THE IMPACT OF MOBILE COMPUTER-BASED PHYSICS LABORATORY IN LEARNING FORCES AND MOTION

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To my beloved mother, Fauziah Hanim Othman and father, Zakaria Hj. Saad

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ABSTRACT

Forces and Motion is a topic in Physics that requires students to relate to real life applications, but most students have difficulties in connecting a physical concept to its corresponding representation and connecting the representation to the real world, contributing to poor conceptual understanding. Conventional teaching approaches whereby teachers use lectures more than experiments also create low interest in studying Physics. Some school laboratories are also not equipped sufficiently and some of the apparatus are outdated, malfunctioning or absent. Meanwhile, international assessments such as TIMSS and PISA have ranked Malaysia below the international average score, indicating low thinking skills among school students. Therefore, a mobile science laboratory (MSL) is used in the research to provide a well functioning laboratory and the use of a microcomputer-based laboratory (MBL) to provide up-to-date apparatus in data acquisition and real time data. This research investigates the impact of the Mobile Computer-based Physics Laboratory (MCPL) which is a combination of the use of MSL and MBL, in teaching and learning Forces and Motion. This research is important in increasing students' interest in Physics, giving insight and experience in doing computer-based experiments, and immersing the students in a university-level laboratory experience. In the study, teachers explored computer-based experiments and used experiments in developing Physics concepts during teaching and learning. The theory underpinning this research was Experiential Learning Theory in which the students learn MCPL through the experiential learning cycle. This research used a sequential explanatory mixed method design with one group pre-test and post-test in six weeks of intervention. 94 Form 4 students were involved in this research, and 13 interviews were carried out. The variables investigated included students' interest, physics achievement at higher order thinking skills (HOTS), students' and teachers' perception and learning using MCPL. A significant and positive impact on students' achievement in the topic was found (M = 15.564, SD = 3.336) and Z = -2.357, p = 0.018. Achievement at HOTS has significantly improved (M = 7.011, SD = 1.909). Impact on students' interest was also significant with med = 62, Z = -5.629, p = .000. Students' and teachers' perceptions were positive towards MCPL experiments in the module. The qualitative findings were used to develop a framework that helps teachers to implement MCPL teaching and learning of Forces and Motion. The framework can be used effectively in integrating experience and computer based experiments which saves time, allows meaningful science exploration, development of conceptual understanding as well as nurturing students' HOTS.

ABSTRAK

Daya dan Gerakan merupakan topik dalam Fizik yang memerlukan pelajar menghubung kait kandungan dengan aplikasi seharian tetapi kebanyakan pelajar mempunyai masalah dalam menghubung kait konsep fizikal dengan perwakilannya dan hubungan perwakilan dengan dunia sebenar seterusnya menyebabkan pelajar mempunyai pemahaman konsep yang lemah. Pendekatan pengajaran konvensional yang mana guru lebih banyak menggunakan kaedah kuliah berbanding eksperimen juga menyebabkan kurangnya minat pelajar dalam belajar Fizik. Sesetengah makmal sekolah tidak berfungsi dengan baik kerana alat radas yang usang, rosak dan hilang. Selain itu, kajian antarabangsa seperti TIMSS dan PISA menunjukkan Malaysia berada di kedudukan bawah markah purata dan ini menandakan kemahiran berfikir aras tinggi pelajar yang lemah. Oleh itu, makmal sains bergerak (*MSL*) diaplikasikan dalam kajian ini untuk menyediakan makmal yang lebih baik dan penggunaan makmal berasaskan mikrokomputer (*MBL*) memudahkan pengumpulan data dan data semasa. Kajian ini bertujuan mengkaji impak Makmal Fizik Bergerak Berasaskan Komputer (*MCPL*) yang merupakan kombinasi *MSL* dn *MBL* dalam pengajaran dan pembelajaran tajuk Daya dan Gerakan. Kajian ini penting dalam meningkatkan minat pelajar dalam Fizik, mencerna pendapat dan pengalaman menjalankan eksperimen berasaskan komputer dan membolehkan pelajar menyelami pengalaman makmal bertaraf universiti. Guru-guru meneroka eksperimen berasaskan komputer dan menggunakan lebih banyak eksperimen dalam membentuk konsep Fizik semasa pengajaran dan pembelajaran. Teori yang mendasari kajian ini adalah Teori Pembelajaran Berasaskan Pengalaman iaitu pelajar belajar *MCPL* melalui kitar pembelajaran berasaskan pengalaman. Kajian ini menggunakan reka bentuk campuran penerangan berturutan dengan satu kumpulan ujian pra-ujian pos yang melibatkan intervensi selama enam minggu. 94 orang pelajar sekolah menengah terlibat dalam kajian ini dan 13 temubual telah dijalankan. Modul Pengajaran dan Pembelajaran menggunakan *MCPL* dibina dan kerangka dibentuk melalui kajian ini. Pemboleh ubah yang dikaji adalah minat pelajar, pencapaian Fizik pada tahap Kemahiran Berfikir Aras Tinggi (KBAT), persepsi pelajar dan guru, dan pembelajaran melalui *MCPL*. Impak positif yang signifikan dalam pencapaian pelajar telah didapati (M = 15.564, SD = 3.336) dan Z = -2.357, p = 0.018. Pencapaian pada tahap KBAT juga meningkat secara signifikan (M = 7.011, SD = 1.909). Impak terhadap minat pelajar juga meningkat secara signifikan dengan median = 62, Z = -5.629, p = .000. Persepsi pelajar dan guru juga positif terhadap eksperimen dalam modul MCPL. Dapatan dari analisis data kualitatif digunakan untuk membentuk kerangka yang membantu guru menjalankan pengajaran dan pembelajaran *MCPL* dalam Daya dan Gerakan. Kerangka tersebut dapat digunakan dengan efektif dalam mengintegrasi pengalaman dan eksperimen berasaskan komputer yang menjimatkan masa dan membolehkan penerokaan sains yang bermakna serta membangunkan pemahaman konsep di samping memupuk KBAT pelajar.

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$m\ s^{-1}$	-	metre per second

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Physics learning problem has been studied since decades ago and as a part of Science, Technology, Engineering and Mathematics (STEM), it is frequently grouped together for learning universally. The ways of thinking involved in these different subjects also have not been established (Ffiseg and Bghymru, 2010). Meanwhile, success in the education system is achieved through the students' mastery in a range of important cognitive skills (MOE, 2013) such as the students' ability to think critically in these subjects (Ffiseg and Bghymru, 2010). Therefore, students are expected to acquire critical thinking as the education systems of the 21st century aims to develop several characteristics among students, including high self-esteem, self-directed learning, active participation, citizenship concerns, self-development, internationalism of culture and identity, communication and media skills, and a sense of responsibility to nature, in order to ensure a sustainable tomorrow (MOE, 2013).

In Malaysia, Science is a combination of the three core subjects which are Biology, Physics and Chemistry (MOE, 2013; Tan, 1991). Based on the Secondary School Integrated Curriculum, better known as *Kurikulum Bersepadu Sekolah Menengah* (KBSM), Form 1 to Form 3 students (aged 13 to 15) learn Science at the introductory level. Form 4 and 5 students (aged 16 to 17) then choose to enrol in either the Science stream or Art stream (MOE, 2013). In the Science stream, they can learn Physics, Chemistry and Biology more deeply as separate subjects (MOE,2013). In particular, Physics education has been emphasised recently due to the government's intention to have more experts and professionals in science by the year 2020, in conjunction with Vision 2020 (MOE, 2013). As one of the STEM subjects, Physics shows lower enrolment at university level compared to Chemistry and Biology (Ffiseg and Bghymru, 2010; Sawtelle, Brewe, and Kramer, 2012). There is a vital need to explore the Physics curriculum, teachers' pedagogical approaches and students' thinking in order to produce students skilled for the 21st century.

Currently, ICT is being used widely in Malaysia in every aspect of life at work and at home. For teaching and learning, computer aided teaching has been practised by most teachers but is still not yet being used in the school laboratory. Computer-based experiments are an example of experiments that have used computers and probewares that minimize the time required for carrying out experiments and data collection. Such experiments have relevance to science teaching involving sophisticated apparatus (Dimian, Cojocariu, and Ursuleanu, 2012).

Meanwhile, some school laboratories are poorly functional and some of them do not have enough apparatus to ensure that all science students can do experiments. Time constraints also lead to fewer experiments being carried out. Therefore, a mobile laboratory 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 (Franzblau *et al.*, 2011), provide new pedagogical approaches to teachers, save costs in laboratory maintenance in the long term (Franzblau *et al.*, 2011) and enrich teachers' pedagogical skills (Erol *et al.*, 2012). Therefore, a study of how technology can be integrated by using ICT and mobile laboratories is a way to improve Physics education. Alongside, it is hoped that teachers and students can also benefit from this research.

There is a decline in the number of students in the science stream at secondary as well as tertiary level (Ffiseg and Bghymru, 2010; Sawtelle, Brewe, and Kramer, 2012; Carlone, 2003; Trumper, 2006; Kamisah, Zanatun and Lilia, 2007). Research has been carried out to identify factors underlying the decline in science enrolments, in order to promote student attachment to scientific and technological disciplines (Richardson, 2013), including Physics (Mujtaba and Reiss, 2012; Bøe and Henriksen, 2013). The Ministry of Education in Malaysia (MOE) has implemented a policy to increase the number of students in the science stream in upper secondary school. However, the 60:40 policy is yet not been achieved (Mohd Salleh *et al.*, 2012). 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 (MOE, 2013) who meet the qualities of human capital.

1.2 Background to the Problem

The role of science education is to produce scientifically literate citizens (Bahbah *et al.*, 2013), technicians and workers for science- and technology-based industry (Schreiner and Sjøberg, 2010). These objectives are unachievable when students face difficulties in science due to their levels of interest not being consistently high (Ainsley, 2012). The study by Ainsley (2012) shows that students who initially respond with high interest continue to express high interest at the end of the course. Students have interest in certain topics and end up losing interest in learning when they do not understand hard and abstract concepts (Stern and Hofer, 2016; Norlidah and Siraj, 2012; Zurida, Mohd Ali, and Ahmad Nurulazam, 2005). In addition, for Physics, students have difficulties in topics that use mathematical representation, abstract concepts, and they memorize more than understand the concept using other learning strategies. Students learn more in school in formal settings, and teaching and learning is the most suitable time allocated to teachers and students for use in a meaningful way. Generally, experiments constitute one strategy used in teaching and learning for secondary school. Students gain benefit while conducting experiments, such as by gaining a better understanding regarding a concept. The topic Forces and Motion involves the study of forces acting on objects, and is a classic study of mechanics. However, students claim that the topic is abstract, hard and rigorous (Carlone, 2003) which involves laws, theories and many mathematical formulas (Zurida, Mohd Ali and Ahmad Nurulazam, 2005). Some teachers do carry out fewer experiments due to the fact that some schools do not have enough apparatus (MOE, 2013), while some teachers tend to finish teaching all the syllabus topics on time, therefore, some students are unable to carry out experiments (Ojediran et al., 2014). Meanwhile, experiments carried out by the students are referred to as structured cookbook experiments (Bolte, Holbrook, and Rauch, 2012), referring to the reference books and text books provided in the Physics Curriculum Specification (Curriculum Development Centre, 2005). The students find that the use of experiments in developing Physics concept does not solve students' learning problems in Physics, especially concerning basic concepts that can be demonstrated by carrying out experiments using conventional teaching methods (Ojediran *et al.*, 2014). Conventional teaching methods in experimenting mainly tend to focus on low thinking skills among students such as remembering and understanding (Ojediran *et al.*, 2014). In addition, most teachers teach science by delivering facts and principles, while a minority of teachers apply teaching along with study skills, thinking skills and problem solving (Salmiza and Afiq, 2012).

Furthermore, teaching material and teaching practices that do not engage students in meaningful learning are not likely to give lasting positive results (Salmiza and Afiq, 2012). Besides, students' interest can be nurtured and consistently developed when they have the hands-on ability to carry out experiments and feel ownership in the construction of knowledge. Experiments are the most suitable way to cater to students' needs in learning. They involve hands-on manipulation of apparatus, critical and creative thinking, as well as reasoning. Since the experiments are important, there are problems in most schools laboratories. They do not have enough apparatus, and some of the equipment malfunctions. Moreover, the funds given by the Ministry of Education (MOE) are not enough to provide equally for all schools. Therefore, a mobile laboratory for science is a way to overcome the problem. This is called a Mobile Science Laboratory (MSL) at international level, and previous studies show that teachers and students both benefit from these laboratories (Franzblau *et al.,* 2011; Long *et at.,* 2012; Erol *et al.,* 2012).

1.2.1 Students' Interest in Physics

Interest in studying Physics is one of the key factors to be considered for engaging in Physics. Interest refers to a person's intrinsic motivation to do something, learn and explore a new set of skills and understand their potential; this will help them to gain good grades or privilege (Ryan and Deci, 2000; Krapp, 1999). Low interest among students lies in their perceptions of Physics itself. It is perceived as a boring (Williams *et al.,* 2003), irrelevant (Trumper, 2006), abstract (Norlidah and Siraj, 2012; Zurida, Mohd Ali, and Ahmad Nurulazam, 2005), difficult (Richardson, 2013; Angell *et al.,* 2004), and rigorous subject (Carlone, 2003). In order to promote interest, students can feel rewarded by doing an interesting task or activity that results in satisfaction (Ryan and Deci, 2000). In this context, secondary school students continue their studies in the discipline even though it is challenging for them. Therefore, the curriculum should be organised to promote students' interest in their learning context (Carlone, 2003) in a way that is relevant to current technology (Trumper, 2006). Achievement will improve as student interest increases because according to a study by Beier and Rittmayer (2008), there is a positive correlation between interest and achievement in Physics. Besides, teachers also have an important role in promoting an interest in science for students (Xu *et al.*, 2011). Besides, engagement and interest can be triggered when activities that are attractive, using sound and movement, can be used to trigger students' interest (Ainsley, 2012). Experiments which allow students to become active and move around are able to create more interest and engage them in learning.

1.2.2 Forces and Motion

According to *Kurikulum Bersepadu Sekolah Menengah* (KBSM) for Form 4, Physics consists of five topics (Curriculum Development Centre, 2005; 2012). These are Introduction to Physics, Forces and Motion, Forces and Pressure, Heat and Light. An investigation on secondary school students' use of the concept of force shows that it is 'hard' due to the way it is taught, and due to students' cognitive representations (MOE, 2008). Reports of the overall performance of the candidates show that students' understanding of facts and concepts in Physics was moderate in the topic of Forces and Motion (MOE, 2010; MOE, 2008) compared to other topics. Analysis from *TIMSS* in 2011 indicates that items related to Physics also showed Force and Motion was moderately understood among the Malysian students (MOE, 2013). The analysis referred to the *Sijil Pelajaran Malaysia* (SPM) Physics Paper 2 in the years 2008 and 2010. Furthermore, the topic covers twelve subtopics from Kinematics to Energy (Curriculum Development Centre, 2005) such that the syllabus takes time to complete.

A study by Turner (2005) states that kinematics becomes problematic for students because they have difficulties in connecting physical concepts to their corresponding representation, and in connecting the representations to the real world. Kinematics is usually represented by varied graphs of kinematics (position, velocity, or acceleration). Students have difficulties in interpreting how aspects of graphical representations (slope, intercept, or area under the graph) correspond to the physical concept (velocity, acceleration, or displacement). This is because students learn the concept in a discrete unit and not within their real life experience (Carlone, 2003), suggesting that concepts should be taught in a contextual way.

Carlone (2003) 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 (Hoffmann and

Ha, 1999). 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 Williams *et al.* (2003) 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.

1.2.3 Conventional experiments and computer-based experiments

The laboratory is necessary for learning science. Physics is the study of matter and natural events and most of them involve empirical observations and quantitative measurements (Ojediran *et al.,* 2014). A lot of experiments and activities can be carried out to enhance understanding in learning and interacting with laboratory apparatus (Dziabenko, Ordufia and Garcia-zubia, 2013), investigate the condition of matter, verify theories, enhance experimenting skills (Ojediran *et al.,* 2014; Sin, 2014), and make linkages between experimental observation and theoretical concepts, helping students to understand abstract concepts, and develop a cooperative and critical attitude towards Physics (Ojediran *et al.,* 2014).

Laboratory activities and experiments are the most central elements in learning Physics, so that students acquire concrete Physics concepts (MOE, 2008) and process skills in science (MOE, 2010). However, not all schools have the capacity to accommodate all appliances and provide enough opportunities to do experiments (Semela, 2010). Some materials are expensive and deteriorate as time goes by (Ojediran *et al.,* 2014). Besides, the government cannot supply all materials and apparatus throughout schools, some schools do not have certain usable expensive apparatus and some schools do not have the latest appliances in teaching science effectively, therefore the laboratories become malfunctioning school laboratories (UNESCO, 2013; MOE, 2013). These constraints contribute to difficulties in exploratory activity and so students lack experimenting skills (Ojediran *et al.,* 2014).

Conventional experiment instruction in the Physics laboratory is perceived as a difficult thing for students, as the Physicist already disseminates the content of knowledge, leading to misconceptions in introductory courses in Physics (Chambers, 2014). Computer-based experimentation is a strategy to connect real motion to its graphical representations using the microcomputer-based laboratory (MBL) (Turner, 2005). A study by Benson (2010) states that computers and Information and Communication Technology (ICT) play a potential role in transforming teaching and learning of science, and help students understand phenomena better by animations and visualizations of multiple representations. According to Trumper and Gelbman (2001) ICT becomes a laboratory data logger, and visualization and its ability to collect data in vast quantities, with high accuracy of measurements, eliminates the drudgery of the data and display, and provides students with easy access of different information. ICT lets students play an active role, reinforcing their conceptual learning of Physics concepts and developing their understanding of the science-technology relationship. ICT is attractive to a larger number of students and it attracts students' interest in learning. Time for learning is also shortened using MBL experiments (Zacharia and Constantinou, 2008). A recent study by Chambers (2014) shows that real-time data using computer-based experiments has a positive impact on students' conceptual understanding of motion.

Also, high performing students can engage in experiments that require a high level of thinking, and low performing students can be traced by the teacher based on their individual difficulties (Chambers, 2014). Another study by Chen *et al.* (2014) showed that students' scores on post tests were the lowest among three groups by using simulated-based laboratory (SBL). MBLs seem to promote the planning, implementation, and improvement of experiments, allowing data interpretation as shown by their performance using the lab manual. The responses to the lab manual revealed that MBL settings may inspire more ideas and more practical experimental designs. Therefore, incorporation of computer-based experiments in the laboratory can contribute a positive impact on students.

1.2.4 Microcomputer-based Laboratory (MBL)

Technology affects every aspect of daily life and Malaysia's education system has changed over the years, such that computers are used as an instructional tool in teaching and learning, integrating ICT by the end of 20th century (MOE, 2013). Numerous studies on the effects of technology in the classroom have been carried out since the 1980s, and high school classroom studies began in early 2000 (Venables, 2008). The integration of technology in education has been widely used since then (Chambers, 2014).

Computer applications have been used in teaching and learning in the classroom as a computer aid instruction. Currently, students are exposed to technology available at school and home, and the applications influence how knowledge and skills are applied in real-world tasks (Norlidah and Siraj, 2012). A study by Norlidah and Siraj (2012) shows how appropriate technology and learning styles increase achievement for active learners, reflective learners and visual learners.

MBL is a computer-based experiment in which experiments are conducted with the use of computers and software, connected with interface and probeware 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 (Redish *et al.,* 1997; PASCO, 2005). 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 (Redish *et al.*, 1997). It has been proven valuable for teachers as they do not have to prepare another test to evaluate student attainment in the lesson (Redish *et al.,* 1997).

Students use MBLs for experiments and data collection. They carry out data collection in a short time and display graphs. They can also compare results from various experiments, which takes less time than conventional measurement apparatus. There is also a spreadsheet where the data is arranged in a table and a sheet is provided to write notes or reports of experiments (PASCO, 2005). MBL is able to solve time constraints during learning in the laboratory, cultivate critical thinking and avoid misconceptions of Physics concepts (Tomshaw, 2006). Studies by Venables (2008) show that MBL has positive effects on students' learning with slightly higher achievement compared to the traditional laboratory. The mean achievement score for students using MBL also increases with the duration of the teacher's work experience. Hence, competent MBL teachers can increase students' achievement in conducting experiments.

In the Malaysian context, teaching and learning processes have improved in classroom and laboratory settings through the use of CD Courseware provided by the Malaysia Ministry of Education in 2003 as a teaching aid in Teaching and Learning of Science and Mathematics in English (PPSMI) (Mohd Salleh *et al.,* 2012). It uses simulations and video in an interactive way. As the students learn higher level concepts in Physics, they must possess experimenting skills, the ability to manipulate various experimental data, and solve problems in a creative and critical way. However, conventional laboratory instruction does not help students to elicit and portray higher order thinking skills (HOTS) in experiments. A study by Christiana *et al.* (2007) shows that MBL in learning instructions starting at a young age can lead to a significant improvement in conceptual understanding and the ability to plot graphs. As a suggestion, MBL in secondary school is suitable to improve students' learning at an early stage of introductory Physics, especially in Mechanics. Therefore, the MBL is one way for students to engaged with experiments and grasp Physics concepts clearly. However, due to its high cost and the lack of up to date software, MBL is not provided in secondary school (Tho and Baseri, 2011), as suggested by the National Report of TIMMS in 2011 (MOE, 2013).

1.2.5 Mobile Science Laboratory (MSL)

A mobile science laboratory (MSL) is a solution to provide equal access to pedagogies and facilities that support meaningful laboratory learning experiences for all students (Franzblau *et al.*, 2011). The MSL is a trailer or specialized bus replicated as a travelling laboratory (Long *et al.*, 2012; *Franzblau et al.*, 2011) and basically offers a service or off-the-shelf version (Erol *et al.*, 2012). The MSL was established in the United States of America in 1998 and since then was widely implemented in outreach activities in the United Kingdom, certain European countries, India, South Africa and other developing countries (Erol *et al.*, 2012).

The MSL was developed by universties such as the University of North Carolina, which established its own Travelling Science Laboratory named Destiny; Lab in a Lorry was developed by the Institute of Physics, London (Erol *et al.*, 2012). Other MSLs in the world are listed in Table 1.1. The MSL is equipped with advanced technology and techniques, instrumentation and teachers' training for using equipment and supplies (Franzblau *et al.*, 2011). It also provides a range of laboratory experiences that involve verifying established scientific knowledge and promoting thought-provoking inquiry for both teachers and students (Franzblau *et al.*, 2011). Hence, it promotes students' engagement, learning and high retention (Franzblau *et al.*, 2011).

In addition, students can do hands-on activities to develop their understanding. A study by Dimian, Cojocariu, and Ursuleanu (2012) shows that students can have better conceptual understanding using hands-on activities compared with only lectures, and can conduct a large number of experiments and measurements at a very low price. This will meet the lack of government funds and in the long run, students will benefit (Tatli and Ayas, 2013).

The time format for activities in the MSL is flexible for teachers, which they can supplement with the curriculum or regularly schedule as student investigation in field trip format (Franzblau *et al.,* 2011; Erol *et al.,* 2012). The activities involved are rich in pedagogical materials which creates meaningful science explorations for students, proven by the increased achievement in state-level tests (Franzblau *et al.,* 2011). In addition, teachers' perceptions towards MSL are positive, and their abilities in teaching science can be improved through MSL collaboration (Franzblau *et al.,* 2011; Erol *et al.,* 2012). MSL offers quality enrichment activities without the cost of taking students off-site and a large number of students can participate. Many students have been inspired to explore science as a career as a result of conducting experiments in the mobile laboratory (Franzblau *et al.,* 2011). In order to achieve improvements in students' engagement in Physics through using MSL, teachers are enriched with professional development workshops. These workshops provide an introduction to experiments and laboratory equipment and teachers' training using the modules provided.

A study by Erol *et al.* (2012) shows that the module, *Modular Mobile Education: Science Experiments* (MOBILIM), when used in MSL activities for teachers, has raised their pedagogical skills and encouraged them to do more experiments in lessons by 96.7%. A study by Long *et al.* (2012) shows that the ChemKits programme has provided 23,450 experiments for 33 high schools from the year 2002 to 2005 and 17 high schools from 2004 to 2005. The teachers are trained on how to use MSL and the module which is developed from previous innovative projects such as the Bristol ChemLabs, by Mobile Teaching Unit in the UK and other relevant experiments or activities.

In the Malaysian context, Universiti Sains Malaysia (USM) has developed the MSL, a solar-electrical generated van, under the Centre for Education, Training and Research in Renewable Energy and Energy Efficiency (CETREE) to increase public awareness regarding renewable energy and using energy efficiently by conducting competitions, displays, science activities for primary and secondary school students as well as research programmes at tertiary level (USM, 2013). However, specifically for

Physics education, less research has been carried out to enhance HOTS and conceptual understanding using MSL activities and experiments, teachers' pedagogical skills using modules in the MSL and its effect on increasing achievement in Physics.

Table 1.1: Some examples of MSLs around the world

MSL Project	Foundation
Destiny	University of North Carolina, USA
Lab in a Lorry	Institute of Physics, London, UK
SCI-FUN	University of Edinburgh, Scotland, UK
City Lab	Boston University, Boston, USA
Agastya	Agastya International Foundation, Gudivanka, India
Science on the Go	University of Illinois, USA
Helmsdale II	West London Floating Classroom Ltd., Middlesex, UK
GB4FUN	Radio Society of Great Britain, Bedford, UK
Bio Bus	CURE, Inc., Connecticut, USA
Vidnyanvahini	Dialogue and Action Group (DAG), Maharashtra, India
SERC's Mobile Ecology Lab	Smithsonian Environment Research Center, Maryland, USA
MOBILIM	University of Bozok, Turkey

Based on the MSL stated in Table 1.1 and current Physics learning context, most of the activities are displays, hands-on activities and experiments using advanced technology equipment in the laboratory. The approach of teachers to using MSL activities has proved to be successful in increasing students' engagement in learning science, providing opportunities to school with low budget supplies for advanced laboratory equipment and rural schools that have a minority of science students, increasing students' achievement as well as their deep understanding in content and process skills, and producing creative thinking skills during the process. Students gain different experiences and views of MSL learning as compared with conventional laboratory learning. In conclusion, Malaysia should study MSL as more developing countries are trying to cope with the problems of learning Physics.

For this research, the integration of MSL and MBL is seen to assist with Physics learning problems. MBL and MSL have proved to be effective in increasing students' achievement, students' interest through experiments and hands-on activities. Therefore, the intervention of the Mobile Computer-based Physics Laboratory (MCPL) is capable of meeting the needs of students with learning difficulties in Physics and enhances students' high thinking skills.

1.2.6 Teaching and Learning Module

Teachers lack an effective module for teaching and learning (Nik Syaharudin *et al.,* 2015; Norlidah and Siraj, 2012; Ojediran *et al.*, 2014). They are only given curriculum specifications which have learning objectives, learning outcomes, suggestion activities and a glossary. Excellent teachers have their own module for teaching and learning but novice teachers must plan and work according to the needs of students regardless of the number of students in class and level of understanding of students. Therefore, an effective module of teaching and learning is required to produce effective teaching and learning, and improve perceptions towards the Physics teacher (Ojediran *et al.,* 2014). For this research, a new module is developed in order to use computer-based experiments that guide the teachers and students to learn effectively.

Furthermore, time constraints become a factor in the process of learning Physics (Ojediran *et al.*, 2014). The syllabus and the teaching and learning process are not consistent with the time allocated (Rosnani, 2003). A study by Trumper (2006) suggested that allocating the appropriate time needed in teaching and learning is crucial for science learning. For better consequences, school teachers use mastery approaches in order to fulfil the objective of student learning, that is to pass examinations for low achievers, and score higher grades for high achievers. Teachers use lectures and rarely use other approaches during the teaching and learning process. Otherwise, there are a variety of teaching approaches as guidance for imparting knowledge. As Cottaar (2012) shows, variation in teaching has strong correlation with interest in regular Physics students.

Besides, learning strategies differ depending on teachers' personal approaches, and situations in the classroom. A study by Trumper (2006) shows that teachers who are familiar with didactic modes of teaching can attract students to learn Physics. Student-centred learning is one way to involve students more in classroom activity compared to one-way instruction that is teacher-centred.

Meanwhile, for student-centred learning strategies, students learn by doing, and by trying to understand how things work. From a scientist's point of view, students should investigate problems and draw a theory or solution (Sin, 2014) but for students, learning Physics is just about knowing the knowledge, and learning in structured and organized ways. Salmiza and Afiq's (2012) study suggests that 91.67% of student respondents use a formula method in solving a problem compared to 8.33% of respondents who use a formula method creatively. Therefore, teachers play an important role in arranging strategies of learning to utilise students' learning.

1.2.7 Students in Rural Areas, Experiential Learning and the Boarding School

The location of a school in an urban or rural area becomes an indicator of students' achievement in Physics. The laboratory in the urban school is complete with sophisticated apparatus which engages students' interest, whereas in rural areas, students do not have enough laboratory apparatus (Franzblau *et al.*, 2011). A study by Franzblau *et al.*, (2011) shows that the number of science students in rural areas are small and the students' sense of achievement is low. Another study in rural schools shows that teachers who lack training on particular subjects have low expectations of students, contributing to low achievement (Long *et al.*, 2012).

In Malaysia, the Ministry of Education (MOE) has developed Science Boarding Schools such as Sekolah Tunku Abdul Rahman, Sekolah Dato Abdul Razak, Sekolah Sultan Abdul Hamid, Sekolah Seri Puteri and Sekolah Tun Fatimah to increase the number of science students from rural areas, as suggested in Laporan Razak 1956 (Alimuddin, 2012). Students in Secondary Religious Schools (*Sekolah Menengah Kebangsaaan Agama*, SMKA) and MARA Science Junior College (*Maktab Rendah Sains* MARA, MRSM) are also encouraged to enrol in the science stream (Mohd Saleh *et al.,* 2012). The academic background for Boarding school students and regular National Secondary School (*Sekolah Menengah Kebangsaan*, SMK) differ since they are screened from Primary School Test results (*Ujian Penilaian Sekolah Rendah*, UPSR) and Lower Secondary School Test results (*Penilaian Menengah Rendah*, PMR). Excellent students in boarding schools are expected to fulfil the need for human capital in science, with an additional minority of science students in regular National Secondary School. As of April 2013, there are 68 boarding schools (MOE, 2014) and yet these schools have been unable to produce as many students in science as the ministry has intended (Alimuddin, 2012).

Students with different levels of achievement are affected differently by the technique of experiential learning. A previous study by Hamer (2014) investigated 158 students with either low, medium or high overall performance. They were tested on HOTS using semi-structured classroom activities. The findings showed that students had low overall performance in HOTS when taught via the conventional lecture format, while their performance increased using experiential learning. The study used semi-structured techniques because it required students to perform activities based on course concepts. The techniques were suitable for low and moderate overall performing students in learning, and low attention was given to high performance students. Therefore, different levels of performance were affected differently by experiential learning.

For both high and low achieving students, experiential learning resulted in better achievement at LOTS (low order thinking skills) and HOTS (higher order thinking skills) (Kiong *et al.*, 2012). A study by Obenchain and Ives (2006) used experiential learning in the study for measuring achievement at HOTS and LOTS. The findings showed that the experimental group gained better achievement in HOTS compared to control groups. However, for LOTS achievement, students in the control group performed significantly higher compared to the experimental group. Hence, research on experiential learning among students at different levels of performance can help determine the solution for the decreasing number of students in science and engineering at the tertiary level.

1.2.8 Students' Higher Order Thinking Skills (HOTS)

International assessments of the quality of education focus on many countries worldwide including Malaysia, with the main assessments including The Trends in International Mathematics and Science Study (TIMMS) and Programme for International Student Assessment (PISA) for 14 and 16 year old students accordingly. Malaysia was ranked below the international average in TIMMS in 2011, two fourfold up since 2009 due to low scores in TIMMS and PISA. It reflects the low achievement in higher order of thinking skills (HOTS) in Science and Mathematics. The same goes for the Malaysia Result of PISA in 2009 (MOE, 2013). Items in these assessments tested a variety of thinking skills, whereas assessments at national examination cover a limited mastery of scientific concepts (MOE, 2013).

The quality of secondary school education affects the progress of Physics students in university as shown by a study by Sadler and Tai (2000). Students with higher grades in examinations do not reflect the cognitive skills that they must possess. As students continue their studies for A-level or degrees, they have limited abilities in practising experimenting skills during laboratory practicals in universities. This is because they neglect the process of knowledge production and the implications of epistemology. Their difficulties are related to how Physics knowledge has come into being and achieved its validation (Sin, 2014). The students lack in the skills needed, especially the subject matter itself, because they pay too much attention to answering examination-based questions (Sadler and Tai, 2000). A study has shown that among 800,000 students who took Physics in high school, only half of them continue to college because they are unable to acquire science manipulative skills (Sadler and Tai, 2000).

Consequently, low thinking skills among secondary students produce low achievement in their tertiary learning. Thus, the call towards Physics should be viewed as the accumulation of coherent structures of concepts. Such perceptions can create students' beliefs and develop problem-solving skills with critical thinking, in order to have a strong knowledge structure (Sin, 2014). A study by Kiong *et al.* (2012) showed that students' thinking skills in Physics were poor. According to Krathwohl (2002), HOTS encompasses applying, analysing, evaluating and creating. Moreover, the Malaysia Curriculum Development Centre (2012) provides a conceptual framework which highlights critical and creative skills, and thinking strategies as a guidance for teachers. However, a study by Habibah *et al.* (2004) shows that creative thinking skills are moderately incorporated by teachers in their teaching in Malaysia. This may be because teachers are unfamiliar with the meaning of thinking skills and the convergent and divergent thinking required to develop HOTS in students (Habibah *et al.*, 2004).

According to the MOE (2013), HOTS refers to students' ability to apply knowledge, have value and skill in reasoning, and reflection in solving problems, making decisions, innovating, and the ability to be creative. Therefore, students must be critical, creative and innovative in becoming competent as 21st century human capital. Hence, teachers must be guided in teaching and learning strategies for the courses provided by the ministry which are still in the early stage of progress. Teachers must have deep understanding of content and pedagogy, and pedagogical change in classroom instruction in order to create HOTS students (Saravanan and Ponnusamy, 2011). For this research, a teaching and learning module by using computer-based Physics laboratory was developed to guide teachers and students to learn and to carry out experiments efficiently. HOTS questions were addressed in the module in order to get students' feedback from the questions. Teachers were not taught on how to deliver HOTS during teaching and learning. The research only accumulates HOTS questions and measures students' achievement at HOTS using questions only. Therefore, the use of computer-based experiment with integration of HOTS and experiential learning through the module can increase the students' higher thinking skills as well as their achievement and interest.

1.3 Problem Statement

The low enrolment in science at secondary and tertiary levels (Bøe and Henriksen, 2013; Mohd Salleh *et al.,* 2012; Mujtaba and Reiss, 2012) has been studied over the decades. It is caused by low interest in learning Physics under conventional teaching approaches (Richardson, 2013; Carlone, 2003) and a lack of effective learning modules for scientific skills in experimenting *(*Nik Syaharudin *et al.,* 2015, Ojediran *et al.,* 2014; Norlidah and Siraj, 2012*)*. Previous studies show that students in rural areas have low achievement (Long *et al.,* 2012; Carlone, 2003), teachers use lectures more than experiments since the laboratory often malfunctions (Ojediran *et al.,* 2014; Richardson, 2013; MOE, 2013; NFER, 2011) and less time is provided in carrying out experiments (Ojediran *et al.,* 2014; NFER, 2011). Apart from this, teachers lack effective teaching modules in Physics (Nik Syaharudin *et al.,* 2015; Norlidah and Siraj, 2012). Hence, most teachers use conventional pedagogical approaches in teaching scientific skills (Ojediran *et al.,* 2014; Richardson, 2013) and students carry out conventional experiments in the Physics laboratory (Chambers, 2014). Meanwhile, international assessments show that students are unable to achieve higher scores for HOTS items. Therefore, they have low levels of HOTS (MOE, 2013; Kiong *et al.,* 2012; Heong, Yunos and Hassan, 2011; Habibah *et al.*, 2004) as they were taught using teacher-centred approaches and oriented towards examinations. There appear to be no in-depth explanations for the effects of experiential learning on high achievers, or studies exploring different levels of achievement among students (Obenchain and Ives, 2006; Hamer, 2014).

Therefore, the Mobile Computer-based Physics Laboratory (MCPL) is seen as a suggested solution to the above problems. This research investigates students' level of interest in Physics and their achievement through a module developed using MBL and MSL for Forces and Motion. Students' and teachers' perceptions of the use of MCPL are investigated by exploring the effect of MCPL on students' conceptual understanding related to experiential learning, the effects of MCPL on students' interest and achievement, and achievement in HOTS due to the MCPL module.

1.4 Research Objectives

This study is carried out to

(i) develop a module for a MCPL teaching and learning experiment in the topic of Forces and Motion using Experiential Learning Theory
(ii) determine the level of students' interest in Physics before and after the use of MCPL
(iii) determine students' achievement levels in the topic of Forces and Motion before and after the use of MCPL
(iv) determine students' achievement in the topic of Forces and Motion on HOTS questions before and after the use of MCPL
(v) identify students' perceptions of MCPL
(vi) explore students' conceptual understanding using MCPL with experiential learning theory
(vii) explore students' perceptions of the MCPL learning module
(viii) explore teachers' perceptions of the MCPL teaching module
(ix) explore the impact of MCPL on students' interest in Forces and Motion
(x) explore the impact of MCPL on students' conceptual understanding of Forces and Motion
(xi) develop a framework of MCPL for teaching and learning Forces and Motion for Malaysian schools

1.5 Research Questions

This study is carried out to investigate;

(i) What are the contents that are suitable for the teaching and learning module using MCPL for the topic of Forces and Motion using Experiential Learning Theory?
(ii) What is the level of students' interest in Physics before the use of MCPL?
(iii) What is the level of students' interest in Physics after the use of MCPL?
(iv) Is there a significant difference in the level of students' interest in Physics before and after the use of MCPL?
(v) What is the achievement of students in the topic of Forces and Motion before the use of MCPL?
(vi) What is the achievement of students in the topic of Forces and Motion after the use of MCPL?
(vii) Is there a significant difference in students' achievement in the topic of Forces and Motion before and after the use of MCPL?
(viii) What is the achievement of students in the topic of Forces and Motion on HOTS questions before the use of MCPL?
(ix) What is the achievement of students in the topic of Forces and Motion on HOTS questions after the use of MCPL?
(x) Is there a significant difference in students' achievement in the topic of Forces and Motion on HOTS questions before and after the use of MCPL?
(xi) What are students' perceptions of the use of MCPL?
(xii) How does experiential learning help in the conceptual understanding of Physics using MCPL?
(xiii) How do students perceive the MCPL learning module?
(xiv) How do teachers perceive the MCPL teaching module?
(xv) How does MCPL influence students' interest in Physics?
(xvi) How does MCPL influence students' conceptual understanding of Forces and Motion?
(xvii) What is the framework of MCPL for teaching and learning Forces and Motion using Experiential Learning Theory in Malaysian schools?

1.6 Research Hypothesis

The hypotheses for the research questions are:

H_0: There is no significant difference in the pre-test level of students' interest and post-test level of students' interest using MCPL.

H_0: There is no significant difference in the pre- and post-test level of students' achievement in the topic of Forces and Motion using MCPL.

H_0: There is no significant difference in the pre- and post-test level of students' achievement in the topic of Forces and Motion on HOTS questions using MCPL.

1.7 Significance of the Study

Malaysia's education policy has been revised and published via the Malaysia National Blueprint Year 2013-2025. The MCPL approach can have an enormous impact on Physics teachers in their teaching pedagogies and students to narrow the infrastructure gap between the diverse backgrounds of students, reducing the achievement gap in HOTS among students with supportive experiments using advanced technology. Hence, our future generation of scientists and engineers can fulfil the nation's vision successfully.

Students are the human capital required to fulfil a nation's vision and teachers are the vital agents for producing quality education, moving towards other developed and industrialized countries. They must have the skills required to meet the needs of future 21st century technology (MOE, 2013), whereby the education system stands out as other successful education systems in developed countries. This research is a call to ensure that students are instilled with motivation, strong academic achievement as well as HOTS. The MCPL intervention in Physics education is able to produce more competent teachers with the use of current technology in assisting pedagogical approaches in the laboratory and helping students to learn better. With guidance and proven competent skills, it is hoped that teachers will apply them without hesitation. The MCPL offers advanced technology instrumentation so that more experiments can be carried out compared to conventional experimental approaches. The use of probeware such as sensors helps students carry out experiments without excess workload in accumulating data, tabulating data and creating graphs. The use of computer-based experiments saves time and allows more investigation. Teaching and learning sessions can be more student-centred, and inquiry and discovery can be carried out by students where the teacher facilitates them. MCPL is rooted in inquiry-based learning, and engages students in experience-based learning. When students conduct various experiments, they grasp the activities and relate them to their own experience. This can help them understand phenomena relevant to life and retain knowledge for longer periods.

MCPL consists of MSL and MBL. It is proven that MSL can increase students' achievement and teacher's pedagogical skills, as well as helping to cope with low funds and the problem of school supplies in secondary school laboratories (Erol *et al.*, 2012; Long *et al.*, 2012; Franzblau *et al.*, 2011). In addition, the use of MBL in experiments enables students to understand concepts from the specific to the more abstract and general, helping students collaborate with each other, actively engage in exploring and constructing their own knowledge. Moreover, it is a powerful tool in reducing drudgery. Therefore, when experiments are integrated in teaching and learning, this can be as important as other teaching strategies, whereby learning can be fun with scientific investigation, shortening the time spent on the topic and focusing on experiential learning.

MCPL is developed with a mobile laboratory named Physics on the Go (PoTGo) which functions as a transporter for laboratory apparatus and advanced tools from PASCO. It is able to supply electricity to run laptops and PASCO tools. It was funded and built for this research study and it has already been beneficial to students as it reaches schools for learning. For instance, experiments carried out in the laboratory create higher interest, positive perceptions toward the use of probes and students engage themselves in doing more investigation. The State Education Department can gain positive impact by ensuring that the quality of advanced apparatus in the MCPL relates to students' conceptual understandings, inculcating interest in science from primary and lower secondary school students. There is no doubt that most teachers find that the use of computer-based experiments in teaching and learning can solve time constraints.

In addition, the application of this research involves the MCPL framework that can help teaching and learning by the teachers, and help students learn by using the MCPL modules. The students can gain achievement and interest and therefore, the learning can be meaningful. Teachers as facilitators ensure authentic learning for students and the students execute the experiment by themselves. Apart from this, HOTS questions were constructed in the module to ensure that they are exposed to higher level thinking using questions that they need to take into consideration based on the experiment. Their answer reflects the concept that they have when they carry out experiments, think about possible outcomes and make applications in different situations using the same concepts.

1.8 Theoretical Framework

This research focusses on the importance of experiments in learning Forces and Motion by using advanced apparatus from MSL. The experience of using the apparatus and carrying out experiments by themselves provides a meaningful learning experience as well as improving memory retention and restructuring their conceptual understanding. The students can also examine their conceptual understanding and HOTS in the research. The students' interest also was investigated in depth on how they perceived learning through the research. Theories related to experience were Constructivism (Piaget, 1976), Social Constructivism (Vygotsky, 1978), Experiential Learning (Kolb, 1984) and Situated Learning (Lave and Wenger, 1991). Constructivism Theory (Piaget, 1976) was a paradigm that posits that learning is an active process. People actively construct and create their knowledge which started with prior knowledge to subjective mental representations. Then, social constructivism by Vygotsky emerged to emphasize the collaborative nature of learning. Peer instruction was focussed during learning (Vygotsky, 1978). Meanwhile, the Situated Learning Theory emphasized that learning occurs when the learners are embedded with activity, context and encompassing culture discourses. Learning occurs when the learner is involved in an activity within a context and becomes a full participant in sociocultural practises. Therefore, the theory supported the students learning viewed by the researcher as a learner, individually was Experiential Learning Theory (Kolb, 1984). Based on the research problem, Experiential Learning Theory was chosen as a theoretical framework since the paradigm of the researcher that students should be seen as a whole.

Therefore, the conceptual understanding and interest of students were investigated. Theories related to human motivation were Need-based Theory (Maslow, 1943), Expectancy-valence Theory (Vroom, 1964) and Self-determination Theory (Ryan and Deci, 2000). The Need-based Theory by Maslow was represented by a hierarchical pyramid that represents the most fundamental needs as physiological needs and the highest needs as self-actualization. Then, Expectancy-valence Theory by Vroom emphasized that whether the individual puts fourth more or less effort is determined by rational calculation made by the individual's evaluation of situations. Individuals have an expectancy of returns for the efforts invested, such as reward. Next, the valence theory refers to the value of reward that the individual would get. This was anticipated with the reward itself. Another theory, the Self-determination Theory by Ryan and Deci, emphasized intrinsic and extrinsic motivation by an individual to do work or task. As intrinsic motivation was explored further, the intention of the research was aligned to determine interest in learning by using advanced apparatus. Therefore, the theory chosen to determine students' interest was Self-determination Theory (Ryan and Deci, 2000).

Therefore, theories underpinning the research are Experiential Learning Theory (Kolb, 1984), Self-determination Theory (Ryan and Deci, 2000) and Revised Bloom's Taxonomy (Krathwohl, 2002). Experiential learning has its intellectual origins in the works of Dewey, Lewin and Piaget. It emphasizes the central role that experience plays in the learning process (Kolb, 1984). Based on the Lewinian Model of Action Research and Laboratory Training, the integration of action research and experience from laboratory methods produces a modification in learners' behaviour and their choices from new experiences. According to Dewey's Model of Learning, experience and education are two different things, because some experiences provide the wrong kind of education. Hence, reflective thought is needed to assist learners in determining the learning that can be drawn from educational experience (Kolb, 1984).

The model of learning stresses on transforming the impulses, feelings and desired concrete experience into a higher order purposeful action. According to Piaget's model of learning, children reorganize perceptions through the process of assimilation and accommodation to make sense of their world (Kolb, 1984). Their learning moves from a concrete phenomenal view of the world to an abstract constructionist view, from an active egocentric view to a reflective internalized mode of knowing (Kolb, 1984).

Experiential Learning Theory is defined as a holistic integrative perspective on learning that combines a continuous process of experience, cognition and behaviour. It involves grasping and transforming the experience into a learning process. Reflection is the final thought in making sense of the situation (Kolb, 1984; Kolb, 2009). Experiential learning theory consists of four stages of the learning cycle:

concrete experience (CE), reflective observation (RO), abstract conceptualization (AC) and active experimentation (AE) (Kolb, 1984).

Two aspects in truly experiential learning are (a) engagement of the learner and the phenomena related to the study and (b) reflection upon the experience, analysing it and learning from it (Hedin, 2010). Methods that suit experiential education are internships, apprenticeships, work or study programs, cooperative education, outdoor education, studio arts, laboratory studies and field projects (Hedin, 2010). According to Clark, Threeton, and Ewing (2010), Kolb's learning styles in Experiential Learning Theory have been developed into the Learning Style Inventory (LSI) to analyse individuals' understanding of the process of learning from experience and the uniqueness of the individual in learning. Figure 1.1 shows the experiential learning cycle (Kolb, 2009) that emphasizes grasping experience which dialectically relates to Concrete Experience and Abstract Conceptualization, and the transformation that takes place dialectically relates to Reflective Observation and Active Experimentation.

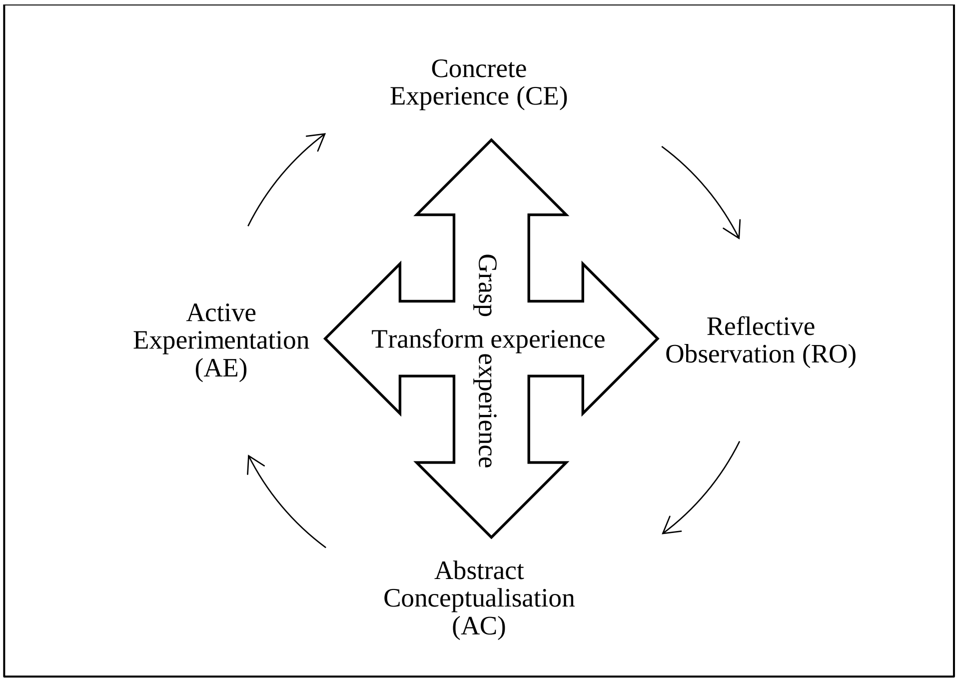

Figure 1.1 Experiential Learning Theory (Kolb, 2009; Kolb, 1984)

Previous studies on the use of experiential learning show significantly better achievement compared to lecture-based teaching for different levels of achievement (Hamer, 2014; Obenchain and Ives, 2006). Experiential learning has been used in science research (Perlman, 2013) but there is less research on Physics students who have different levels of achievement. Therefore, experiential learning is suitable as a learning environment whereby learning using the MCPL module was developed according to the Experiential Learning Cycle (Kolb, 1984) with a cognition process of experiencing, reflective observation, abstract conceptualization and active experimentation. Based on Hamer (2014), experiential learning has been used in the discipline of science and corroborated with real world experience. It has been proven able to increase instructor and students' interest, students' performance, enjoyment in enhancing learning and increased perceived value of the learning experience. For this research, experiential learning is suitable to provide enjoyment and students' interest by coping with students' learning difficulties. Students' interest and their perception have been important in teaching and learning. Therefore, their motivation can be seen from their experience of the value given to learning.

According to Self-determination Theory (Ryan and Deci, 2000), motivation is varied for people with different levels of motivation and orientation. The orientation of motivation is the concern that moves a person to do work or an action. For a student, he or she does homework because of curiosity and interest. Curiosity and interest shows the willingness to learn a new set of skills which are also developed due to joy and interest (Ryan and Deci, 2000).

Based on Self-Determination Theory, motivation is divided into three types. Motivation can be autonomous motivation, controlled motivation and goal motivation. Autonomous motivation primarily involves high intrinsic motivation which one controls oneself. For the individual, it is important, especially among students, to learn new things using varied advanced technologies with high interest and consistently have high motivation. For this research, autonomous motivation is the main focus since students' interest is affected by intrinsic and extrinsic motivation. Interest is a subjective criterion with specific meaning for intrinsic learning – motivation which is associated with self-intentionality for a person (Krapp, 1999).

In addition, students' higher thinking skills were investigated under Revised Bloom's Taxonomy (Krathwohl, 2002). Bloom's taxonomy of learning was originally developed in the year 1956 by Benjamin S. Bloom, and comprises low thinking skills (knowledge, comprehension), medium thinking skills (application, analysis) and high thinking skills (synthesis and evaluation) (Krathwohl, 2002). The framework is cited and translated for almost 22 countries. The Revised Bloom's Taxonomy was created by Krathwohl (2002) with two dimensions. The first is the knowledge dimension and the second is the cognitive process. Figure 1.2 shows the cognitive and knowledge dimensions of the Revised Taxonomy. In this research, students were analysed on their ability at Applying and Analyzing (under the knowledge dimension), which involves students carrying out experiments and distinguishing relevant from irrelevant parts (Anderson *et al.*, 2001), while conceptual understanding was also analysed (under the cognitive dimension). Each dimension is elaborated from lower order thinking skills (LOTS) to higher order thinking skills (HOTS). HOTS students are expected to able to evaluate and creatively solve problems based on their awareness of their own reflective thinking and their extent of knowledge.

In the Malaysian context, HOTS refers to the top four levels of Revised Bloom's Taxonomy, which are applying, analysing, evaluating and creating (MOE, 2013). Based on these theories, students are encouraged to learn Physics with motivation which is cultivated by the MCPL experiments and activities. The laboratory experience can increase their interest to a consistent level, creating higher curiosity and engaging higher order thinking skills (HOTS). There is a positive relationship between interest and experiences, learning as a person does work or study (Boswell, 2013).

Higher order thinking skills (HOTS)		
Cognitive Dimension *(verbs)*	↑	Knowledge Dimension *(definitions)*
Creating *(designing, generating, inventing)*		Metacognitive *(awareness of own cognition; strategic or reflective knowledge of how to solve problems; contextual knowledge; knowledge of self)*
Evaluating *(accessing, checking, critiquing)*		
Analysing *(distinguishing, differentiating, attributing)*		Procedural *(Ability to do something specific; methods of inquiry; specific skills, techniques, methodologies)*
Applying *(executing, implementing)*		Conceptual *(classifications, principles, theories, models, structures)*
Understanding *(classifying, summarizing, inferring, comparing, explaining)*		
Remembering *(recognizing, recalling)*		Factual *(essential facts, terminology, elements)*
Lower Order Thinking Skills (LOTS)		

Figure 1.2 The Cognitive and Knowledge Dimensions of the Revised Taxonomy (Krathwohl, 2002)

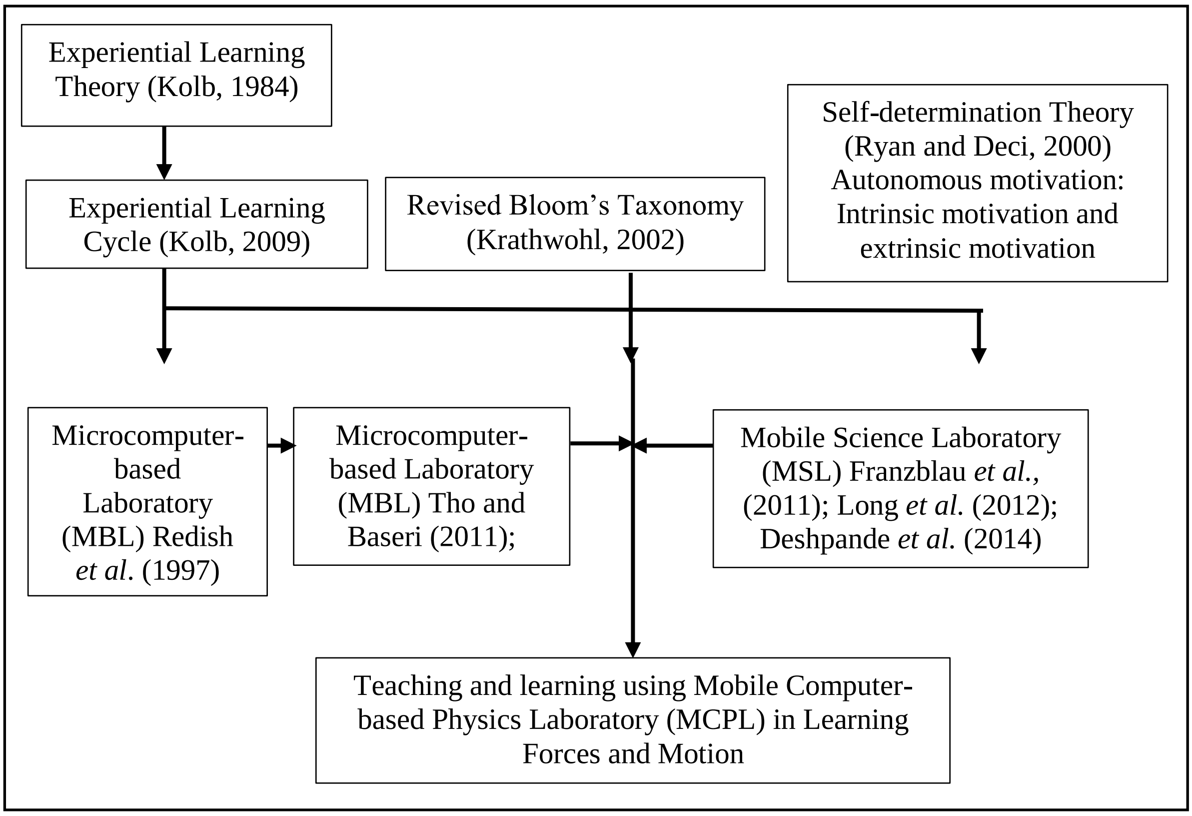

Figure 1.3 Theoretical framework

Figure 1.3 shows the theoretical framework used in the research, based on Experiential Learning Theory (Kolb, 1984). The framework is used to provide experience-based learning for students who can use computer-based experimentation to develop their understanding of the subject matter, and Revised Blooms' Taxonomy is used to explore the relationship with different HOTS that can be developed and nurtured using experience-based learning in experimentation. Students' interests are also investigated to measure the level of their interest towards MCPL.

Apart from this, students' achievement and perceptions are measured as they are important variables in investigating the impact of the research. Therefore, MCPL can contribute to self-development for students in achievement, so that they can equip themselves for 21st century challenges, and so that teachers can use experiments for effective teaching and learning strategies (MOE, 2013; Preus, 2012).

1.9 Conceptual Framework

Based on the theoretical framework discussed above, the variables investigated in this study were students' interest, students' perceptions, module and how students' achievements relate to Experiential Learning Theory (Kolb, 1984). All variables that were supported by the Experiential Learning Theory, were integrated accordingly. MCPL and the related experiments involved activities that can have an effect on students' interest and achievement in HOTS used in Forces and Motion. Perceptions of MCPL were also analysed in order to explore its impact on students and teachers. Meanwhile, teachers can use MCPL teaching module with their regular teaching. The MCPL framework was constructed to guide teachers and students to have better achievement and interest in Forces and Motion. The independent variables were the Form 4 students. Dependent variables were interest, achievement, achievement at HOTS and perception. Figure 1.4 shows the conceptual framework of the study that shows how MCPL was designed in the research. The researcher as an instructor helped the students by assisting them in carrying out experiments while the teacher monitored the students and guide them along the intervention process.

Currently, the routine experiments carried out in schools with prepared procedures do not improve students' understanding and achievement in Physics (Ojediran *et al.,* 2014). Therefore, students need to explore experiments with guided instruction as well as by eliciting their higher order thinking skills (HOTS). Students need to learn with their own willingness, and such learning in active experimentation contributes to better conceptual understanding (Ryan and Deci, 2000). Therefore, students with little or zero background of the subject matter of science can have the interest to explore scientific learning (Ojediran *et al.,* 2014; Chambers, 2014).

The laboratory provides the tools needed to help transform abstract knowledge into clear comprehensible knowledge. Conceptual understanding is a level of knowledge that can be achieved by the learner. Achievement is the benchmark of conceptual understanding of knowledge for students. Hence, grasping knowledge during learning is important to increase achievement and interest in exploring science. In this research, the MCPL intervention helped the teachers enhance the content of their knowledge in experimenting skills and doing science, helping them to convey knowledge and strengthen theoretical learning (Salmiza and Afiq, 2012) as well as time management (Carlone, 2003). Teachers experience time constraints (Ojediran *et al.,* 2014) and the call for computer-based experiments is better in this regard than in conventional laboratories (Chambers, 2014). Previously, experiments carried out by students would help verify theories by referring to a manual as a structured cookbook (Ojediran *et al.*, 2014). Therefore, the MCPL enables the teaching and learning process in a non-traditional way, giving an opportunity to students to achieve HOTS. It also saves cost in the long run as the completed laboratory with advanced apparatus such as PASCO and computers involve high costs. Students gain benefits such as increasing exposure to concrete concepts, and they pursue science in tertiary education with deep understanding.

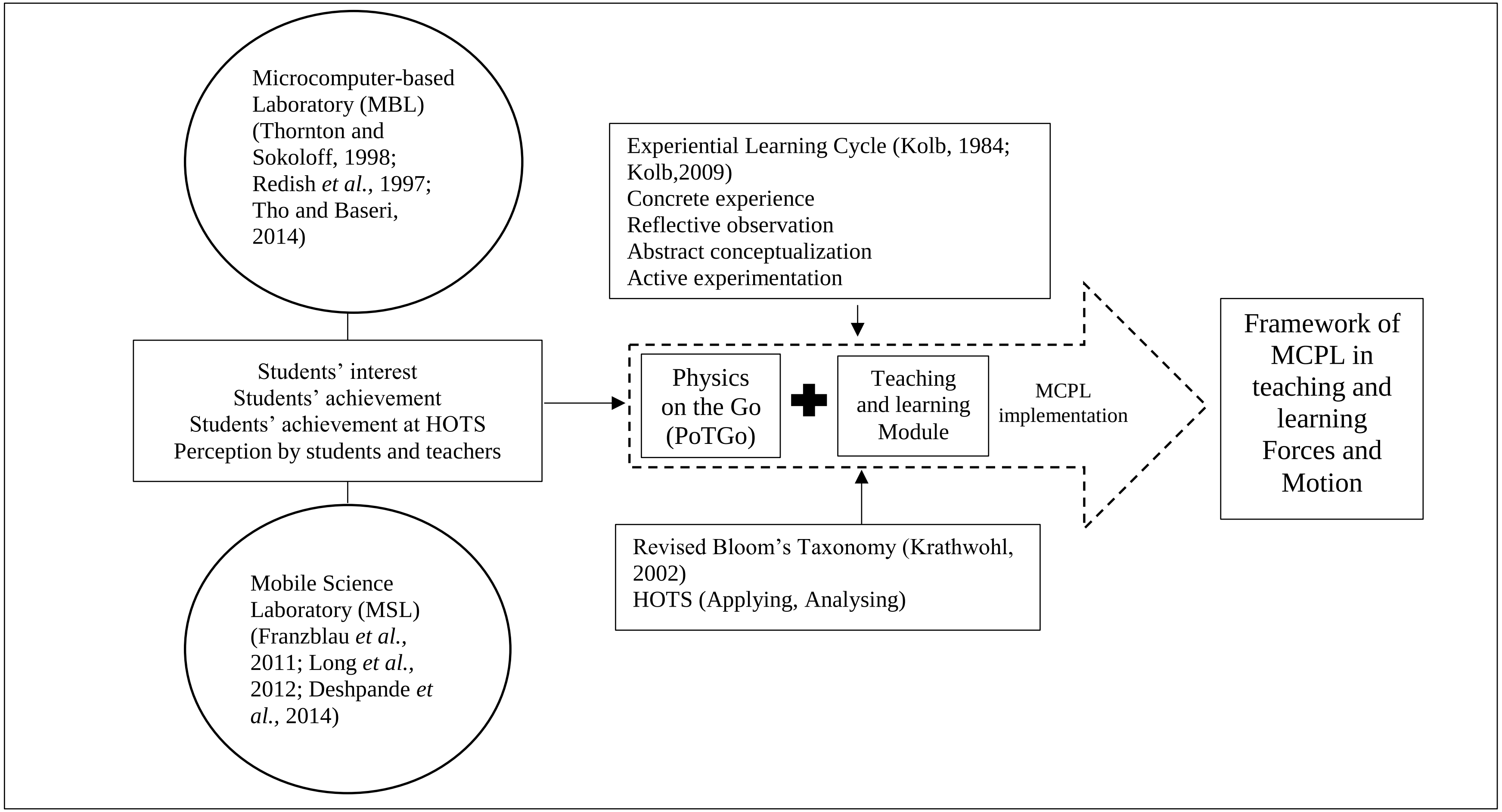

Figure 1.4 Conceptual framework

1.10 Operational Definitions

The following section contains terms used within the context of the study. These operational definitions are provided for the reader to fully understand the terminology utilized in this study.

1.10.1 Interest

Interest refers to the intrinsic learning-motivation which is associated with learning a task, and an individual's object of interest contributes to their self-intentionality (Krapp, 1999). It is a motivation which is discussed under Self-determination theory by Ryan and Deci (2000). In this study, interest is measured as a dependent variable, emphasizing situational interest in learning outcomes due to the 'interestingness' of an object. Within this study, the first step is a stimulus, then interaction of the students with the object, and finally the rating of 'interestingness' and performance is determined (Krapp, 1999).

1.10.2 Achievement

Achievement refers to the score that is achieved by students. For this research, achievement also represents students' conceptual understanding obtained in a test. The test referred to in the study is Force and Motion Conceptual Evaluation (FMCE), adapted from Thornton and Sokoloff (1998).

1.10.3 Achievement of HOTS

Achievement in HOTS refers to the score obtained by students and for this study, questions in HOTS is verified as analysis level based on the Revised Blooms' Taxonomy (Krathwohl, 2002) and the test used is adapted from the FMCE of Thornton and Sokoloff (1998).

1.10.4 Perception

Action involves reasoning and evaluating using subjective processes in the mind, relative to sensory perception such as observation, hearing, touch, experience, reading or prior experience (stimulation), registration (selected stimuli), organization (based on selected prior experience) or interpretation (analyze and understand based on prior experience). It affects behaviour, communication and the feelings of a person, and what the person interprets or perceives may be substantially different from reality (Pickens, 2005). In this research, perception is evaluated for internal attribution which reflects causality to factors within the person.

1.10.5 Teaching and Learning Module

A unit of teaching and learning discusses certain topics systematically, and is connected continuously as it is easier for a novice student to learn on his or her own, without the teacher being around in order to grasp particular units of learning content easily and precisely (Sidek and Jamaludin, 2005). This research uses a module of teaching and learning using the MCPL for secondary school laboratory science experiments. The experiments conducted by the teachers and the students use PASCO products (PASCO Scientific, 1999).

1.10.6 Forces and Motion

The subject-matter consists of linear motion (in 1-dimension, 1D), motion graph, inertia, momentum, effect of forces, impulse, gravity, motion (in 2-dimension, 2D) forces in equilibrium, work, energy, and elasticity (MOE, 2005).

1.10.7 Microcomputer-Based Laboratory (MBL)

Experiments are carried out using computer technology for practical experience and learning theory content. It helps students to grasp the essence of the depth and nature of experience and knowledge of the subject matter, and it fulfils the training needs of modern engineering talent (Redish *et al.*, 1997; Shiming and Bin, 2014). PASCO is a product that consists of probeware, data logging software called Data Studio which is a data collection and analysis software for advanced physics and engineering**.** The probeware included is Motion Sensor and Photogate which measures positions, velocity and acceleration of a target, and the interface used is The PASPORT Interface. The apparatus provided by PASCO products can analyse Mechanics from basic Kinematics work and energy concepts. Forces and Motion can be explored using the PASCO apparatus (PASCO Scientific, 1999).

1.10.8 Mobile Science Laboratory (MSL)

MSL is a travelling lab that offers off-the-shelf versions (Agastya International Foundation, 2014b). It is equipped with advanced technology and techniques, instrumentation and teachers' training of using the equipment and supplies (Erol *et al.*, 2012; Franzblau *et al.*, 2011; Agastya International Foundation, 2014b) and it is proven to be able to increase students' achievement in the state level test (Franzblau *et al.*, 2011). For the research, the Physics on the Go (PoTGo) is a mobile lab that serves to transport the PASCO and features that are cost effective and scalable.

1.10.9 The Mobile Computer-Based Physics Laboratory (MCPL)

MCPL involves an integration of MSL and MBL. MSL is a trailer or specialized bus replicated as a travelling laboratory (Long *et al.*, 2012; Franzblau *et al.*, 2011) and it is offered as a service or off-the-shelf version (Erol *et al*., 2012). It is accomplished with a module on teaching Physics for teachers, and activities as well as experiments to enhance creative and critical thinking skills among students (Franzblau *et al.*, 2011). The module is accomplished with PASCO products for data collection and interpreting data (PASCO Scientific, 1999).

1.10.10 Learning

Learning in the research refers to students learning by conducting experiments on the topic Force and Motion within an environment of experientce-based learning. The experiential learning theory by Kolb (1984) consists of four modes; concrete experience, reflective observation, abstract conceptualization and active experimentation. The process of learning involves the use of the MCPL Learning Module. The learning outcome is assessed from students' interest, achievement, achievement at HOTS and perception towards MCPL.

1.10.11 Impact

According to the OECD (2002), impact refers to positive and negative, primary and secondary long-term effects produced by a development intervention, directly or indirectly, intended or unintended. According to Hearn and Buffardi (2016), there are six dimensions in the measurement of impact; application, scope, subject and level of change, degrees of separation and immediacy, rate and durability of change and homogeneity of benefits. In the case of this research, impact refers to positive and negative effects, primary effects produced by the MCPL intervention directly, as intended with dimensions of the application. It encompasses projection (changes to subjects' achievement, interest and perception), prospective (researcher controlled threats) and retrospective (evaluation designed and conducted at the end of the intervention).

1.11 Conclusion

Factors affecting Physics learning problems include low interest under conventional teaching and laboratory instruction, the lack of effective modules, and teaching strategies that are more teacher-centred, which leads to rote learning and poor understanding of concepts. Teachers find that time constraints in teaching Forces and Motion lead to less experiments being conducted among students in the laboratory. Meanwhile, the lack of apparatus and laboratory malfunction give students no opportunity to carry out experiments hands-on. By analysing these factors, this research develops a teaching and learning strategy outside the conventional laboratory and at the same time generates a variety of hands-on experiments to elicit among HOTS students.

The next chapter discusses previous studies in further detail. As a conclusion, research on students' learning in Physics and science in general are vital to produce a competent future generation of human capital with expertise in science to serve the 21st century nation's development and beyond.

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