Physics on the Go: A Mobile Computer-Based Physics Laboratory for Learning Forces and Motion

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Abstract—"Forces and Motion" is a topic that requires students to relate contents to real life applications but most of them have difficulties in connecting physics concepts to its corresponding representations and the connections of the representations to the real world. This contributes to poor conceptual understanding among the students. Conventional teaching approaches also create poor interest among the students in studying Physics. Some school laboratories are not equipped sufficiently and some apparatus are broken or out dated. Therefore, a Mobile Science Laboratory (MSL) is applied in the research to provide an alternative to better functioning laboratory which also uses Microcomputer-Based Laboratory (MBL) in providing up-to-date apparatus in data acquisition. This research investigates the impact of Mobile Computer-based Physics Laboratory (MCPL) which is a combination of the use of MSL and MBL in teaching and learning "Forces and Motion" called PotGo (Physics on the Go) using semi-structured interview. The data was analysed using thematic analysis. The result shows that MCPL improves the students' understanding in Forces and Motion because the students can see and experience the concepts in real life and getting the data in real time. MCPL is interesting for students because they can conduct Physics experiments using computers and technology, it is fun and the students can explore the Physics concepts with little time for setting up the experiments. Therefore, the use of PoTGo in MCPL affects students' learning in "Forces and Motion" and interest towards Physics.

Keywords—Forces and Motion, mobile science laboratory, microcomputer-based laboratory, interest.

1 Introduction

Microcomputer-Based Laboratory (MBL) is a computer-based experiment in which experiments are conducted with the use of computers and software, connected with interface and probe ware such as a motion sensor, force sensor, voltage sensor, temperature sensor, sound sensor, acceleration sensor, light sensor, charge sensor, rotary motion sensor and magnetic field sensor [1,2]. Various approaches are widely studied such as Computer Aided Data Acquisition and Analysis (CADAA), Internet Virtual Physics (IVPL), Global Web Laboratory (GloLab) and Interactive Simulations using Physics Education Technology (PhET). MBL provides hands-on experiments and the potential for doing and testing at the same time. It has proven for teachers as they do not have to prepare another test to evaluate student attainment in the lesson [2]. However, MBL is very expensive although it has a lot of benefits in learning Physics. To solve this, MBL could be shared by schools using the concept of Mobile Science Laboratory (MSL).

Mobile Science Laboratory (MSL) is a vehicle replicated as a travelling laboratory [3,4] or an electric wide-beam barge [5] and basically it offers as a service or off-the-shelf version [6]. MSL is established in America in 1998 and widely implemented to outreach activities in United Kingdom, then India, European country and other developing countries such as South Africa in 2006 until recent year [6,7]. MSL has benefited the rural area high school students, schools selected which are lacked of science laboratory and do not have adequate funding to conduct experiments and for teachers to gain science teaching skills in laboratory [8].

This research combined MBL and MSL to develop Mobile Computer-based Physics Laboratory (MCPL) called Physics on the Go (PotGo) for students to learn Forces and Motion in order to increase their interest, achievement and higher order thinking skills.

2 Problem Background

Physics is perceived by students as an abstract subject [9] with many abstract concepts. Physics usually is related to mathematics [10] and understanding relationships between mathematics and natural laws causes the students to learn in a complex process. Therefore, they have difficulty in understanding and using the concepts. An investigation of high school students' use of the concept of force is 'hard' due to the way it is taught and students' cognitive representations [11].

A study by [12] states that kinematics becomes problems to students because they face difficulties in connecting physics concepts to the corresponding representations and the connections of the representations to the real world. Kinematics usually is represented by graphs of kinematics variables (position, velocity, or acceleration). Students have the difficulty in interpreting the qualities of the graphical representations (slope, intercept, or area under the graph) correspond to the physics concepts (velocity, acceleration, or displacement). This is because students learn the concept in discrete unit and not in their real life experience [10].

In order to achieve the learning, in suggestion, the topic should be taught in contextual way. As students are able to make sense of Forces, their understanding of the topic is improved. It has been proven by [13] who states that relevance and students experience are able to make them understand and clarify the abstract of Newton's First Law and Newton's Second Law concepts. Besides, the transition process from concrete to abstract is different for every student due to their cultural background, past experience, learning environment and context of learning. Therefore, their mental model in constructing knowledge is a continuous process for investigation in science learning.

Carlone [10] constructs a module to disseminate the usual physics course by integrating several concepts of Physics with activities such as roller coasters and in sports. For real life situations, a contextual approach is able to distinguish between the usual conventional Physics discourse and new learning discourse [14]. Besides, students' experiences in real life situations can be useful for carrying out scientific teaching in the laboratory. This involves practical work such as experiments and hands-on activities for interesting science exploration. A study by [15] shows that practical work is interesting for students to learn Physics and they perceive these as 'relevant', referring to the relevance of studying Physics in the context of everyday life.

However, some school laboratories are poorly functional and some of them do not have enough apparatus to ensure that all science students can conduct experiments. Time constraint also leads to fewer experiments being carried out. Therefore, a MSL that serves as an alternative laboratory can be a solution for this problem. Several studies suggest that such laboratories promote students' motivation, improve performance on high-stakes tests [4], provide new pedagogical approaches to teachers, save costs in laboratory maintenance in the long term [4] and enrich teachers' pedagogical skills [6]. The MSL could be enhanced with MBL to minimize the time required for carrying out experiments and data collection.

Besides, there is a decline in the number of students in the science stream at secondary as well as university level [16]. Research has been carried out to identify factors underlying the decline in science enrolment, in order to promote student attachment to scientific and technological disciplines [17], including Physics [18]. Therefore, appropriate actions should be taken to promote interest among students in science and technology, as we need more expert professionals such as engineers and scientists [19] who meet the qualities of human capital. The Mobile Computer-based Physics Laboratory (MCPL) is seen as a suggested solution to the above problems. This research designed MCPL for learning Forces and Motion and study the effects of MCPL on students' learning in Forces and Motion.

3 Mobile Science Laboratories

Many MSLs are carried out since 1992 in America. DESTINY, Science on the Go and Physics Van are the MSLs with same objective which is an urgent action to overcome declining numbers of students in science career. The MSL has been carried out in the England, Ireland and Scotland such as Lab in a Lorry and SCI-FUN. Both MSLs focuses on students aged 11-14 year-old which serve objectives such as promote interest in science using experiments, increase awareness of relevance in science and hands-on activities. 92.1 % teachers rated the visit experience for pupils as 9/10 and the most important element is the collection of hands-on exhibits and 94 % of contact teachers strongly recommend it to other teachers [20].

MOBILIM is another example of MSL that was initiated by universities in United Kingdom, America and other European countries. MOBILIM emerged as a vital arise in Turkey Education System as the country faces declining number of scientists, students' interest in science study correlated with teachers' teaching and innovation, and international assessments such as PISA and TIMMS. The MOBILIM targets to improve teachers' pedagogical skills in teaching especially in laboratory work. The MOBILIM provides a network of interested teachers in laboratories and teaching techniques, a medium for discussion, obtain new ideas for science fair, inculcate interest through training sources in rural areas. This effort by reaching out rural area teachers with laboratory experiments in MOBILIM has shown a positive report. The report of MOBILIM from year 2007 until year 2009 states that 93.3 % the participating teachers enjoyed visiting MOBILIM and 96.7 % of them have assured to do more experiments in their lessons. For students, achievement in science can be portrayed by result of TIMMS year 2007, Turkey is ranked 31 with mark of 454, increase to 21 in TIMMS year 2011 with mark of 483 [6].

In India, the MSLs' project such as Agastya and Vidnyanvahini focus on students and teachers in rural area by providing laboratory and lesson carried out in interesting ways. The students gain interest and develop scientific skill. The Lab in a Box (LIB) is introduced in 2011 as it promotes curiosity and spreading creativity to the rural area students in hands-on experiments. It strengthens effort of scientific works for teachers and students, as well as communities. The objectives are inculcation of hands-on learning, increasing impact of practical work such as exposure to experiments. The LIB is brought into schools by Agastya's low-cost and effective science model through mobile lab van to intensify the interactive hands-on experience. The LIB gives teachers freedom to utilize model introduced by the instructors to suit with their teaching and learning. The lesson becomes more interesting and students become more pro-active instead of chalk-and-talk. Teachers can continue the teaching method although the mobile lab leave the school [21].

Methods in implementing MSLs are different because of their different objectives. Mostly, the MSL is carried out by teachers and educators such as MSL staffs, university students or lecturers. The MSL provides modules and supplement current curriculum to strengthening teaching and learning. Period of learning using MSL is ranged from hours in a day until four days at one place. Some MSLs provide access such as Website and professional development to enhance skills for teachers using apparatus provided. Most of the MSL evaluations are interest, achievement, science literacy, and students and teachers' skills in pedagogical elements. The MSL has proven positive in creating motivation as interest and achievement are increased. However, what and how MSL impacts the students were not explained in depth. Hence this study explored what actually makes students interested in Physics and how they can better understand Physics concepts through the use of MSL.

4 Development of Physics on the Go (PotGo)

In this research, PotGo was developed to bring MBL to schools through MSL so that learning Physics can be more interactive, fun and inquiry-based. Most MSL vehicles are funded by a university grant and founders. For Vidnyanvahini, the MSL is fully funded by founders with awards received. Compared to DESTINY and Lab in a Lorry, it was funded by several agencies. Lab in a Lorry is operated by the Institute of Physics in partnership with the Welsh government, the Schlumberger Foundation and STEMNET, and funded by them. DESTINY is funded by the Morehead, Planetarium and Science Centre. MOBILIM is funded by the Center for European Union Education and Youth Programmes grant [6]. Big grants and funds are allocated for equipping the mobile lab and to cover travelling costs, maintenance, and running programs, such as for material usage, exhibitions, conferences and workshops.

In this research, the ability to supply low cost electricity and modules for learning is taken into consideration in developing PotGo. As the research is operated by the researchers, the funding was provided by the university. A small compact national car was developed to fulfil the research objectives. It is 3.3m length, 1.4m width and height 1.4m. PotGo was designed based on the suitability of a small compact car which entailed low cost in travelling and provided power supply in running the experiment using laptop and PASCO [1]. The funds were minimized by using one of the researcher's car and the car was converted into PotGo with reasonable cost. The cost covers a powerful car battery, alternators, wiring and maintenance of the car engine. The PotGo for this research was designed with electricity supported by a DC-AC converter. It used 12V from a car battery and increased voltage output to 230V. It has five two-point plugs and it can support up to 700W. This means that five computers can be supported with power of 65W, and the total power used was 325W. The interface used was PASCO Passport 550 and 700 and these required 8V and current of 400mA that produced 3.2W for every set and for 5 sets, 16W is needed. The total power used for the research is 341W. Therefore, the PotGo was able to supply electricity when the DC-AC Converter was charged. All 5 set of computers and interfaces could be used for about one hour when fully charged.

Figure 1 shows the PotGo used in the study, a small compact car that functions as transporter and can accommodate all apparatus and two persons (driver and one assistant). The converter is attached at the rear of the PotGo. Apparatus such as lab apparatus, ruler, trolley, interface and motion sensors were put inside a container. They were well-kept in three containers. PotGo could be used anywhere such as on the football field, canteen and hall.

Meanwhile, the MCPL Teaching Module and MCPL Learning Module were developed to conduct the learning sessions. The researcher and teachers from the four selected schools implemented the intervention. The MCPL modules were developed using ADDIE model and adapted Experiential Learning Theory by Kolb [22]. During the intervention, the students encountered phases; firstly a Concrete Experience, then Reflective Observation, Abstract Conceptualization and finally Active Experimentation. The MCPL experiments involved advanced apparatus which is using probe wares and data logging from PASCO [1]. PASCO is a tool which provides probe wares, interface and Data Studio software. The laboratory apparatus was connected with probe ware such as motion sensor, interface and laptop. As the experiment was running, a real time data was recorded in the Data Studio and the graphs were viewed on the screen. The experiments were run many times and analysing graphs were easier. The MCPL experiments were rearranged to suit open inquiry to produce active learning in practical laboratory work at form four topic, Forces and Motion. The actual time taken for the topic currently is quite long but by using the MCPL Module, learning by doing many experiments were shorten time taken for learning. Some experiment applied more than one concept. Therefore, students can learn by doing experiments while teachers guide them conducting the experiments.

Fig. 1. Physics on the Go (PotGo) in Mobile Computer-based Physics Laboratory (MCPL) with DC-AC converter

5 Research Method

A sequential mixed method research was applied in this research [23]. The first phase was a quantitative study to measure the HOTS of the students before and after using PotGo in learning Forces and Motion. For the second phase of qualitative research, the researchers used interview protocol to better understand the impact of MCPL on the level of students' interest in Physics and the students' achievement in Forces and Motion. The data was collected through interviews after they have went through the learning using PotGo. The data in the form of audio and video were then transcribed. The transcript was divided into segments of information. Every segment was coded and the overlap and redundancy of codes was reduced. It visually represents codes and their interconnection [24].

This paper reports only the second phase of the study. The first phase of the quantitative study report elsewhere [25] shows that the students exhibited significant gain in interest, conceptual understanding and HOTS. In the second phase, the study explored how MCPL has helped in increasing their interest, conceptual understanding and HOTS in the Physics topic.

It took six weeks and in average, 60 minutes for every one unit of learning. Six weeks were enough for implementing the intervention [26]. 94 students from four schools were arranged in groups of six students and they took turns in using the apparatus of PASCO. 13 students were randomly selected to be interviewed to explore their perception of MCPL in relevance to their level of interest, conceptual understanding in the topic Forces and Motion and in HOTS.

6 Results

Thematic analysis [27] was used to analyse the interview data. It consists of six steps which are familiarization with the data, generating initial codes, searching for sub-themes, reviewing sub-themes, defining and naming themes and producing the report. Coding is a process of examining data, identifying and noting aspects that relate to the research [28]. The transcripts were read and codes were constructed such as "skill in using computer" for excerpts by Zul, Yus, Andika and Sarah (pseudonames).

- "For me, very good" (Zul)
- "I am good in using computer" (Yus).
- "For me, my skill is moderate" (Andika)
- "My level is moderate" (Sarah).

The students gained more understanding of concepts after carrying out experiments. For example, Faris understood more after doing the MCPL experiment, he said, "I feel happy because I can do experiments on a topic that I do not understand and after carrying out experiments, I understand more" (Faris, 65-67). Another student named Andika mentioned that he now knew the principles of Physics after doing the MCPL experiment. From his statements from lines 64 to 69 he said, "My level of understanding is good. Because maybe previously I only knew momentum concepts from Newton. After carrying out the experiment, I really know how momentum is produced."

For Elias, he understood more because of more exposure, he said, "….I understand more about the topic compared to experiments in the lab because the experiments in the lab give less exposure about what we actually learn" (Elias, 21-24). Zana also said, "It is now easier for me to understand Physics concept examples; momentum, I know inertia" (Zana, 43-44).

Based on the various understandings, the students were able to state and compare their prior knowledge, level of understanding and relate one concept to another concept. The students related to their personal experience in doing experiments. Hazri mentioned that experience which involved doing experiments helped him to understand more.

- 18 By experimenting, I understand more
- 19 because I did it
- 20 I remember more compared to reading etc.

(Hazri)

For Yus, he claimed that the experience makes learning easier for him to understand. "It's easier for me to understand concepts in Forces and Motion" (Yus, 20-21). The MCPL experiment gave the students new experience. Zul and Zana claimed that the experiments are beneficial because they gain new experience and learning. Zana said, "I like it because it gave me new experience" (Zana, 56). Zul mentioned three times:

- "For me, yes. Because it gives me experience and new education for us" (Zul, 26-27).
- "It gives new experience to the student" (Zul, 64).
- "It gives new experience" (Zul, 67).

The students were able to see how things happen in relation Physics concepts. Sarah found that experience based on experiments allowed her to see how things happen. She stated from lines 17 to 18, "Because of this experiment, we can see with our own eyes", from lines 25 to 26, "Yes, like I said just now. I can see with my own eyes how it happens. I did it by myself" and from lines 57 to 59, "I can see with own eyes how the value changes for every movement made. I can see with my own eyes". Adi also stated that he can see how forces affect velocity and acceleration. Adi said, "for example I see how force affects velocity and acceleration" (Adi, 45-46).

According to Elias, he found that the MCPL module gives new experience and helps him to understand the topic, he said, "After completing the module, we feel excited because we had new experiences using the MCPL module, rarely used in our school, it really helps in learning the topic we learn." The students also gained new knowledge from the MCPL experiment. Elias said, "By carrying out experiments with my friends, I have new knowledge" (Elias, 19-20).

For the mobile lab setting, students such as Andika, Amir and Yus claimed that the mobile lab helped in term of teacher's teaching, and they were interested in learning. Andika said, "I think the mobile lab concept is easy because it is movable which is moving one place to another" (Andika, 87-88). And Yus said, "because it can help teachers bring apparatus more easily to wherever, outside class" (Yus, 61-62). Amir said, "because we do not feel bored because we always stay at the same place" (Amir, 65-66). For Azlina, she stated that MCPL has advantages in term of setting. She said, "For example, the lab has no electricity, still it can go to another place. If the lab is in the school, the situation is just the same. Lots of experiments can be carried out but outside. It's fun" (Azlina, 150-153).

The researchers found that the skill in using computers is important to ensure that the students are capable of using computers without fear, and are competent enough to use tools especially in assembling sensors from PASCO apparatus with the computer.

Besides, the students found new things that they experienced at school make them more interested to learn. The researchers found that they gain interest by exploring the new apparatus in doing experiments in MCPL.

- 29 because I know lots of new thing
- 30 from these experiments
- 60 It was interesting because I have got (to know) many new things
  (Faris)

- 71 It is a new thing that has never been done at my school
  (Zul)

Apart of it, some students found that MCPL helps them in assembling the apparatus, especially through the module. This was evidenced when they were asked how they use the MCPL module in conducting the experiment. Faris said "It gave me information to do experiments, for example it gave me guidance to connect wires" (lines 40-42).

When the students were asked "Did you use MCPL module while conducting experiment? How?" Faris answered,

- 40 It gave me information to do experiments
- 41 for example it gave me
- 42 guidance to connect wires

(Faris)

The researchers found that assembling apparatus is easy as the students were able to follow steps in the module. In addition, the students also said that they gained experience in conducting many experiments of different kinds. For example, "experiments can be carried out" (Faris); "I think the mobile science lab is beneficial because it is easy to carry out experiments, various experiments" (Hazri).

Based on the codes, the researchers redefined the sub-theme related to respondents and find relationships with each sub-theme. After that, the theme for teaching and learning using Experiential learning theory was developed. Finally, the framework was produced.

7 MCPL Learning Framework

Based on experiential learning using MCPL, the learning improves students' interest and conceptual understanding. Characteristics of the MCPL module, computer-based experiments and PotGo are the strands that fulfilled students' need in teaching and learning, which shows their acceptance. The theme that emerged is MCPL teaching and learning for Forces and Motion. Therefore, a framework of MCPL teaching using Experiential Learning Theory in schools was developed in Figure 2. It consists of three main strands. These are MCPL module, computer-based experiments and PotGo. MCPL teaching and learning can be carried out when computer-based experiments, MCPL modules and PotGo are applied. The MCPL Module is dialectically related to (see two-way arrow) computer-based experiments and the same goes to the MCPL module that is dialectically related to PotGo. Eventually, PotGo can be used with computer-based experiments. The uni-directional arrow shows that PotGo is a part of computer-based experiments and the availability of PotGo is necessary, only then can computer-based experiments be carried out.

The framework also consists of experience and engagement with interest by the students. Firstly, the students have concrete experiences which involve engaging fully and freely in their own new experience. At the same time, they engage with interest such as in new experience, hands-on activities that relate to real life contexts, easy instruction and systematic procedures, and are able to understand relationships, analyse and reflect, and experience satisfaction with data accuracy. The students then engage in reflective observation. They are in a state of reflecting upon their knowledge of concepts and experiences. They distinguish between meaningful variables and concepts from the observation and conceptualize concepts. They determine variables that should be investigated such as control, manipulated and responding variables. These were at a stage of abstract conceptualization and analysis. Next, they engage in active experimentation. They want to investigate the variables. They then run experiments using PASCO and data is displayed in tables and graphs. They interpreted the graphs shown. Then, they answered the questions in the module as they assessed their understanding and were able to answer correctly. In this mode also, their conceptual understanding can be seen when they understand the concept behind the given phenomena, exploring learning by investigating variables, relating changes to values and physical quantities, strengthening understanding and finally carrying out application in daily life. The cycle is continued when the students are exposed to new experience.

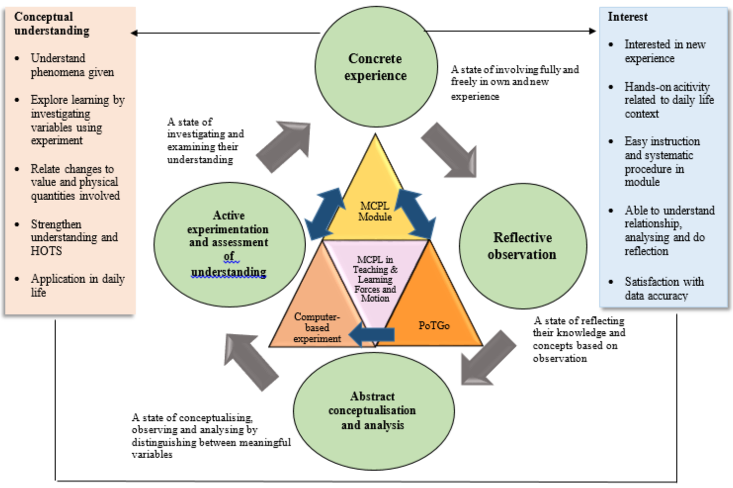

Fig. 2. The MCPL Framework teaching using Experiential Learning Theory in schools

8 Discussion

The framework developed from this research is an essential guide for teachers to implement MCPL teaching and learning for Forces and Motion using experiential learning. It helps teachers to use MCPL in relation to modules and the use of PASCO. The PotGo is an additional element that can be used together or separately. The framework guides teachers to facilitate students to grasp concepts and structure in the context of daily life. Students must be able to have concrete experiences first, then they must be able to reflect their observation [22]. They can transform their experience to their knowledge of the concept. They distinguish meaningful variables and concepts from their observation and conceptualize the concepts. They determined variables that should be investigated and that are relevant to students who are engaging in abstract conceptualization and analysis. Next, the students investigate these variables. Then, they run the experiment, data is displayed in tables and graphs, and they interpret the graphs. This is active experimentation. Then, they answer the question in the module as they assess their understanding. At this point, their conceptual understanding can be seen when they understand the concept behind given phenomena, explore learning by investigating variables, relate changes to value and physical quantities, strengthen their understanding, and finally apply these to daily life. Based on the MCPL framework, the teachers can ensure that the students will increase their understanding and interest by using MCPL.

For this study, the researchers used interviews to investigate how MCPL helps in increasing students' interest and understanding. Findings show that the students gained interest when they met new things and encountered sophisticated tools. They learned by eliciting their experiences. Then, they followed systematic instruction and were able to explore more than what was in the module. They explored by using different situations and were still able to measure and differentiate concepts and relate to their daily life context. Then they applied the concepts by answering questions in the module. At the end of the module, they were challenged to answer a HOTS question. As they were able to answer the question, they achieved the ability to think using HOTS. The findings are aligned with [29]' students who were motivated and curious, and wanted to engage in more problem solving, learning by discovery, control tasks, open-ended learning goals, and have more regular evaluation.

The time taken to carry out teaching and learning is also shorter compared to usual experiments at school. Even different settings such as the place and time for doing experiments give different interests to the teachers and students. They become more excited and interested when they stay outside the classroom, a finding that is aligned with the study by [30] states that interest is affected by teaching strategies. Safety can still be taken into serious consideration as the students are outside the classroom. They are free to move around and surround the place as part of the experiment. Teachers are also able to scaffold students' interest in Physics as proven in the study by [31] by providing new exposure, encouragement and monitoring students during learning. Therefore, MCPL experiments made students more interested as they are good at doing experiments and gain understanding of the Physics concepts.

Therefore, when MCPL is used instead of simulation used by [32], this results in increased conceptual understanding. This is also similar to a study by [4] which showed that student learning using experiments was better than field trips such as a visit to a museum and other informal science experiences. Therefore, low achievement in the topic of Forces and Motion can be increased by using MCPL. As the topic covered wider areas of real-life context and mathematical representations, by using computer-based experiments and experience, their overall achievement in the subject can lead to a stronger understanding of concepts. Interviews carried out to explore students' understanding shows that they gained better understanding. Therefore, students can have better achievement and teachers can apply MCPL in teaching and learning.

The research on the use of technology in experiments was similar to a previous study by [33] which involves research on web-based instruction for university students. The findings show moderate perception aligned with the result from the study [33]. Based on semi-structured interviews, the researchers found that the students have good computation skills and their anxieties and dissatisfaction was reduced when they used MCPL. This differs from the research by [33] where negative perceptions from technology users emerged such as anxieties and negative attitudes towards the course. This is because computation skills are important, and students should be familiar with the technology before being assessed on it. This research is also similar to a study by [34] exploring perceptions of mobile science laboratories as a tool for intervention. The findings show positive perceptions which are align with the study by [34], claiming that the students' experience was able to change negative to positive perceptions and motivated students to pursue science.

Moreover, the students perceived the MCPL as an easy tool to be used. These findings are supported by [6] who show positive perceptions of MOBILIM such as the notion that it is easy, helps in science lessons, can be recommended to friends, is interesting, and more experiments are desirable in lessons despite the moderate percentage achieved in learning science and technology. Teachers gain more benefits in terms of improve skills in conducting experiments, along with lessons or teaching and learning sessions. This is aligned with [4] who showed that student engagement towards science learning and teacher ratings were better through mobile labs than field trips and other informal science experiences. The ChemKits program [3] also provided computers and probes. The experiments were successfully carried out in the program. The study was also carried out to expand benefits, and the program was made for outreach a decade ago due to lack of funds by the state and the university. For MCPL, the module used was based on experiential learning and emphasized experiences and meaningful learning in context. The students took their experience as an initial step in learning while teachers assisted in delivering their prior experience and knowledge. The students may recognize the phenomena yet do not have meaningful contexts for them. Therefore, experiential learning provides students with meaningful learning and the ability to retain memory and involve learning by doing to understand concepts. The engagement using experiments and activities make students meet new tools and new experiments. When they experience new things, they also connect past memory into new meaningful experiences. They have reflective observations and conceptualization. They also analyse their variables and carry out experiments and finally assess their own understanding. In conclusion, this shows that MCPL is able to engage students' learning processes through teaching strategies, which is a positive perception of teachers and students.

In fact, experiments are able to increase conceptual understanding and a study by [35] showed that both simulation-based laboratories (SBL) and microcomputer-based laboratories (MBL) improve conceptual learning. The experiment is one approach in teaching and learning that is an alternative to mere lectures. This is aligned with the suggestion by [36] that teachers should teach science in a more interesting way by variation in laboratory practices (eg. experiment) and demonstration, and that students should explore and discover meaningful concepts by themselves scientifically. Teachers with varied ways of teaching cater to all needs of students [30]. Previously, most teachers apply "chalk and talk" and usually impart contents of Physics to students by lectures [36, 37] and most teachers teach in one-way communication which is more teacher-centered [38]. Hence, student-centered learning should be applied more in teaching and learning strategies. The MCPL is a branch in teaching and learning implementation, instead of discussion, simulation, field trips and the use of technology. Therefore, integration of the use of computers in experiments is able to increase students' conceptual learning and understanding more than traditional ways. Therefore, MCPL is a way to save in terms of cost, and schools can use the apparatus from the MSL like PotGo.

Currently, computer-based experiments are not yet implemented in secondary school in Malaysia. Students still use conventional laboratory apparatus with limited budget from the Ministry of Education. Some rural schools do not have enough apparatus. The cost of using sophisticated tools such as PASCO is high. Therefore, MCPL that applies MSL is a suggestion for school to use in order to give more conceptual understandings, save time, develop HOTS while conducting experiments and promoting interest in learning science, especially Physics. Computer-based experiments in MCPL can increase students' conceptual learning and understanding more than conventional ways. It is also aligned with a study by [35] that investigates conceptual learning using MBL, both of which show significant improvement in the test. Experiments using MBL are computer-based experiments with inquiry-based instruction. The study by [3] also showed the use of computer-based experiments (e.g. computer, pH probe, voltage probe, conductivity probe and thermometer probe) along with ordinary apparatus.

The MCPL module is accepted by students which consists of easy experiments, systematic instructions and computer-based experiments (eg. computer and sensors) that is interesting, consumes less time in data acquisition and gathers real time data. The MCPL module was developed using structured inquiry and students can create their own experiments to deepen their understanding. They create their experiments by selecting their own probes and set variables to be investigated. The conclusions of this study are aligned with a study by [3] that used ChemKits. The MCPL module also provides benefits such as critical hands-on experiments like Lab in a Box (LIB) [21]. This was found to promote curiosity and spread creativity to students in rural areas in hands-on experiments. It boosted efforts on scientific works for teachers and students, as well as communities. It was proven in inculcating hands-on learning and increasing impact of practical work through exposure to experiments. MCPL helps students to be critical and the module helps them boost their thinking and learning.

9 Recommendations

The laboratory is important to serve as a tool in providing practical works and experiments for the students to explore learning. Problems relate to laboratory malfunction such as a lack of apparatus, and non-availability of certain apparatus leads to a lower number of experiments being carried out [19, 39]. As a suggestion, PotGo can be a solution. As the study shows that PotGo is able to serve in MCPL intervention, it can also travel to more places and more schools. The Ministry of Education can use PotGo to implement formal science learning especially Physics. Other than that, engagement in science can be nurtured when students have new experience in conducting experiments. As we noticed, the computer-based experiments have gained a lot of attention such that students want to do more experiments. Problems regarding to the lack of apparatus and functional laboratories can be solved. The facility of PotGo can be upgraded and is replicable for a cost saving travelling science laboratory. The teaching and learning module is developed to guide students to carry out experiments and activities. Further experiments in different districts can be carried out as the PotGo travels. The PotGo can serve as activities to generate interest among various levels of students, from lower primary school until secondary school such as games, displays, and experiments using probe ware. They spend a shorter time and it is safer for them to learn. Programs such as Science is Fun, or STEM learning can also involve the PotGo in different settings and at different times for convenience.

Besides, time constraints are faced by most Physics teachers [39, 40]. Teachers need to focus on important concepts and details for every topic. The module of MCPL helps in reducing longer times to shorter time consumption. Furthermore, PotGo can also be conducted during non-formal learning when it reaches the schools and as informal learning as suggested by [39]. Teachers can also apply teaching and learning using computer-based experiments. Students can be engaged in science and further studies in science and have future careers in science. Teaching and learning can be conducted in a new way by using various experiments. In the long term, teachers in every rural area have the opportunity to use up to date apparatus and new experiments that make them want to know more and imply higher thinking in understanding concepts. The students can also allocate longer learning time for computer-based experiments compared to conventional laboratories [39] that they had before doing experiments. MCPL is a complete module for teachers to help students explore concepts in Forces and Motion while they explore their learning and use experiences.

As a suggestion for further research, the computer-based experiment can be implemented for different topics in Physics such as Heat and Pressure and Light. The probe ware from PASCO is available to use to investigate various issues such as light, heat, pressure etc. Furthermore, Arduino programming is an alternative low cost replacement for PASCO. Sensors for Arduino set can be set up and a real time data can be developed. In addition, a variety of tests can be used instead of multiple answers only. Open-ended questions can be used to analyse students' conceptual understanding. The thinking process using computer-based experiments can be explored in detail. HOTS can be assessed for students' thinking level by developing new instruments that cover conceptual understanding with HOTS.

10 Conclusion

PotGo with MCPL benefit students in a long run. Students can have better understanding and continue to learn Physics in fun and inquiry ways. At the same time, MCPL brings technology into learning Physics in preparing students towards the challenges of Industry Revolution 4.0.

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