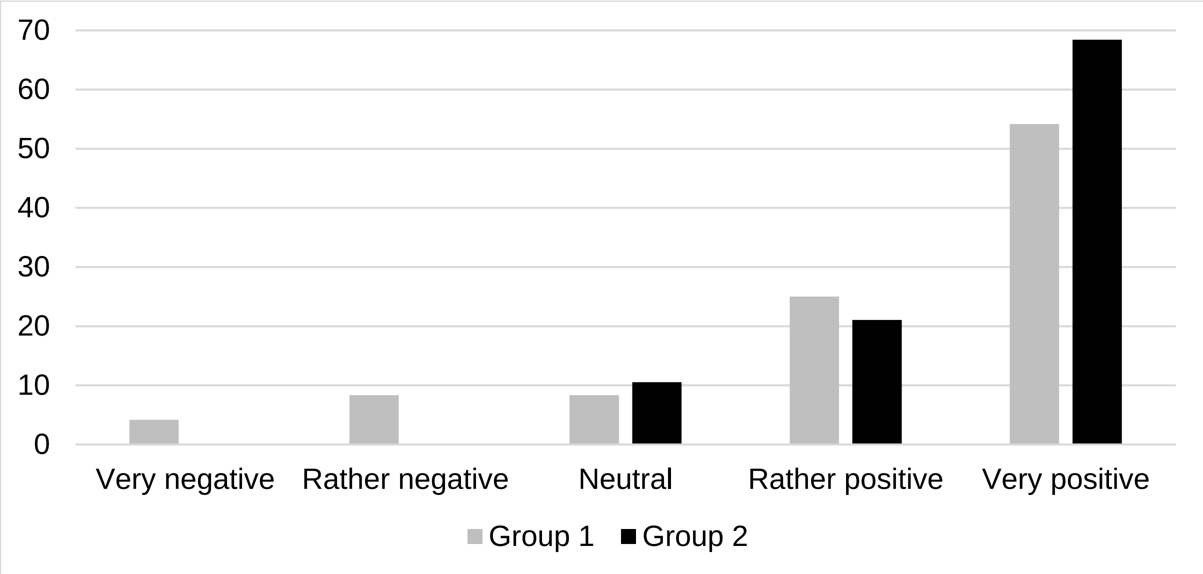

Figure 4: Chart of respondents' rating

The concept of PPT-Lab has been escalated and explored in another engineering experiment, indicating a transferrable knowledge of the initiative. Nevertheless, a study revealed different tools have their targeted audience and some features which are more prevailed for a certain nature of the experimental design (Mircik & Saka 2018). One of the limitations of PPT-Lab lies in the possible nature of the experiment that can be supported by the available functions in PowerPoint. Due to the different device operating systems, users may have difficulty accessing the PowerPoint software as well. This feedback was recorded by respondents who categorised it as 'very negative'.

4.0 CONCLUSION

The practical lab work experience has been obstructed due to the non-accessibility to lab facilities. A simple and cost-effective PPT-Lab tool has been developed with the readily available PowerPoint software. This is in favour of the potential lab instructors/developers without the need to learn a new technology skill set in preparing an immediate virtual lab tool. The interactive 3D CAD models serve as physical hardware substitutes, while the PowerPoint animation and triggering buttons allow a live data collection by users. The collected responses from a survey were very positive. Highlighted that the students could experience a similar quality of lab experiments when compared to the past if exercising physical lab work on campus. However, this approach may need to investigate further to study the range of experiments that could be complemented by the PowerPoint functions. Comment from the survey state that even though the physical lab is preferred, this approach can serve well given the current learning environment. In the future, the exploration shall be the hybrid of sampling video recording with PPT-Lab to enhance the learning effectiveness and extended scalability of PPT-Lab mechanics.

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