DEVELOPMENT OF TASKS AND RUBRICS TO MEASURE PHYSICS PRACTICAL SKILLS OF FORM FOUR STUDENTS USING DIRECT OBSERVATION AND WRITTEN TEST

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UNIVERSITI SAINS MALAYSIA

2017

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by

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Thesis submitted in fulfilment of the requirement
for the degree of
Doctor of Philosophy

July 2017

ACKNOWLEDGEMENT

I would like to address my gratitude to all the professionals, individuals, groups, and organisations whom had assisted and guided me in making this thesis possible. First of all, a very big thank you to the Ministry of Education of Malaysia for awarding me the scholarship that enables me to pursue my PhD degree. My journey towards a doctorate degree would have been much more challenging without thier financial support.

Next, I would like to thank my supervisors, Dr. Lim Hooi Lian and Dr. Salmiza Saleh who had guided me patiently along my academic journey. I also address great appreciation and thanks to Dr. Ong Saw Lan whom had retired from her service but continued to assist and advise me in my study. Without their professional advices, my thesis can never be a success. I thank all the lecturers and staff of School of Educational Studies, Universiti Sains Malaysia, as well, for their patient assistance and guidance during my days in the institution.

Then, I would like to address my appreciation to the officers of various education departments for their cooperation in providing me the ease of access to schools for data collection. Thank you as well to all my colleagues, teachers and students whom had given me full support and cooperation in the period of my study.

Last but not least, I address my greatfulness to my friends and family. Thank you to my friends and comrades along my academic journey, who have selflessly gave me motivation and encouragement to complete my study and produce this thesis. Without their company, the journey would have been much tougher. Thank you to my family members whom had given me full support during the process of my study so that I can move ahead on the road towards success in my study with no worries.

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LIST OF ABBREVIATIONS

AVE	Average Variance Extracted
CDD	Curriculum Development Division
CVI	Content Validity Index
CVR	Content Validity Ratio
DSP	*Dokumen Standard Prestasi* (Standard Performance Document)
GC	*Guru Cemerlang* (Expert Teacher)
KBSM	*Kurikulum Bersepadu Sekolah Menengah* (Integrated Curriculum for Secondary School)
KBSR	*Kurikulum Bersepadu Sekolah Rendah* (Integrated Curriculum for Primary School)
KSSR	*Kurikulum Standard Sekolah Rendah* (Standard Curriculum for Primary School)
MCQ	Multiple Choices Question
MEB	Malaysian Education Blueprint
MES	Malaysian Examination Syndicate
MNSQ	Mean Square
MOE	Ministry of Education
NRC	National Research Council
PCA	Principal Component Analysis
PEKA	*Pentaksiran Kerja Amali* (Practical Work Assessment)
PISA	Programme for International Student Assessment
PLS-SEM	Partial Least Square – Structural Equation Modelling
PMR	*Penilaian Menengah Rendah* (Lower Secondary Examination)
PT3	*Pentaksiran Tingkatan* 3 (Form 3 Assessment)
PT-MC	Point Measure Correlation
RPCA	Rasch Principal Component Analysis
SPM	*Sijil Pelajaran Malaysia* (Malaysian Certificate of Education)
SPSS	Statistical Packages for Social Sciences
TIMSS	Trends in International Mathematics and Science Study
UPSR	*Ujian Pencapaian Sekolah Rendah* (Primary School Achievement Test)

LIST OF APPENDICES

PEMBANGUNAN TUGASAN DAN RUBRIK UNTUK MENGUKUR KEMAHIRAN AMALI FIZIK PELAJAR TINGKATAN EMPAT MENGGUNAKAN PEMERHATIAN DAN UJIAN BERTULIS

ABSTRAK

Penggunaan kerja amali dalam pengajaran fizik boleh meningkatkan pemahaman pelajar terhadap konsep dan teori fizik yang abstrak. Pelajar perlu menguasai kemahiran amali supaya kerja amali yang dilakukan memanfaatkan mereka dalam pembelajaran. Di Malaysia, kemahiran amali pelajar ditaksir melalui pentaksiran berasaskan sekolah dan ujian bertulis yang mementingkan evidens secara bertulis. Namun, tiada suatu garis panduan yang khusus untuk pentaksiran kemahiran amali fizik sedangkan kemahiran amali seharusnya ditaksir dalam keadaan sebenar di mana kerja amali dilakukan. Kajian ini mencadangkan dua mod pentaksiran yang berbeza, iaitu pemerhatian dan ujian bertulis, untuk mengukur kemahiran amali fizik pelajar memandangkan kemahiran amali terdiri daripada pelbagai dimensi. Satu kaedah pentaksiran sahaja adalah kurang komprehensif untuk menentukan keupayaan pelajar dalam menjalankan kerja amali. Dalam kajian ini, kemahiran amali fizik dikategorikan kepada empat domain iaitu Perancangan, Pelaksanaan, Analisis dan Penilaian. Tugasan amali dan rubrik pemarkahan dibangunkan berasaskan model hipotetikal-diduktif untuk mengukur kemahiran amali fizik pelajar menggunakan mod pemerhatian. Ujian bertulis dibangunkan sebagai mod pentaksiran yang kedua. Kesahan dan kebolehpercayaan instrumen yang dibangunkan disemak dengan pelbagai cara dan didapati bahawa instrumen tersebut menunjukkan kesahan kandungan, kesahan konstruk dan kebolehpercayaan yang memuaskan. Instrumen ini ditadbir kepada 153 orang pelajar Tingkatan Empat dari 10 buah sekolah menengah di bahagian Kuching, Sarawak. Dapatan kajian menunjukkan bahawa korelasi adalah lemah antara dua mod pentaksiran. Pengusasaan kemahiran amali fizik pelajar adalah pada tahap sederhana. Pencapaian pelajar adalah berbeza dalam tugasan yang berbeza dan juga domain yang berbeza. Kajian ini memberi pendedahan tentang kemungkinan untuk mengaplikasikan kepelbagaian kaedah pentaksiran untuk mengukur kemahiran amali pelajar dan boleh dijadikan asas dalam kajian masa depan supaya mempertingkatkan penguasaan kemahiran amali fizik dalam kalangan pelajar sekolah menengah.

DEVELOPMENT OF TASKS AND RUBRICS TO MEASURE PHYSICS PRACTICAL SKILLS OF FORM FOUR STUDENTS USING DIRECT OBSERVATION AND WRITTEN TEST

ABSTRACT

Utilising practical work in physics learning can enhance students' understanding of abstract concepts and theories. Students need to have good mastery of practical skills so that practical work is effective in enhancing learning. In Malaysia, students' practical skills are assessed through school based assessment and written test, which emphasize on the written work produced by students. However, there is no specific guideline to assess physics practical skills which should be assessed in the actual setting where practical work is being carried out. This study suggests two different modes of assessment, direct observation and written test, to be used in measuring students' physics practical skills because practical skills are multidimensional and single method cannot provide comprehensive information on the ability of students in performing practical work. In this study, physics practical skills are grouped into the domains of Design, Execution, Analysis and Evaluation. Hands-on practical tasks and scoring rubrics are developed based on the hypothetical-deductive model to measure students' physics practical skills by the mode of direct observation. Written test is developed as a second mode of assessment. The validity and reliability of the instruments developed were checked with different methods and were found to be of sufficient content validity, construct validity and internal consistency. The instruments were administered to 153 Form Four students from 10 secondary schools in the division of Kuching, Sarawak. The findings of this study indicated that there were weak correlations between the two modes of assessment.

Students' mastery of physics practical skills is at a moderate level and their performances differ in different tasks and domains of practical skills. This study provides an insight into the requirements of utilising different modes of assessment to measure students' practical skills and set the foundation for future research as to determine how physics practical skills among secondary school students can be improved.

CHAPTER ONE

INTRODUCTION

1.1 Introduction

Science is a study of the natural world. Before the science education is initiated, natural phenomena were explained through myths (Atkin & Black, 2007). Looking at the world through systematic observation and measurement emerged in the late Renaissance and early modern period, marking the beginning of modern western science (Buxton & Provenzo, 2011). According to Buxton and Provenzo (2011), science became important in the basic education of children in Great Britain and France at the beginning of 19th century. During 1960s which sees the era of science education reform, science curricula engaged students in scientific investigations with inquiry and hands-on activities so that students have a better understanding of the nature of science (Lunetta, Hofstein, & Clough, 2007).

Development of science education in Asia, especially in the developing countries, is influenced by the west. Countries which are formally collonised adopt science curricula of the western countries and invested in science education since the 1960s (Coll & Taylor, 2012), as quality science education can raise a nation's economic growth and development (Takeuchi, 2002; Tan, 1991) especially with high dependence on technology nowadays. However, many developing countries still measure their quality of science education by western standards (Magno, 2007). Assessment of science education in these developing countries are dominated by high-stake, external, summative examinations that focused on low cognitive skills (Coll & Taylor, 2012).

Malaysia as one of the developing nations began science education during the British colonization. According to Subahan (1998), the government of the Straits Settlement (Penang, Malacca and Singapore) and Federated Malay States (Selangor, Perak, Negeri Sembilan and Pahang) at that time set up a special committee to enact the purpose and arrange the syllabus of science education. After gaining independence from the British in 1957, Malaysia continues to adopt British science curricula (Subahan, 1998; Thair & Treagust, 1999). However, Malaysian children had different social and economic background compared to the British who are from a society which is more developed in science and technology (Tan, 1991). It is difficult for Malaysian students to relate what is taught with their everyday experience (Magno, 2007; Thair & Treagust, 1999). Hence, the Ministry of Education (MOE) of Malaysia initiated efforts to improve science curriculum reforms in the country to make it relevant to the Malaysian students. The most recent reform in the education system is the twelve years plan of the Malaysian Education Blueprint (MEB) which was launched in 2012, following the dismal performance of Malaysian students in international student assessment such as Trends in International Mathematics and Science Study (TIMSS) and Programme for International Student Assessment (PISA).

1.2 Science Curriculum in Malaysia

Formal science education for Malaysians starts in primary school. Science is taught as a core subject in primary school which is compulsory to all students. The National Science Education Philosophy of Malaysia states that:

> "In consonance with the National Education Philosophy, science education in Malaysia nurtures a Science and Technology Culture by focusing on the development of individuals who are competitive, dynamic, robust and resilient and able to master scientific knowledge and technological competency."
>
> (Ministry of Education of Malaysia, 2003a, 2003b)

The primary science syllabus is divided into two levels. At the first level which is from Year 1 to Year 3 of the primary school education, students learn about living things and the world around them. At the second level (Year 4 till Year 6), the curriculum contents consist of five themes where students start to investigate living things, forces and energy, materials, the Earth, the universe and also technology (MOE, 2003a). Curriculum specifications prepared by the Curriculum Development Division (CDD) suggests suitable learning activities and list the expected learning outcomes to be achieved by the students as a guideline for the teachers (MOE, 2012a). Apart from learning science concepts, students are expected to develop science process skills as well as creative and critical thinking skills through the learning of science. Practical work in the school science laboratory is among the methods used to develop such skills as practical work engage students in investigations and inquiry (Lunetta et al., 2007).

Students sit for the primary school achievement test (*Ujian Pencapaian Sekolah Rendah,* UPSR) which is conducted by the Malaysian Examination Syndicate (MES) at the end of their primary education. Science was previously assessed through paper-and-pencil test which consists of multiple-choice questions (MCQs). From the year 2008, practical skills such as science process skills are given more emphasis. Structured questions that test students' knowledge on science process skills are included in the test. School based science practical work assessment (*Pentaksiran Kerja Amali Sains*, PEKA) are conducted to assess science process skills and science manipulative skills of the students (MOE, 2008). Score of PEKA is printed on the UPSR result slip.

Under the new MEB, the formal Integrated Curriculum of Primary School (KBSR) was replaced with Standard Curriculum of Primary School (KSSR) from the year 2011. Schools are required to use the Standard Performance Document (*Dokumen*

Standard Prestasi, DSP) prepared by the MOE (2010) for school based assessment of each subject, including Science. The DSP provides a series of descriptors for the students to attain. Students need to provide evidence required for the descriptors to achieve the standard outlined. The evidence is used to assess how much students have learnt. KSSR is implemented in stages and is fully implemented by the year 2016.

After six years of primary education, students proceed their studies in secondary school, which is divided into lower secondary, upper secondary and post-secondary education. Science continues to be a mandatory subject. Science education at secondary level consists of nine themes: introducing science, man and the variety of living things, matter in nature, maintenance and continuity of life, force and motion, energy in life, balance and management of the environment, technological and industrial development in the society, and astronomy and the exploration of outer space (MOE, 2003a).

At the end of the three years lower secondary education, students sit for Lower Secondary Examination (PMR) as a diagnostic evaluation of student learning (Ong, 2010). Prior to 2004, science was evaluated through 75 MCQs in a paper-and-pencil test. From 2004 onwards, students need to sit for two papers for the examination of PMR Science: Paper 1 consists of 40 MCQs while Paper 2 consists of two sections of short answer structured questions. The first section of Paper 2 assess students on their science concepts while the second section assess students' basic and integrated science process skills based on their written responses in the papers. Students are also assessed through PEKA in their lower secondary forms. It can be inferred from these assessment scheme that practical work and practical skills are highly valued in science education in Malaysia.

With the enforcement of school-based assessment in secondary schools, DSP is used to assess students formatively in their lower secondary forms starting from 2012 (MOE, 2014a) while PMR was replaced by PT3 (*Pentaksiran Tingkatan 3*) in 2014 (MOE, 2014b). However, for the assessment of science, the instrument used is still a paper-and-pencil test consisting constructed-response items (MOE, n.d.). Based on the information released by the MES, PT3 is not a standardized test as the instruments used are randomly picked from a pool of items and printed by individual schools.

Subsequently, all students are promoted to upper secondary level regardless of how they perform in their lower secondary education. Students are either streamed into science, humanity or art discipline for upper secondary level, where they are given a choice to determine the elective subjects that they want to study. Students in the humanity and art stream will continue to learn science by taking the subject General Science, whereas those in the science stream will specialise in subjects such as Physics, Chemistry, Biology or Additional Science. If a student chooses to continue post-secondary science education in school, he or she has a choice of either taking Physics or Biology but Chemistry will be compulsory.

Students' achievement in their secondary education is evaluated through the Malaysian Certificate of Education (SPM). For the assessment of science, all students are involved in PEKA which will be a continuous assessment throughout Form 4 and Form 5. During the SPM examinations, students who are taking General Science will be tested using two papers: Paper 1 of MCQs and Paper 2 of constructed-response items. Students in the science stream will sit for three papers for the subjects of Physics, Chemistry, Biology and Additional Science. The third paper, a written practical test is believed to assess students' skill of experimenting (MOE, 2002). This paper was proposed to be replaced by practical examination in 2015 (MOE, 2014c) but its implementation was postponed (MOE, 2015) and no further announcement was made related to this issue until the time this thesis is prepared.

The science curriculum of Malaysia consists of three main domains: science knowledge, scientific skills and scientific attitudes (MOE, 2003a; MOE, 2012a). In addition to the science knowledge and scientific concepts, after eleven years of science education, students are expected to master scientific skills which consist of science process skills, manipulative skills and thinking skills. At the same time, students also acquire scientific attitudes and noble values through science learning activities. Moreover, elective science subjects such as Physics, Chemistry and Biology prepare students for further study and careers in science related fields and hence contribute to the country's science and technology development.

However, there is a risk of inconsistency between curriculum aims and assessment scheme as they are placed under the responsibility of different departments of the MOE. For example, science process skills and manipulative skills are practical skills that are essential for practical work in the science laboratory. Yet, Dewani (2009) reported inconsistency between skills outlined in the curriculum specifications by the CDD and the assessment guide by the MES, especially on manipulative skills. Process skills are specified as important skills in the curriculum specifications (MOE, 2003a; MOE, 2012a), but these skills are assessed through written test, science teachers only practise science demonstrations, hands-on laboratory investigations, field work and virtual experiments at low frequency (Pandian & Baboo, 2011). Students can be trained to answer the questions in the written test through repeated exercises and drills in answering questions of the same examination format without actually mastering the specific skills.

1.3 Physics Curriculum in Malaysia

Physics is a subject taught at upper secondary level in Malaysian secondary schools. However, students had been exposed to physics since first year of primary education as physics had been part of the primary science syllabus even before the era of New Primary School Curriculum (Subahan, Koh, Ramli & Sharifah, 1988). Basic physics topics taught in science include energy, water, air, light, shapes, structure, size, weight and volume. Physics continues to be part of the science subject at lower secondary level and integrated science at upper secondary level. Only students in the science stream at upper secondary level will learn physics as a subject.

Physics is distinguished from other sciences by its extremely high level of abstraction and idealisation. Physics is chosen as the subject of this study as many students think physics is difficult because they need to understand a lots of theories and laws which are represented by complex mathematic formulae (Pattar, Raybagkar, & Garg, 2011). This might be the reason why the number of students who chose to continue studying physics at higher level is decreasing (Oon & Subramaniam, 2011). Khaparde (2009) considered physics as the most quantitative science where foundation is set from continuous observation, measurement, data collection, analysis and interpretation. What is more, physics thinking cannot be formed by simply observing the surrounding world but need to be reconstructed through assumptions of theoretical principles.

Practical work is believed to be able to assist students in developing and understanding scientific knowledge, apart from acquiring the skills of how to manipulate and use the apparatus and equipment in the laboratory (Abrahams, 2011). Through practical work, students are able to see and experience phenomena that rarely occur in real life and hence help students to create link between theory and practice

(Prades & Espinar, 2010). For example, for topics related to motion, practical work in the laboratory helps students to remember better and improve their concepts of velocity and displacement (Sengel & Ozden, 2010). Therefore, practical work can provide concrete evidence for the abstract ideas in physics and thus enhance understanding of abstract physics concepts (Sneddon, Slaughter, & Reid, 2009). Zacharia and Olympiou (2011) reported that experiments help to enhance students' conceptual understanding of heat and temperature. However, students can only benefit from practical work if it is planned effectively. Thus, ability to conduct quality practical work through experience and training in the physics laboratory is very important in physics learning. Poor practical skills may lead to incorrect interpretation and deduction that cause misconception in learning.

Inquiry based practical work revolved around questions, starting with a question to be answered, followed by experimental procedures to solve it and then concluding the solution to solve the problem (Bell, Smetana, & Binns, 2005; Harwood, 2004). Thus, practical skills required for conducting practical work in the laboratory include planning how a problem can be solved, executing the investigation to collect data, analysing the data obtained and evaluating the findings from the practical work. As the learning of physics often involve the quantitative aspect of relationship, physics practical work are normally planned to help students in learning to deduce a relationship between two variables (Tiberghien, Veillard, Le Maréchal, Buty, & Millar, 2001). Hence, an equally significant aspect in conducting practical work especially in physics is procedural knowledge on how reliable evidence or data can be obtained (Millar, Lubben, Gott, & Duggan, 1994) so that a valid relationship can be deduced. Yet, this aspect is often neglected in the training of physics laboratory (Khaparde & Pradhan, 2002).

Students' practical skills are assessed to determine if they have adequate training in the school physics laboratory. Assessment of physics practical skills had been conducted using different methods. Assessment scheme for physics practical skills had experience several reformations. Prior to the implementation of Integrated Curriculum of Secondary School (KBSM) in the 1980s, students went through the Malaysian Modern Physics course which was adapted from the England Nuffield Science Project (Chia, 1988). A guided discovery approach was used where laboratory activities were integrated into the teaching and learning activities. Students were encouraged to investigate, inquire and find things out by themselves. Since science is about collecting and analysing data in the laboratory, in learning science such as physics, assessing student practical work is vital (Towndrow, Tan, Yung, & Cohen, 2008). As such, towards the end of the Modern Physics course, students sit for practical examination which is a compulsory component and contributes 10% in the grade for physics in the SPM examination.

The practical examination was conducted in the form of performance assessment where students are asked to perform practical work following certain procedures and provide responses to the questions given. In spite of this, score is given based on the written responses only. Hence, it can be asserted that the practical examination is a written test using constructed response answers as students can be trained to answer most of the questions without actually conducting the practical work as similar practical tasks are being used repeatedly to assess the practical skills (Moeed & Hall, 2011). This could be one of the reasons why students perform poorly in physics experiments at post-secondary level that is in their High School Certificate, STPM (Chia, 1988).

Practical examination was maintained in the SPM examinations under KBSM until 1999 where it was replaced by the school based assessment PEKA. Constructs of practical work which are assessed in Physics PEKA include: planning of investigation; conducting of investigation; collecting and recording data; interpreting data and making conclusion; scientific attitudes and noble values. Unlike the practical examination, the score of PEKA has no contribution to the grade of Physics in the SPM examination. PEKA was initiated to enhance science learning through continuous formative assessment on practical work but when implemented, turn to become a tool to evaluate students' science process skills and manipulative skills (Ooi, 2011). However, the most common instrument used for assessment in PEKA is the practical reports produced after the practical sessions (Dewani, 2009). Although the score of PEKA is not included in the grades in the SPM examination, teachers' instruction for practical work in the physics laboratory are driven by the assessment modules. Students hence focus on completion of practical work rather than the acquisition of practical skills (Nabilah, 2011). As students focus on fulfilling the criteria of assessment, they concentrate on completing steps to obtain results without spending time to explore and judge the rational of the procedures (Cheung, 2008).

In the year 2002, the assessment scheme of PEKA was revised and a written practical test is introduced into the assessment scheme of SPM 2003 onwards. The written practical test aims to assess student ability in solving problem through scientific investigations. Students shows their skills of planning systematic scientific investigations, collecting and analysing data by answering two structured questions and one open response question in the written practical test (MOE, 2002). The score of the written practical test weighs 20% in the final score of the examination. At the same time, PEKA is conducted by school subject teachers and its grade reported on a separate certificate (Ong, 2010). MES had recently announced the abolishment of PEKA and written practical test beginning 2015. According to its director, assessment of practical work will revert back to centralised practical examination (MOE, 2014c) but there is no publication of empirical study to support this decision. However, this decision was later postponed due to insufficient facility and equipment in schools (MOE, 2015). Details of the assessment method has not been disclosed until the date of completion of this thesis. However, considering the previous practice of science practical assessment, irrespective of how the assessment method changes, focus is still solely placed on written reports or written work. Performance of technical skills is seldom assessed (Fitch, 2007). Consequently, students do not master practical skills although they obtain good grades in assessment (Stacey, 2014).

Table 1.1
Enrolment of Students in Science Stream

Year	Form 4	Form 5	Lower 6	Upper 6
2007	116512	117988	12972	13540
2008	122649	115078	12396	8560
2009	124064	121356	10135	8572
2010	124982	121798	10185	8428
2011	125451	122735	10088	7931
2012	124624	123322	11777	7850
2013*	122470	121936	10059	8959

Notes. Extracted from Education Statistics of Malaysia by MOE available on http://emisportal.moe.gov.my. *Modular examination system starts to be implemented for STPM 2013.

Student enrolment into science stream had declined in recent years (Phang, Abu, Ali, & Salleh, 2012). Table 1.1 shows the number of students registering in science stream from 2007 to 2013. Even though the number of students at upper secondary level is increasing, the number of science students at post-secondary level (Form 6) is dwindling steadily every year. This is a worrying phenomenon as Malaysia aspires to become a developed industrialised nation by 2020. A review by Phang et al. (2012) on studies done in Malaysia suggested the lack of practical work as one of the reasons for the decline of student enrolment in science related fields. According to a study by Pandian and Baboo (2011), less than 50% of the teachers allow frequent hands-on in the science laboratory. Teachers agree that students like doing practical work and find it interesting and this help them to maintain their interest in learning science (Abrahams & Saglam, 2010). Yet, teachers teach what is assessed and tested and do not have much time for practical work which are not included in examinations. There is a need to examine how practical work is being implemented and assessed in schools but studies related to science practical work assessment in Malaysia mainly focus on the perceptions of teachers and students towards the implementation of PEKA and its effects on student achievement (Azidah, 2005; Lim, 2012; Salawati, 2011; Saliza, 2009).

1.4 Problem Statement

Practical work helps students to understand abstract physics concepts through the reproduction of physical phenomena in the school laboratory (Deacon & Hajek, 2011). Hence, assessment of practical work in physics should be given more emphasis so that students and teachers are aware of the importance mastering practical skills. However, physics practical skills are currently assessed using written practical test which contributes 20% to the grade in SPM (MOE, 2002) while school based practical assessment (PEKA) has no influence on students' grades. Practical work is best assessed in the actual setting where it is carried out and not solely based on paper-and-pencil test (Hunt, Koenders, & Gynnild, 2012). In countries such as Singapore, Hong Kong and England, practical skills are assessed through observation where students are observed for their performance in conducting scientific investigation and then supported by reports or written answers to questions in practical test (Reiss, Abraham,

& Sharpe, 2012). Teachers and students treat practical skills assessment seriously as it contributes 20% to the final grades in school exit examinations.

There is a need to revise practical skills assessment in Malaysian schools, especially in physics, considering the importance of practical work in enhancing students' physics learning (Sneddon et al., 2009). Problem with the assessment of practical skills is noticeable as low mastery of practical skills had been reported in local researches. Abu Hassan and Rohana (2003) tried to determine mastery of science process skills among students using self-developed instrument. They found that students are weak in experimenting. Salawati (2011) reported students have moderate mastery of integrated science process skills when assessed in a laboratory practical test. Her findings was supported by Lim (2012) who also pointed out that students actually do not know what are the skills being assessed but merely follow teachers' instructions. Likewise, Chong (2012) who conducted a study using mastery test found that students have medium level of mastery in science process skills. However, there is no research that reports the mastery of physics practical skills.

Coupled with the results from studies on science process skills is the studies on science manipulative skills. According to Baskar (2009), students are not confident in conducting practical work and have not acquire the skills of manipulating the instruments and apparatus in the science laboratory. Hidayah and Rohaida (2013) mentioned that students' manipulative skills improve as they proceed to secondary school but Mariam and Rohaida (2009) found students still need to be guided while conducting practical work. Chong (2012) on the other hand discover that students had high level of understanding in manipulative skills but self-reporting questionnaire was used as an instrument for the study. Thus, it can be concluded students' practical skills need to improve further and one of the methods is to develop a comprehensive scoring rubrics to assess practical skills so that practical skills that are important are identified.

Instruments to assess physics practical skills using direct observation should be developed so that assessment can be carried out continuously in school. Different instruments had been used by researchers to measure practical skills in their studies. Usage of questionnaires is popular among local researchers, while others prefer to use self-developed written test items. However, assessing practical skills through observation while students are performing practical work is rarely carried out. As such, instruments for this mode of assessment is still scarce.

Different modes and methods should be applied in science practical assessment to provide a more comprehensive view of students' ability in conducting practical work. As science teaching has changed from text based to activity based, multiple modes of assessment need to be carried out to gauge students learning. Assessing students in only one single examination, whether it is in the form of written test or practical examination, cannot measure the ability of the students accurately (Shavelson & Baxter, 1992) as it may be affected by many factors such as anxiety and other constraints. As each individual is unique, a student may perform better in practical task than in written test (Gray & Sharp, 2001) or vice versa. Furthermore, practical work in the laboratory is multistage and multifaceted and thus its assessment need to involve different components of different elicitation methods (Jacobs-Sera, Hatfull, & Hanauer, 2009). Students' performance in different modes of assessment and different practical tasks can be compared to verify this.

The implementation of PEKA is actually an effort to realise multiple assessment method to assess student practical skills. Instruments such as portfolio, project reports, scrap book, check list and model can be used to assess student ability in conducting practical work. The scoring rubric of PEKA as shown in the PEKA assessment guide (MOE, 2003b; MOE, 2009) awards score to students on their performance while conducting the experiment, such as the ability to set up apparatus correctly. However, there is no report on research being carried out to evaluate the validity and reliability of PEKA except for Dewani (2009) who evaluated the context of PEKA at lower secondary level.

Reliability and validity of score from PEKA is also debatable as there was no frequent and consistent moderation (Lim, 2012) from external bodies. Due to problems such as large number of students, lack of apparatus, class control and increase workloads of teachers (Baskar, 2009), score may not be given accordingly during the short time allocated for practical work in the school laboratory. Teachers claimed that they were not trained for inquiry-based laboratory activities and thus have low confidence in conducting and assessing practical work which required scientific inquiry skills (Edy, 2012). It is possible that teachers provide grades for the students without actually engaging them in the practical work (Tan, 2010). Teachers also find it difficult and challenging to prepare practical work for physics (Nivalainen, Asikainen, Sormunen, & Hirvonen, 2010). Consequently, an instrument which outline the criteria of mastering physics practical skills can help teachers in planning practical work and build up their confidence in conducting and assessing practical work in physics.

Furthermore, there were inconsistencies between the skills listed in the curriculum specification by the CDC and criteria listed in the PEKA scoring rubric by the MES (Dewani, 2009). Hence, a clear and user friendly guideline on what to assess in practical work specifically in physics and how to assess it comprehensively is needed in the Malaysian education system. The assessment on practical skills at present focuses on the acquiring of certain science process skills (MOE, 2009) and do not outline the practical skills for physics. There is no specific guideline on physics practical skills until the time of this research being carried out.

An equally significant aspect in the assessment of practical work is the limited number of practical tasks that are being used for assessment. The written practical test assessed students' practical skills through four constructed-response items from different topics (MOE, 2002) that involved different conceptual knowledge where students only have to answer three out of the four items. PEKA required scoring from a minimum of three practical tasks (MOE, 2003b; 2009) while former practice of practical examination required students to perform two practical tasks only. Conceptual knowledge of students influences their performance on the tasks as they are not of equal difficulty to the students (Solano-Flores et al., 1997). Shavelson, Baxter and Gao (1993) suggested more tasks to be executed in order to obtain reliable measurement of achievement. As such, more practical tasks need to be developed for assessment of physics practical skills.

1.5 Purpose of Study

The purpose of this study is to assess students' practical skills in the secondary school physics laboratory using two different modes of assessment. Current assessment of practical skills focuses on the acquirement of science process skills which are generic for all science subjects. This study would like to identify the practical skills needed specifically for practical work in the secondary school physics laboratory.

This study proposed that a direct approach should be used to assess students' practical skills. Students are observed when they are conducting practical work in the actual school setting of secondary school physics laboratory. As such, hands-on practical task and scoring rubrics to assess practical skills required to conduct the tasks are developed specifically for the purpose of this study. Important domains of practical skills in physics are identified and outlined in the scoring rubric so that a more comprehensive way of assessing students can be generated.

This study also aims to determine the mastery level of students' practical skills. Hence, scores obtained by the students for hands-on practical tasks are divided into three levels. Previous researches mainly focus on the grasp of science process skills and use instruments such as written test (Abu Hassan & Rohana, 2003; Chong, 2012; Salawati, 2011) or questionnaire (Baskar, 2009; Chong, 2012, Lim, 2012). Practical skills related to open-inquiry laboratory activities are yet to be discussed (Edy, 2012). This study will be able to fill up this gap.

Apart from assessing students through observation, this study also wishes to determine whether students' performance in practical work when assessed directly is comparable to their performance on written work which had dominated the assessment of science practical skills. Baxter, Shavelson, Goldman and Pine (1992) had suggested that notebook is a viable alternative to direct observation of hands-on performance. This study would like to find out whether the claim by Baxter et al. (1992) can be made between direct observation and written test in the context of Malaysia.

1.6 Objectives of the Study

The objectives of this study are as follows:

1. Develop valid and reliable instruments for direct observation to assess students' physics practical skills.
2. Develop valid and reliable written test to assess students' physics practical skills.
3. Examine and compare students' performance of physics practical skills when assessed using direct observation and written test.
4. Compare students' performance of physics practical skills in different tasks.
5. Compare students' performance in different domains of physics practical skills.

1.7 Research Questions

The result of this study is hoped to answer the following questions.

1. Are the instruments developed for direct observation valid and reliable in terms of
    a. Content validity?
    b. Interrater reliability?
    c. Internal consistency?
    d. Construct validity?
2. Is the developed written test valid and reliable in terms of
    a. Content validity?
    b. Construct validity?
    c. Internal consistency?
3. What is the performance of students on practical skills when assessed using direct observation and written test?

4. Is there any significant difference between students' performances in direct observation and written test?
5. Is there any relationship between students' performances in direct observation and written test?
6. Is there any relationship between students' performances in different tasks during direct observation?
7. Is there any relationship between students' performances in different domains of physics practical skills?

1.8 Significance of the Study

This study attempts a different approach to determine the mastery level of students' physics practical skills, which is by observing students when they are performing practical tasks, and hence provide an alternative assessment method in the current education system. Literatures show the importance of assessing science practical skills of the students (Abrahams & Saglam, 2010; Matz, Rothman, Krajcik, & Holl, 2012; Şengel & Özden, 2010). Unfortunately, written test especially multiple-choice questions are used to assess practical skills (Edy & Lilia, 2010; Feyzioğlu, Demirdağ, Akyildiz, & Altun, 2012). As for performance tasks, written reports produced from the practical tasks are generally used to assess science practical skills (Kamilah et al., 2012; Ottander & Grelsson, 2006).

Assessing students through direct observation during practical work apart from written responses from the practical work impart a more comprehensive way of assessing student practical skills. Observing students while they are performing the practical work allows the assessor to evaluate how well a student can perform a certain practical skill (Chabalengula, Mumba, Hunter, & Wilson, 2009). Assessment of practical work becomes more authentic, that is in the actual setting of the laboratory.

The hands-on practical tasks and scoring rubrics developed in this study are able to serve this purpose. Furthermore, the instruments developed provide guidelines for teachers on what to assess and how to assess in physics practical work. The scoring rubrics can be used as continuous assessment in schools, and thus can be an instrument for school based assessment in conjunction with the suggestion in the MEB (MOE, 2012b).

The recently announced MEB which is to take effect for the next 12 years (from 2013 to 2025) make an effort to change its examination-oriented education system. The Ministry of Education of Malaysia realises that students of the 21st century need to be able to reason, to extrapolate, and to creatively apply their knowledge in different settings rather than answering examination questions only (MOE, 2012b). More focus is given on training the students to think critically and to apply knowledge in different setting. The methods of assessment used in this study is an example of evaluating students on applying their knowledge and skills in different settings as indicated in the education blueprint (MOE, 2012b). Different types of assessment allows teachers to observe different dimensions of students to obtain a global picture of their knowledge and skills (Figueroa & Montenegro, 2010). This study intents to use more authentic performance assessment to evaluate students in the laboratory setting, through direct observation while students are performing hands-on practical tasks. Hence, the result of this study will give an insight on the assessment methods of science and science related subjects in the Malaysian education system, as assessing students using different modes of assessment can give different results.

At the same time, this study also hopes to give information on whether different methods of assessing practical work as suggested in higher education can be applied at secondary schools. Kamilah et al. (2012) tried to investigate the level of practical skills acquired by undergraduates administering laboratory practical test. Low and Timmers (2011) tried to divide practical task into checkpoints where students can be assessed. For secondary school, PEKA has been proposed to be abolished in SPM 2015 but no alternative programme had been introduced to replace it in terms of school based assessment. This study suggests a systematic approach to assess students through the use of rubrics during observation. This approach provides an alternative tool for teachers to evaluate themselves and their students in terms of practical skills specifically in physics. Through continuous assessment using suitable practical tasks, teachers can identify the strength and weaknesses of their students. This helps the teachers in planning practical tasks for their students in order to improve their practical skills for further study or job prospects.

Results from this study are able to provide valuable information on the practical skills in physics that are still lacking among students. In this study, the components of practical skills that are essential for practical work in the physics laboratory are identified. Performance of students in different domains of physics practical skills are identified. Domains and skills which students are weak in are identified so that suitable remedies can be planned. Relevant personnel such as teachers and district officers can make an effort to plan activities and programs for students to improve on the related skills. Students are found to be weak in analysing data and evaluating results, which directly influence their performance in international student assessment such as TIMSS and PISA. It is hoped that the information derived from this study can create awareness on appropriateness of assessment methods in assessing practical skills and hence lead to program development to improve the practice, such as programs to enhance teachers’ competency in assessing physics practical skills.

1.9 Limitations of the Study

This study wishes to identify the practical skills required for scientific investigation in the Malaysian secondary school science laboratory, and then assess students on these skills and evaluate whether they have master the skills required or not. Due to limited cost and time, this study will only be carried out with Form 4 Physics students as the subjects. Assessment should be carried out after students have learnt all important concepts in the Physics curriculum for secondary school, which is towards the end of their secondary school education as certain important skills and laboratory equipment will only be introduced and exposed to the students at Form 5 level. Unfortunately, the MOE does not approve the use of students who are preparing for their SPM examination to be involved in the study. Hence, the practical skills that will be assessed in this study are limited to what the students should have acquired in Form 4 Physics only.

This study employs performance assessment which use direct observation to assess students' practical skills. Performance assessment takes time to be designed and implemented. Hence, the tasks designed for this study are related to one topic in the Form 4 Physics syllabus which is taught at the beginning to the academic year. This is to ensure that data can be collected in the limited time frame. Limiting the tasks to a single topic also reduce the variation due to content knowledge so that scores obtained are comparable between direct observation and written test as this is one of the purpose of this study. Yet, due to this limitation, whether students' interest in different areas of knowledge affect the mastery of practical skills cannot be determined.

Performance assessment using direct observation is limited to small classes with 25 students, as students need to be observed and scored individually in a practical session. Hence, only small classes can be chosen. This limit the sample of schools and students that can be selected for this study. The generalizability of the result of this study will hence be limited. Direct observation is rated by different raters using the developed scoring rubric. However, there are various sources of variance involved that might contribute to errors in measurements. Although variance can be reduced by training the raters and reduce the number of tasks, it is difficult to generalize the result of this study to a larger population.

This study uses a direct observation method to assess students' practical skills in the school laboratory. The practical task chosen for observation has to be similar to the ones that students learnt in physics lessons, so that students have basic knowledge on how the task is to be carried out. This might affect the reliability of the result as students are expected to perform better if the practical task had been done before and they are merely repeating it. At the same time, there are limited resources in the setting of school physics laboratory, especially in the availability of instruments and apparatus for students to choose from in planning for the performance tasks. Hence, it is challenging for the researcher to assess the students' practical skills in a completely authentic setting.

Although this study uses direct observation to assess students' practical skills, the skills observed are limited to two of the components identified, which are planning and execution, as not all skills are easily observable. The other components of practical skills (analysis and evaluation) are assessed through written responses provided by the students based on the practical work done, which are feasible, less costly and time consuming. As a complement to direct observation, written practical test is used to assess students' practical skills as well. Comparison will be made between what is observed and what is written by the students.

1.10 Definitions of Terms

The followings are the definitions of terms that are used in this study.

a) Practical work

Practical work refers to all investigative experimental work that is used in the teaching and learning of science (Nivalainen et al., 2010) at schools. In this study, practical work refers to all the hands-on activities with manipulation of instruments, apparatus and tools specifically in the school science laboratory. Simple activity to get familiar with an apparatus, experiments to view a phenomena to improve understanding of concepts, and investigation which involved planning and analysing are all considered as practical work in this study.

b) Practical skills

Practical skills are skills required for conducting practical work and is often equalized with science process skills (Akinbobola & Afolabi, 2010; Ongowo & Indoshi, 2013). In this study, practical skills refers to scientific inquiry skills which are skills required to conduct an open-inquiry scientific investigation type of practical work in the school laboratory. Practical skills in this take into account not only science process skills but also manipulative skills and procedural knowledge that are ought to be considered while conducting practical work. These skills are group into the domains of planning, conducting, analysing and evaluating science practical work. Details of the skills will be discussed in Chapter 2.

c) Domains of practical skills

For the purpose of this study, practical skills in physics are classified into four main domains: design, execution, analysis and evaluation. Skills embraced in the domain of design are skills that are needed to plan a scientific investigation. Skills in the domain of execution include skills while carrying out the investigation, which