UNIVERSITY OF LINCOLN

Investigation into the Effectiveness of Practical Work in Achieving Curriculum Objectives for Engineering Studies in Secondary Education

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INVESTIGATION INTO THE EFFECTIVENESS OF PRACTICAL WORK IN ACHIEVING CURRICULUM OBJECTIVES FOR ENGINEERING STUDIES IN SECONDARY EDUCATION

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Abstract

Practical work is a component in most STEM (science, technology, engineering and mathematics) curricula. It can be defined in engineering education as students experience by manipulating real objects or materials inside or outside the classroom. Mechanical Engineering Studies has been introduced at technical schools in Malaysia since 1994 which included 60% of practical work elements. Although research on practical work in science is well established for several years, there is insufficient research on practical work in engineering education. Previous studies have suggested that the curriculum objective is an important element in the curriculum development in most countries, however, until recently, deficient study has evaluated the achievement of the curriculum objective. This study aims to evaluate the effectiveness of practical work in achieving curriculum objectives, to explore the international perspectives on the effectiveness of practical work in STEM education and to investigate the challenges faced by teachers in implementing practical work for engineering studies in secondary education. This study provides an indicator to classify effectiveness into five specific categories. It was conducted by evaluating the practical work elements in the seven curriculum objectives for Mechanical Engineering Studies. This study combined the questionnaire, interview and observation through triangulations of methods for data collection in multiple case studies. Additionally, it investigated previous ten years studies on practical work in STEM education worldwide through a systematic review. This study involved (n = 261) mechanical engineering students and (n = 10) mechanical engineering teachers as the participants from five technical schools. This study adopted the model of the process of design and evaluation of a practical task by Abrahams and Millar (2008), to investigate the effectiveness Level 1 (the domain of observable). The results indicate that practical work is ‘effective’ in achieving four curriculum objectives and it is ‘highly effective’ in achieving the other three. The results align with the international perspective of practical work that suggested practical work is important to assist students in understanding the topic, developing their interest and encouraging them to cooperate well in group work. These findings have shown the success of the calculation for the degree of effectiveness in achieving the curriculum objectives. It also indicated a reliable process of transformation from qualitative data to numerical score in mixed methods data analysis. This study also discovered the challenges in the implementation of practical works are the difficulty of curriculum, insufficient of the budget, unclear objectives, lack of facilities, limited human resources and the time constraint. The discussion and conclusion have been structured based on the idea from the Dynamic Model of Education Effectiveness (Creemers

and Kyriakides, 2008) which integrated four main factors that influenced the educational effectiveness which are the education system, the school, the teacher and the student. The original contribution of this study is the development of the table of degree of adverbs as an indicator of a systematic quantitative scoring process for qualitative data. This table allowed the mixed methods of data analysis compatible the triangulation of data collected from the questionnaires, the transcriptions from the interviews and the observations to provide the mean scores to classify the level of effectiveness. Finally, this study suggests for the practical work to be highly effective, the ministry should review the curriculum, involves supports from local universities and industries, increases the time allocation for practical work, provides teacher training, and placement a teaching assistants in all technical schools.

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CHAPTER 1: INTRODUCTION

Structure of the chapter

The structure of this chapter is presented as follows; the first section presents the general information of the research background. This section included the introduction to the Malaysia education system, the focus on engineering education at technical schools and the Mechanical Engineering Studies subject. It discussed the reasons that triggered this research, in part inspired by the announcement of the Malaysia Education Blueprint 2013-2025. The next section explained the rationale for conducting this study that aligned with the fact that insufficient research has been conducted on practical work in secondary engineering education in Malaysia. This section also provided the statement of the aims, the objectives and the research questions for this study. The final section is the justification for the selection of pragmatist paradigm that has been applied in this research within the philosophical reflection. This section presents the methodological, ontological, epistemological and axiological consideration in pragmatism that leads to the application of a mixed method design, and the influenced on the selection of the participants in which at the same time has determined the setting of the study.

1.1 Introduction to study

Following the 2012 Programme for International Student Assessment (PISA) results, a major transformation in the primary and secondary education curriculum in Malaysia began with the Malaysia Education Blueprint 2013- 2025 (OECD, 2013). The overall PISA 2012 performance of Malaysian students were in the bottom three (51 out of 65 participating countries) [53rd place in science (score 420) and 52nd (score 421) in mathematics] and was below the international and OECD average score (528 for science and 511 for mathematics). The fundamental objectives of any education system are to prepare their students with the knowledge and skills required for success in life (Greenhill, 2010). The debate about the ability of the Malaysia education system to prepare young Malaysians for the challenges of the 21st century has gained new prominence in recent years. The blueprint reported that parents and employers voiced their concerns regarding their expectation and questioning the quality of the current education system. At the same time, the blueprint has identified the skills and competencies that are needed to improve the education system and to increase the students' performances (Education Performance and Delivery Unit, 2013). These skills have included 21st century skills, problem-solving skills, and creative thinking skills and have been emphasised in the development of curriculum objectives for certain subjects. Each curriculum begins with the statement of curriculum objectives as the foundation to determine the purpose and focus of the curriculum (Merritt et al., 2012). The achievement of the curriculum objectives is the critical measurement of the success of the curriculum and at the same time worked as the evaluation for the effectiveness of teaching and learning process (Selin and Olander, 2015). The process of curriculum development began with the curriculum developer on behalf of the Ministry of Education is given suggested outcomes of the curriculum and the government stated their expectation of the possible ability of the students by the end of the studies (Curriculum Development Division, 2016). It is guided by the outline of the curriculum objectives before the content and curriculum specification is produced. Despite the importance of measuring the effectiveness of the components in the syllabus, there remains a scarce of evidence in the evaluation of the statement of curriculum objectives (Adams and Wolf, 2008).

In many countries, engineering education which is part of science, technology, engineering and mathematics (STEM) increasingly appears in high schools as both stand-alone courses and as components of science, mathematics, and career-tech courses (VanMeter et al., 2014). In particular, as synthesised in the National Academies (National Academy of Engineering and National Research Council, 2009) review of K-12 engineering education in the USA, it is expected that engineering education will: (1) focus on design and problem solving; (2) incorporate appropriate science, technology, engineering, and mathematics (STEM) concepts; and (3) "promote engineering habits of mind". A similar trend is seen in the current framework for K-12 science education standards (National Research Council, 2011). Additionally, Hudson et al., (2009) suggested that engineering education must include the assessment of students learning outcomes and evaluation of the teaching and learning process. In the majority of the engineering curricula at every level worldwide, approximately 50% of the curriculum content involved practical work which focused on dominating the engineering skills (Khairiyah et al., 2015).

There are the elements in the curriculum that Philip and Taber (2015), Abrahams and Millar (2008) and Bekalo (2000) describes as the `intended' and the `implemented' curriculum. The intended curriculum is the curriculum objective written, and the implemented curriculum is what takes place in the classroom. Several studies worldwide found that there is a gap between policy and practice in secondary science concerning practical work (Martindill, 2015). Bekalo and Welford (2000), in their study about curriculum practice, found that there is very little correlation between the written curriculum and its application in the classroom teaching and learning. Majority of a teacher, curriculum developer and the policymaker agreed that there is no better predictor of the future of a nation than what is currently happening in the classrooms (Malaysia Education Blueprint, 2013). Written curriculum specification in engineering education Malaysia showed that practical work elements cover over 60% of the total curriculum content. However, the initial finding from the informal discussion with officers in the Ministry of Education Malaysia at the early stage of this research indicated that the ministry is aware of the decrease percentage on the implementation of practical work in most technical schools. However, the ministry has no evident and exact data on either the technical schools involved or the percentage of reduction that currently happened.

Despite the ministry realised about this issue earlier on, until recently no investigation has been done to tackle the cause of this problem. This action reflected that less attention had been given to evaluate the 'implemented' curriculum in the technical schools and most likely the focus of the ministry in the blueprint is on the 'intended' curriculum. The government launched the Malaysia Education Blueprint in 2013 to define the aims of education reform over the next decade and to respond to the challenges faced by the education system. There is an urgent need to address the challenges in the implementation of practical work because this is the time for major transformation in Malaysia education system including for engineering education. There is a growing body of literature that recognised the importance of practical work in science education, so far, however, there has been little discussion about the practical work in engineering education. This study focused on the specific element in the curriculum which is the practical work and not to evaluate the other elements in the Mechanical Engineering Studies curriculum that has been taught in Malaysia technical schools for the form 4 and form 5 students at the age of 16 and 17 years old.

1.2 The education system of Malaysia

Malaysia education system begins at the age of 5 years old in pre-school, 6 to 11 years old in primary school, 12 to14 years old in lower secondary school, 15 to 16 years old in upper secondary school and then students enter the post-secondary or tertiary education after the age of 17 years old. Figure 1.1 shows the journey of students in Malaysia through the Malaysia education system from the early stage until the students enter the higher education. Malaysia education system, like other countries around the world, emphasised the development of strong content knowledge in subjects such as science, mathematics, and languages from primary education (Tan, 2011).

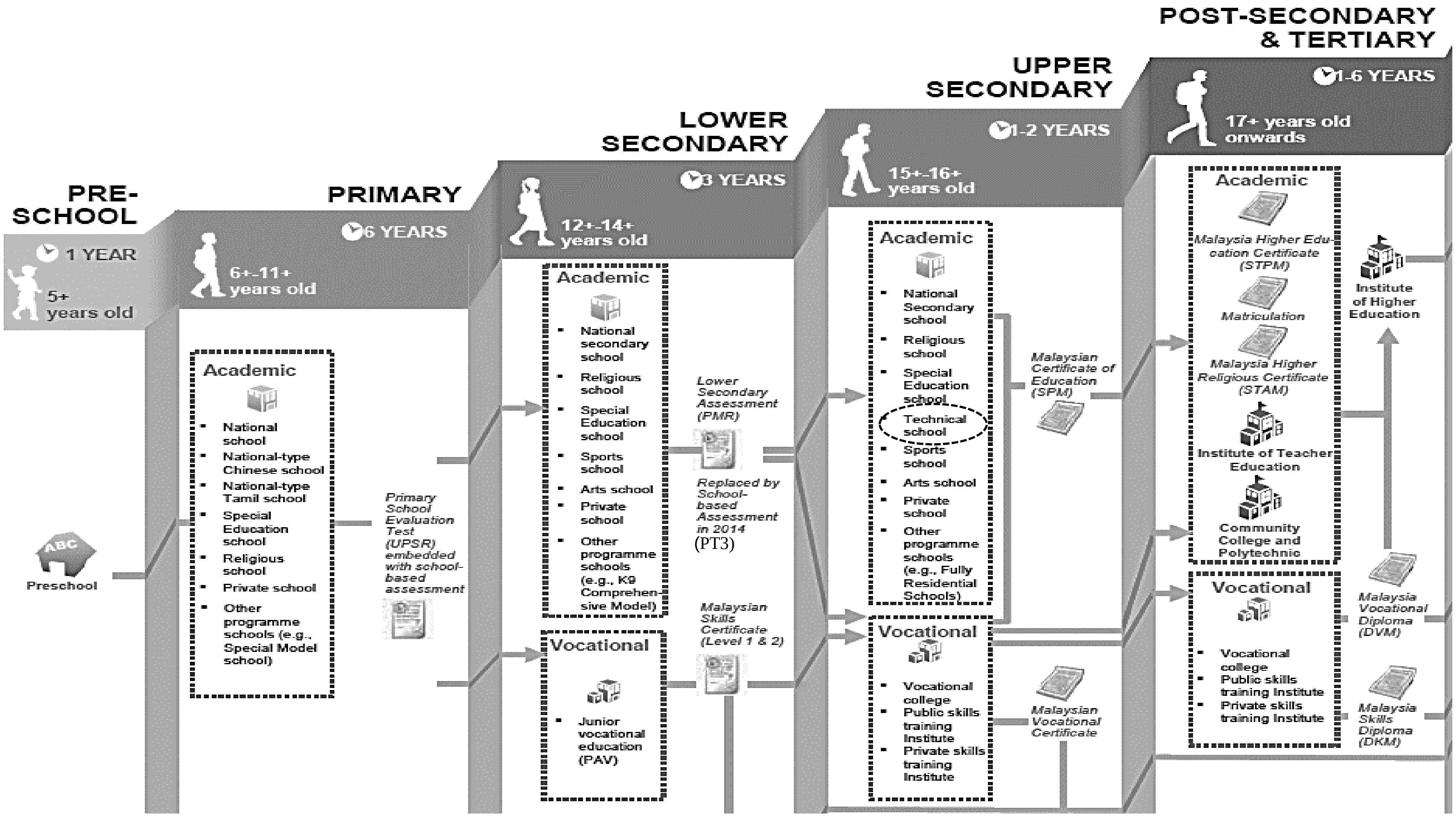


Figure 1.1 Illustrates the journey for students in Malaysia education system from preschool to tertiary education and the position of the technical school in upper secondary level.

Source: Malaysia Education Blueprint 2013, chapter 7- page 2

These subjects are categorised and commonly known as a mainstream academic curriculum. Similar to some other countries like the UK, the USA, and New Zealand, all students in the primary and secondary education in Malaysia are required to follow the standard of the national curriculum for the eleven years of their compulsory education before entering the tertiary education at their selected institution regards their interest and aptitude (Educational Planning and Research Division, 2015) .The government provided free education for the primary and secondary level of education where the students finally sit for the common public examination, the Malaysia Certificate of Education (SPM).

After the primary education, there are two main education streams that the students can choose to pursue their secondary level which is the academic stream and the vocational stream based education. The academic stream is the education that involved common subjects including STEM subject, history and languages which at the end has to sit for the Malaysian Certificate of Education (SPM) before they can pursue their higher education to become professional workers or government officers. While the vocational stream provides a more specific vocational training for students with the minimal of academic subjects and at the end would get the Malaysian Vocational Certificate as the preparation for the students to become highly skilled workers in industries.

The multiple types of academic schools which have specific purposes is to cater to the diversity of the cultures, the talents and the needs of Malaysian students. There are more than ten types of upper secondary schools including the majority of 2,397 National Secondary Schools, a special customise talent schools like three Special Education Schools, four Art Schools, four Sports Schools and nine technical schools (Education Performance and Delivery Unit, 2017). The Malaysia Education Blueprint has defined the criteria of each school and presented the different focus of each school in preparing students for their specific purposes in the future including the technical schools.

Three main divisions in the Ministry of Education Malaysia worked together to manage the technical schools (Ministry of Education Malaysia, 2018). First is the Technical and Vocational Education Division that managed all the facilities, students' intakes, allocation of the yearly budget and the arrangement of the teachers in the technical schools. The second division is the Curriculum Development Division that focused on the planning, development, as well as to provide and review the curriculum for the technical schools. The third division is the Examination Syndicates for which they are responsible for the design, development, distribution and the conduction of the examination for the terminal examination or other related assessments. These three main divisions which have different tasks and focus had worked together to ensure that the technical schools are fully functioning. According to Gulic and Urwick (2004), the advantages of having separate divisions for specific purposes is that each division can focus on their area of expertise. While the disadvantages are it appears that there is some grey area of tasks where no division admits on taking the responsibility especially in conducting the fieldwork research on teaching and learning at technical schools. Since there has not been any statement from the ministry about the connection of task, very little is currently known about the gap of works that was observed in those divisions in managing the technical schools.

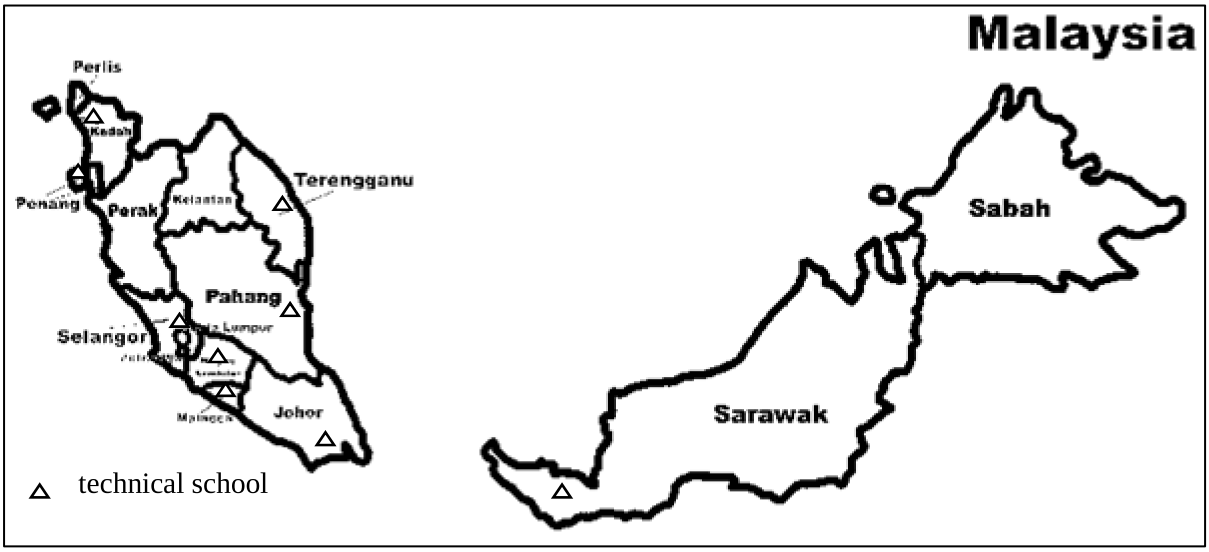
1.3 Technical school

Technical schools are boarding schools equipped for selected students to pursue their study in the field of engineering at the upper secondary level. The intake of students for the technical schools is based on the PMR or PT3 results (a terminal examination administrated to all form 3 students at the age of 15). The minimum result of C for four subjects (Malay language, mathematics, living skill and English language) is required to qualify students to enter the technical schools. Although the minimum requirement is C, most of the students enrolled in the technical schools gained entry with straight A's for all of the four subjects (Technical and Vocational Education Division, 2016). The competition to be accepted to the technical schools has become tougher each year because of the limited placement offered compared to the number of applications. From the total applications (only 20% of students have been accepted to study in the technical schools). As mentioned in the education blueprint that there are, mainly, male students that struggle with other electives subjects in the mainstream schooling system who would benefit better from getting better access to the technical school because of the nature of its related coursework (Bell, 2016).

The limited places in technical schools prevented this from occurring. The statistic showed that 90% of technical schools graduates pursue their studies in tertiary engineering education in polytechnics, matriculation colleges and other training institutions (Education Planning and Research Division, 2016). The remaining 10% of the technical school graduates continue to work in the industry as semi-skilled workers or they pursue their studies in other engineering fields. Over the years, the technical school transformations have shown that there has been a decrease in the numbers of technical schools. From the total of 91 technical schools established in 1994, only nine technical schools remain in the year 2018.

The other technical schools have undergone restructuring and rebranding to become a Vocational Colleges. This major transformation has occurred in stages from the year 2009 where the economic factors have influenced the educational system to provide more skilled workers (Kaur, 2016). It caused several changes of government focus on the sustainability of technical schools where it gradually converted to the Vocational Schools (at that time) and currently become the Vocational Colleges. The process continued until the year 2013 when the Blueprint is first announced, and the final process of transformation has signified the nine technical schools was preserved.

The impact of these transformation process is the decreasing number of schools offered the Mechanical Engineering Studies subject and the teachers who taught this subject has to teach other subjects like welding and machine shop in the Vocational Colleges. The remaining eight technical schools located in the peninsular of Malaysia (West Malaysia) and one in the island of Borneo (East Malaysia) have been maintained for the specific purpose which is to prepare students for future engineers (Education Performance and Delivery Unit, 2017). These technical schools have maintained the three main engineering streams which are mechanical, civil and electrical and electronic engineering. Figure 1.2 shows the location of all the current technical schools in Malaysia.



Source: adaptation from http://ontheworldmap.com/malaysia/malaysia-states-map.html

Figure 1.2 Illustrates the location of all nine technical schools in Malaysia.

The blueprint has categorised the technical education as a stream of education to prepare students for higher education and careers in the engineering and professional fields (Education Performance and Delivery Unit, 2016). It is recognised as part of the academic stream which often requires a strong academic foundation for many students who will be furthering their tertiary qualification. Students in technical schools have to study most of the same academic subjects as students in mainstream schools like additional mathematics, chemistry, and physics. They must also learn the engineering drawing subjects, and they could choose from a set of technical electives ranging from civil engineering, electrical and electronic engineering or mechanical engineering.

This study will investigate the Mechanical Engineering Studies curriculum in technical schools where the students between the age of 16 and 17 years old are undertaking the engineering studies in pursuing their upper secondary level schooling. One of the transformations for the technical schools that the ministry has suggested in the blueprint is on the improvement of the attractiveness and relevance of the technical education pathway. It involved a streamlining process for the technical elective options to a few critical areas including introducing the design and technology subject (similar to the curriculum in the UK).

However, action from the ministry to date has not yet provided any evidence of the effort in regards to the particular transformation. Additionally, the research regards the milestone for the transformation of the technical schools is still vague (Education Performance and Delivery Unit, 2017). Despite the intentions to improve the current engineering education in Malaysia, the aspects that not yet clear is the strategy from the ministry to evaluate the effectiveness of the current curriculum in the technical schools including the Mechanical Engineering Studies before any improvement can be made.

1.4 Mechanical Engineering Studies curriculum

The curriculum for mechanical engineering studies has been developed with the combination of three main components which are the 60% of practical, 20% of mathematical and 20% of theoretical elements (Technical and Vocational Education Division, 1994). Figure 1.3 indicates the distribution of topic in this subject where the practical work elements consist of the combination from the three main topics which are design, Computer Aided Drafting (CAD) and workshop practice. This curriculum has been designed to be taught at technical schools where all the facilities and machine has been provided. This curriculum as other engineering subject has been taught to the form 4 (16 years old) and form 5 (17 years old) students at technical schools. This subject is not taught at other National Secondary Schools because of the complexity of content in practical work elements which require specific workshop facilities and equipment.

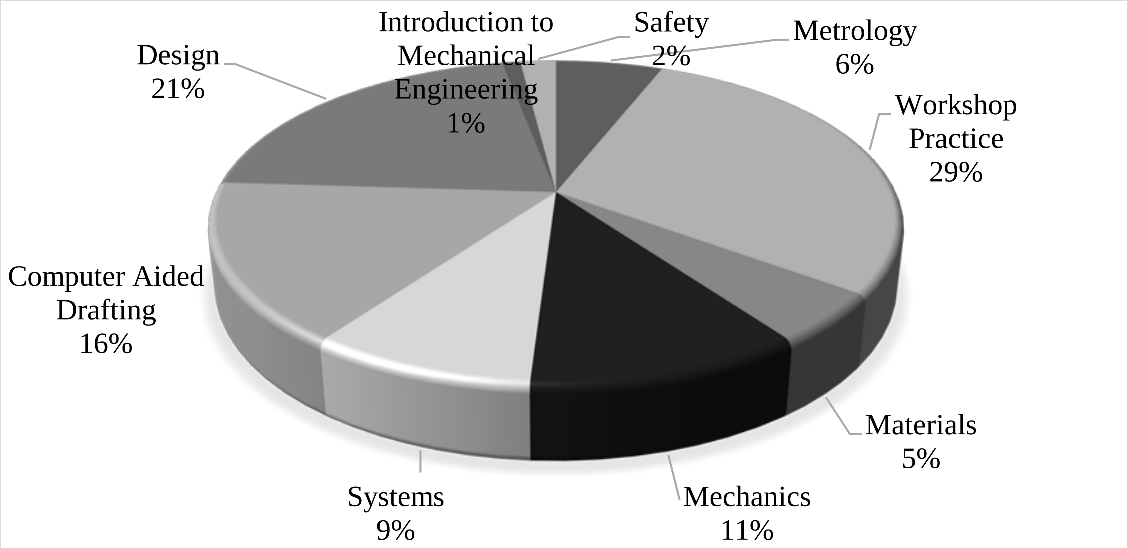


Figure 1.3 Illustrates the distribution of topic in Mechanical Engineering Studies subject based on time allocation per week in a formal education session.

Mechanical Engineering Studies is a practical-based subject, and the learning oriented has been designed for this purpose is the project work or the practical work. Table 1.1 (below) shows the practical work elements in the Mechanical Engineering Studies subject for form 4 and form 5. All of the topics and contents listed in the table is the component of practical work in the subject. This component has been classified into the category for form 4 and form 5. The table shows that the weight of practical work for form 4 is on the workshop practice while for form 5 is the design. The content in this table indicates the elements of practical work that written in the curriculum for both forms in technical schools. In additions, this information is essential to the development of the research instruments for this study where the focus in practical work for form 4 is more to the introduction of basic knowledge and the practical work for form 5 is focusing on the applications and advanced machining technology.

Table 1.1 Illustrates the practical work elements in the Mechanical Engineering Studies Curriculum Specification for Form 4 and Form 5.

Form 4	**Form 5**
Topic: Workshop Practice 1) Joining a) Types of fastener: Bolts, Nuts, Washers, Studs, Screw b) Riveting: Type of rivet, Round head, Pan head, Flat head, Countersunk, Conical head c) "pop" riveting: Device and process d) Soldering and brazing: Principles	**Topic: Workshop Practice** 1) Casting a) Introduction to casting: Types of casting, Sand casting, Die casting and Wax casting 2) Press work a) Introduction to press work b) Press work processes and example of press work 3) Advance machining

e) Gas welding and arc welding: Principles, Steps of arc welding, Devices and Safety 2) Cutting a) Cutting by division: Principle b) Cutting by chipping using hand tools: Types of hand tools and their uses: chisel, saw, file and Safety c) Cutting by chipping with machines: Types of machine, Drilling machine, Lathe machine, Milling machine and Grinding machine and Main parts of the machine, uses and safety	a) Type or machine, computer numerical controlled machine, wire-cut discharge machine, plasma cutting machine, laser cutting machine, principles, uses and advantages
Topic: Computer Aided Drafting (CAD) 1) Introduction to CAD 2) Differences between manual drawing and CAD 3) The advantages and disadvantages of CAD 4) CAD commands a) Start drawing, create object, view and edit, array, print/plot, open, save and exit from drawing file	**Topic: Computer Aided Drafting (CAD)** 1) Draw the design project 2) Full scale with dimensions
Topic: Design 1) Introduction to design a) Concept and Objectives	**Topic: Design** 1) Design Elements a) Design Process: Analyse problem, investigate, preliminary ideas, analyse preliminary ideas, refining, decision making, implementation b) The application of technologies: Selecting the appropriate application of technology example gear, belting and pulley, joints, wheels c) Structure: Rigidness of designed tool, size of tool designed, assembly and maintenance factor, safety, construction process such as cutting and joining materials d) Economy in designing: Materials and construction processes e) Material selection: Mechanical properties and physical properties f) Design compatibility: Aesthetic and ergonomic 2) Designing a) Producing designs b) Presentation methods of design produce

Source: *Mechanical Engineering Studies Curriculum Specification, 1994*

1.5 Research rationale

Studying the nature of the Malaysia education system, the author agreed that, it would take several years for fundamental changes to be felt. It makes the need for ambitious actions now both important and urgent. Tyler's model of curriculum development suggested that the construct of curriculum begins with the aims or objectives, and at the end of the teaching and learning process, it is important to evaluate the achievement of the objectives (Tyler, 2013). Tyler asserted that the development of objectives is necessarily the first step in curriculum planning because this is the most critical criteria for guiding all the other activities in the curriculum cycle. This formulation happens before the curriculum maker can continue with all the further steps of the curriculum planning (Laanemets and Kalamees, 2013). Despite the importance of the curriculum objectives, until recently, the mechanisms that underpin the process to determine the effectiveness of the elements in the curriculum objectives is not clearly explained.

According to Lam (2013), the effectiveness of the curriculum planning and the implementation can be improved by aligning the curriculum objectives with what is already implemented and learned in the school. The other important aim in education is to prepare students to succeed well in settings beyond the school (Soule and Warrick, 2015). However, what is happening instead in Malaysia is that schools and the education system are giving more focus in preparing the students to achieve good grades in their final examinations (Ozay, 2011). In many other countries, the terminal examination results have been used as indicators to measure the achievement of the curriculum. There is still uncertainty, however, whether the terminal examination is thoroughly evaluating or portraying the effectiveness of each of the elements in the curriculum (Missett and Foster, 2015).

In Malaysia, the statement of the curriculum objectives for the Mechanical Engineering Studies contain elements of both cognitive and affective domains. According to Creemers (2010), it is impossible to evaluate the affective domain in the terminal examination or by asking a question. Specific instruments and approaches are needed as indicators to determine the outcome of the affective domain (Kasilingam et al., 2014). Educators and policymakers in Malaysia are well aware that the purpose of engineering studies is to produce successful engineers in the future (Soleha et al., 2013). They are aware of the skills engineering students obtain during the education process and the importance of applying these skills as a preparation to becoming a good engineer in the future. Practical work has been included in most of the engineering curriculum at all level of studies as a workshop practice, where students would need to experience the hands-on work related to the topics they have learned in the classroom (Wenshan et al., 2017).

This engineering curriculum has been designed with clear objectives depending on the need of the country to achieve particular aims related to the policy and educational goals (Berland et al., 2013). Practical work is, from the author own experience as an engineering teacher, not only widely, but also frequently, used in the teaching of engineering subject in technical schools. The aims of practical work in engineering education is to familiarise students with the engineering tools, equipment, machines and techniques, to help student to remember the engineering terms and understand concepts and provide students with experience of different work roles that they are likely to encounter once they become a professional engineer (Technical and Vocational Education Division, 1994). However, little is known about practical work in engineering education in Malaysia, and as mentioned by the education officer for this subject it is not clear what factors caused practical work not to be fully implemented in the technical schools. Likewise, it is still not known whether or not the practical work is effective in enhancing the ability of students in specific criteria that is written in the curriculum objectives. These reasons derived a need to understand the various perceptions of practical work that exist among mechanical engineering teachers and students.

According to Skilbeck (1971) and Verhoeven and Verloop (2002), the statement of objectives is vital to ensure that what is taught in the classroom correlates and aligned with what is written in the curriculum. In many countries, the revision of the curriculum is undertaken continuously to ensure that it is relevant and current (Lam and Tsui, 2013; Plaza et al., 2007). Earlier research has shown that to increase the students' performance, the school, especially the teaching and learning process must be efficient (McDermott, 1991). However, there has been a deficit of research worldwide on the practical work in engineering education, its effectiveness and the link between the curriculum objectives (Bell, 2016; Halizah and Ishak, 2008; Jackson, 2013; Vries, 2011; Williams et al., 2015).

In Malaysia, since the curriculum for the Mechanical Engineering Studies was implemented in 1994, no research has been done to measure whether the curriculum has achieved its original objectives. Until recently, not a single research has been published or presented on the study of the engineering education at any schools level in Malaysia including the technical schools. Table 1.2 and Table 1.3 by Jayarajah (2014) is the review of STEM education in Malaysia between 1999 and 2013. The tables show the gap between the reviewed STEM education in Malaysia between 1999 and 2013. Table 1.2 indicates that only 12 out 95 (12.65%) from the total area of research in STEM education in Malaysia is in engineering education. This figure shows that the research in engineering education in Malaysia is limited, compared to other fields in STEM.

Table 1.2 Illustrates the summary of the number of studies in the STEM area from published research on STEM education in Malaysia between 1999 and 2013.

No	Research area	Science & Mathematics	Technology	Engineering	Total
1.	Teaching tool (ICT)	2	16	2	20
2.	Teaching & learning	10	6	3	19
3.	Learning strategies	2	7	1	10
4.	Gender	2	6	2	10
5.	Innovation	2	4	-	6
6.	Interest & motivation	4	4	-	8
7.	Assessment	2	4	-	6
8.	Problem solving	1	1	3	5
9.	TIMSS 2003 & 2007	3	-	-	3
10.	Other issues	-	7	1	8
	Total number of issues	28	55	12	95

Table 1.3 (below) shows that from the total of 58 participants involved in the overall reviewed, only 9 participants (15.52%) are in the engineering education field. Additionally, there is not one single study on engineering education at school level, and it led to predictions of limited information about engineering education at the secondary school level in Malaysia since no research has been published. Regarding this, the author realised that it is vital to contribute to knowledge in engineering education especially, at the school level. The development of students, as mentioned earlier, is the primary target of the Malaysia Education Blueprint and this blueprint has been designed to enhance the performance of the students and to overcome challenges in the Malaysia education system. It focused on evaluating the performance of the current education system with considerations of the historical starting points against international benchmarks (Bush et al., 2018). Likewise, the ministry has highlighted the need for equal access to quality education of international standards and to strengthen the quality of STEM education. However, until recently, there has been no research evidence that the curriculum in Malaysia is achieving the global standards (Education Performance and Delivery Unit, 2013).

Table 1.3 Illustrates the type and number of participants involved in the study on STEM education in Malaysia between 1999 and 2013.

No	Participant		Science & Mathematics	Technology	Engineering	Total
1.	Students (School	Pre-elementary	-	1	-	1
		Primary	2	2	-	4
		Secondary	9	3	-	12
2.	Graduates (University)	Under	6	13	8	27
		Post	-	1	-	1
3.	Practitioners	Teacher	1	3	-	4
		Lecturer	1	-	-	1
4.	Adults		1	6	1	8
	Total number of samples		20	29	9	58

While research in STEM education has been implemented and widely established in a few other countries such as the UK, the USA, and Australia for several years (Millar, 2010; Osborne et al., 2003; Pitt, 2009; Rammel et al., 2006; Tytler et al., 2008), limited research on STEM in Malaysia has been conducted until recently (Meng et al., 2013). To be exact, according to Jayarajah et al., (2014) only 57 articles on STEM education in Malaysia were published from 1999 to 2013. One of the biggest challenges is to identify the areas that the government needs to work on and how they can go about making any improvements. Hence, to implement changes for improvement in the Malaysia education system, meticulous efforts should be conducted in the broader perspectives and beyond just the national contact (Educational Planning and Research Division, 2015). This improvement is the principal rationale for Malaysia to develop more research on STEM education and at the same time, acknowledge successful methods on the teaching and learning in STEM in other countries that have been identified in its previous research.

The importance of measuring the effectiveness of practical work in the teaching and learning for engineering subject not only as a response to the blueprint but, it is part of the process in the curriculum development cycle (Tyler, 2013). According to Baker et al., (2008), the reflection on the effectiveness of the teaching and learning in achieving curriculum objectives by teachers and curriculum developers can contribute to the success of the subjects. The improvement of the education system is impossible to achieve if there is a lack of action taken in evaluating the present curriculum (Stehle and Spinath, 2014). Due to these reasons, this study is going to evaluate the specific aspect of education which is the practical work, and the achievement to address the curriculum objectives in engineering education.

1.6 Research aims

This research aims to investigate the effectiveness of practical work in achieving the curriculum objectives for engineering studies in secondary education in form 4 and form 5 technical schools in Malaysia. This study was conducted by evaluating the practical work teaching and learning session through the triangulation of data collection and the mixed methods data analysis of the practical work in the Mechanical Engineering Studies subject in Malaysia. The systematic reviews of the literature on the practical work in STEM secondary education from previously published research worldwide is the process to attain the international perspectives of the practical work in the STEM subjects in the secondary education. This study adopted the principle idea from Abrahams' and Millar's model (2008), which discussed further in 2.5.1as a guideline to explore a suitable approach to investigate the effectiveness of practical work that focused on the effectiveness of Level 1 (students do what teacher expects them to do). The main idea is to look at the intended and implemented curriculum objectives that have been rendered through lesson objectives at a specific practical work session (Morris and Hiebert, 2011).

Since the lesson objectives for the Mechanical Engineering Studies subject is a reflection of the effectiveness of Level 1 (student do what teacher asks them to do) rather than Level 2 (students learn what teacher expects them to learn), the case study considers the most suitable methodology to be implemented in order to identify the best solution to the problem. In this study, the focus is to observe the aspects of achieving the curriculum objectives and not to evaluate students learning outcomes. This study also focused on the element of practical work in the Mechanical Engineering Studies curriculum which is consist of 60% of the total curriculum content. The important to investigate the effectiveness is to classify the degree of effectiveness where at the end would help the curriculum developer on behalf of the ministry to measure the quality of teaching and learning and provide the suggestion for the improvement of the curriculum.

1.7 Research objectives

Based on the considerable gaps in the implementation of practical work in Mechanical Engineering Studies at technical schools in Malaysia, this study has determined three research objectives which are;

i. To investigate the students' and the teachers' perspectives on the effectiveness of the practical work in achieving the curriculum objectives for engineering studies in secondary education in Malaysia

ii. To evaluate the international perspectives of the effectiveness of practical work in achieving the curriculum objectives in STEM secondary education

iii. To understand the challenges of practical work implementation for engineering studies in secondary education in Malaysia

1.8 Pragmatist paradigm

Pragmatism is a new paradigm appear in research philosophy which has been agreed by most of mixed methods studies as a useful paradigm to support the mixed method research (Morgan, 2007; Rescher, 2000). According to Karafillis (2012) John Dewey, being one of the founders of the American philosophy of pragmatism. It is a well-developed philosophy for integrating perspective and approaches, offer an epistemological justification and provide a logical rationale behind the combination of methods (Martyn, 2008). Another characteristic of pragmatism for mixed methods research is that pragmatism included a wide range of theorists which is practical for the multiple research design. This study applied the concept of pragmatism of the middle, introduce by Johnson et al., (2007) which is useful to support philosophy for mixed methods. They believed that the concept of integrations in the pragmatist paradigm works between qualitative and quantitative approaches which allowed the studies of mixed methods to coexist with both philosophies peacefully.

The design of this study regards to the methodological, ontological, epistemological and axiological consideration in the pragmatist paradigm. Healy and Perry (2000), discussed ontology as the reality that is investigated by the research, epistemology is the relationship between that reality and the researcher, a methodology is a technique used to investigate that reality and axiology places a value to the reality. The author in this sense of philosophy believed that the pragmatism relies on multiple perceptions about a single reality. Below is the explanation of each aspect of the philosophical consideration of this research that emerges from the pragmatist paradigm.

1.8.1 The methodological consideration

Joel (2003) agreed that pragmatism prepared a path to a researcher on how research approaches can be mixed which believed that research approaches should be incorporated in ways that offer the best opportunities for answering important research questions. As outlined in the pragmatist paradigm, mixed methods research should use a method and philosophy that attempt to fit together the insights provided by the qualitative and quantitative research into a workable solution. Cohen et al., (2014, p.64) has suggested the characteristic of pragmatism in mixed methods research design was to include the integration of approaches, research purposes and research questions, sampling, instrumentation and data collection, data analysis, data interpretation, conclusions and reporting results. The design of this study took into consideration the most suitable approach which is the mixed method approach to answer the research questions.

Despite considering other established paradigms in educational research, the pragmatism is the best to represent this research because it allowed the author to determine what works to solve the problems and enable all forms of qualitative, descriptive and inferential statistics analyses (Onwuegbuzie and Leech, 2004). The methodology derived on pragmatist paradigm has been recognised as suitable for this study. The author placed a stand to acknowledge the pragmatism as the base paradigm for this research because of the suitability of pragmatism that worked to answer the research questions. Miller and Gatta (2006) agreed that the focus of mixed method is to resolve the issue on both epistemological and ontological consideration of pragmatism. It views the reality either as a single phenomenon that can be accessed by different methods separately or the reality is multiple in nature and can only be measured through a collaboration of methods. There is where the mixed method of data collection and analysis come together in the design of this research.

1.8.2 The ontological consideration

The ontological considerations in pragmatist paradigm accepted that the reality, meaning and knowledge are tentative and changing (Onwuegbuzie et al., 2009), which aligned with the development of a curriculum where the nature of the curriculum is dynamic and evolves. For over a decade, research by Vygotsky (1978) discussed the ontological perspective in pragmatism that recognised the education process as a human construct, rather than a static body of knowledge. This perspective allowed the study in education to become more subjective, and it is open to constant interpretation (Li, 2012). The main idea behind the ontology in pragmatism is that reality is subjective, and it needs more than just a single view. Dewey (1963), suggested the importance of the evidence-based findings to determine further action in demonstrating and understanding the reality. Pragmatism believed that for certain information, the perspective from different sources is needed. The author believes that the reality of the implementation of practical work can be observed through the information gathered from different sources which are the teachers and students.

1.8.3 The epistemological consideration

The epistemological consideration of pragmatist accepts that knowledge is both constructed and based on the reality of the world we experience and live in. Wellington (2000) believed that the reality is based on the construct from people and this view leads to the idea of understanding the real world from a different perspective by Goldkuhl (2012). According to Dewey (1909), the sense of reality can be constructed or formed through experiencing the environment. Dewey has observed that pragmatism offers a view of knowledge as demonstrated in action and the reflection of the action to address particular problems. This view means that what we know is tentative or fallible for it has been created in specific circumstances to meet particular ends and to express distinct values. This decision also puts pragmatism in a distinctive position about positivist and interpretivist inquiry where the data in the form of qualitative and quantitative can be interpreted to generate the findings.

Then, to understand the phenomena and to discover the truth, it is vital to observe the experience and develop social interaction with the students and teachers in the field of Mechanical Engineering Studies. After having taught engineering subject for five years, the author has recognised the weaknesses in the implementation of the practical work in the technical schools. This flaw is further observed through the author’s experiences in facing difficulties to determine the effectiveness of the curriculum after spending another five years in managing the curriculum and the examination of the Mechanical Engineering Studies at the ministry of education. Until recently, no suggestion method has been introduced to determine the effectiveness of the elements in the curriculum. For several years, the implementation of the mechanical engineering curriculum has its limitations, and the limitations remain as hearsay without any further investigation by the stakeholders (Educational Planning and Research Division, 2016). The statement of the objectives in the curriculum has become more tentative because of the way it is measured. It is through the author’s experience working in the field that has become the driving force behind this research to study the objectives of the mechanical engineering curriculum.

There are two aspects of epistemological in this study; first is the interest to do this research derived mainly from the author’s experience in the teaching and managing the Mechanical Engineering Studies subject and the author’s educational background. The second aspect is the focus of each design in the data collection process is to investigate the participants' experiences toward practical work in engineering education.

1.8.4 The axiological consideration

The axiological consideration is another element in which the author used to determine the design of this research. According to Killam (2013), axiology balanced and guided the researcher's values with belief to determine any ethical decision in conducting the research. Additionally, axiology focused on what the author value in this research and how to place judgement in research conditions. This value is significant because it affects how the author conducted the research and what kind of findings the author valued in this research (Creswell, 1998). The author has considered two aspects of axiology or values in pragmatism within this research which are the flexibility and fairness.

In certain circumstance, the nature of pragmatism gave flexibility to this research and allowed the author to develop the ideal research design to answer the research questions. This element has included the value in data collection process (the approaches to be applied that is fair to every participant, and flexible to maximise the gathered information), the setting of research has taken into consideration the availability of the participants, the most flexible approach that can be implemented, and at the same time did not interrupt the teaching and learning process while still generating as much information as possible. It takes an explicitly value-oriented approach to research that derived from the cultural values as well as the involvement of human as the participants (Guillemin and Gillam, 2004). Due to these reasons, the research design has taken into consideration the flexibility and fairness of every aspect to assure that at the end of the study the author would be satisfied and be able to value the findings as they are supposed to be.

1.9 Chapter summary

This chapter has provided an overview of the introduction of the research, followed by the research rationale, the aims and the objectives. The overall process is, explored the effectiveness of practical work in achieving the curriculum objectives, in which the focus to investigate the degree of effectiveness has been derived. Finally, this chapter concluded by laying out the basic dimensions of the research, as well as looking at how the pragmatist paradigm works in the methodological, ontological, epistemological and axiological considerations in providing a path to the design of this research. This chapter has introduced the essential information about the education system in Malaysia, the characteristic of technical schools and the content in Mechanical Engineering Studies curriculum regards to the element of practical work. The next chapter is going to discuss the review of related pieces of literature that emphasised the definition of terminology, the engagement of framework or model that emerged in the significance of research context and the development of the conceptual framework for this study.

CHAPTER 2: REVIEW OF THE LITERATURE

Structure of the chapter

This chapter presents a review and discussion of the literature relating to the research on practical work in STEM education, education effectiveness and the curriculum objectives of Mechanical Engineering Studies. This chapter discusses the implementation of learning engineering at secondary school as well as the framework for the K-12 engineering education. The first section provides current research on the practical work in STEM secondary education worldwide for the past ten years. It highlights the variety of research based on the experiences that students and teachers faced during the process of teaching and learning with regards to practical work for STEM subjects. The second section draws out the main themes that underpin the idea of this research which is investigating the practical work, the engineering education and educational effectiveness. This section also provides the rationale behind the studies on students' and teachers' perceptions in an educational aspect. The final section explores the research concerning more inductive parts of models and framework which emerged from the main themes which are the framework for K-12 engineering education. It provides a model for the process of design and evaluation of practical task, the Dynamic Model of Education Effectiveness and subsequently, Tyler's Model of Curriculum Development. It ends with the development of the conceptual framework that illustrates the relationship between different sources of literature. Identified gaps in the knowledge are then considered and used to develop the research questions. Finally, the limitations of the literature reviews are presented, and the chapter concludes with a summary.

2.1 Introduction to research background

This chapter reviewed and discussed literature relating to the main themes of the research. The purpose is for the author to understand the idea of previous studies that are relevant to this research and for the generation of research questions. The search strategy incorporated both educational and engineering database searched in an aim to capture both the education practice-based literature as well as that focusing on the more engineering aspects of human experiences. Search terms also included 'STEM', 'practical work', 'effectiveness', 'curriculum objectives' and 'secondary level engineering education'. Resources used for research include the search engine Endnote via an integrated library computer (an online search mode with a standard integrated interface link) as well as the Journal of Education and the Web of Science core collection. Besides, the use of other direct journal providers such as Elsevier, the Taylor & Francis online and the Sage publications has been utilised to explore current publication research simultaneously. These processes have been limited to the publications in the same themes and ideas only. The breadth of the literature suggested various terms with the same meaning and function existed in the research. Therefore, for consistency throughout this study, the following terms are used irrespective of the terminology used in a primary source unless as part of a direct quotation:

- *Practical Work* is the terminology for the experiment, laboratory work, workshop practice, inquiry-based learning, problem-based learning, a hands-on or other term related to learning by doing that widely used in secondary education.
- *Mechanical Engineering Studies* is the subject taught in technical schools students in Malaysia at the age of 16 to 17 years old (form 4 and form 5).
- *Dynamic Model Education Effectiveness (DMEE)* refers to the model that has been introduced by Creemers and Kyriakides (2006) and few series of research have proven to evaluate the effectiveness for most of the elements or factors in education.
- *Curriculum Objective(s)* refer to the statement of aims for each curriculum specification that students supposed to achieve at the end of the study.
- *Engineering Education* as part of STEM in this study refer to secondary engineering education that has been teaching in technical schools as part of elective subjects, and one of the subjects is the Mechanical Engineering Studies.
- *Blueprint* is referring to the Malaysia Education Blueprint 2013-2025 that has been announcing by the Ministry of Education Malaysia as the major transformation planning for Malaysia education system. This blueprint also provids the guideline for the criteria of improvement where one of the focused is to enhance the quality of STEM education.
- *Ministry* or *the government* is referred to the Ministry of Education Malaysia that is responsible for the development and management of the Mechanical Engineering Studies curriculum which provided the teachers and the facilities to encourage teaching and learning process at all technical schools.
- STEM (Science, Technology, Engineering and Mathematics) education, each subject focused on producing more experts and professional in a particular field.
- K-12 Engineering Education refers to the engineering subject or integrated engineering approaches that are taught at schools in the USA for students aged 4 to19 years old.

2.2 The systematic review

The systematic review is the analysis of previous research in the selected field (Andrews, 2005). Systematic reviews of educational research have been the focus of considerable debate in many educational research journals. This methodology according to Thomas and Harden (2008), is a protocol-driven and quality-focused approach to summarising the evidence in categorised research. Bennett et al., (2005) define systematic reviews of educational research as the process of answering specific review questions from published research reports by identifying relevant studies, characterizing these to form a systematic map of research in the area, extracting relevant data to establish the value of the findings, and synthesising and reporting the outcomes. According to Cohen et al., (2014) systematic review can combine qualitative and quantitative studies as long as both have a specific intersection in the topic. The most vital point to make about the presence of systematic reviews in education research is that this method presumed that existing knowledge is useful and can be synthesised (Thorpe et al., 2005).

It was mentioned by Clegg (2005), that the systematic review is the approach of gathering information using the consistency technique of incorporating findings with a similar purpose. The timeframe of the previous research is important in systematic review because it ensures the contents are relevant to current situations (Smith et al., 2011). This study acknowledges the vastness of previous ten years research on STEM with regards to practical work in secondary education only. The period of ten years as suggested by Stefan and Petri (2006), is the suitable duration to sustain a temporal validity for the findings in most studies on science and technology. Temporal validity refers to the extent of the findings and conclusion of the study is valid about the progression of time (Anderson and Filipe, 2003). The status of publication was not a constraint on this study, and it is limited to the research on practical work for STEM subject in secondary education only. This process provides the evidence to the ministry about the findings emerge from the studies worldwide that might suit the effort to enhance the quality of STEM education as outlined in the blueprint.

Bearman et al. (2012), addressed the systematic review as different from narrative reviews of literature because of the transparent, structured and comprehensive approaches to searching the literature and its requirement for formal synthesis of research findings. This approach according to Tranfield et al., (2003) is a baseline process of bridging the findings from previous research and the results from the main data collection in order to construct the body of knowledge or the genuine of research contributions.

Overall, this research has been designed with the application of mixed method analysis for the main data collection and to address the findings from previous research in order to suit the research aim. It then, makes the systematic review best conducted to bridge these two general structures of research and build the argument for further discussion (Shah and Corley, 2006).

The aim is to acknowledge previous research that might address the ten elements and sub-elements (see 2.9) in the curriculum objectives for Mechanical Engineering Studies syllabus. These elements consist of: the understanding of the terminology, the application of knowledge, the development of interest, the encouragement of creative thinking, the utilisation of the computer/workshop equipment, the awareness and application of safety regulations, the ability to solve problems, the increase of motivation, the meet of demand and finally, the creation of rational opinions. The results from this systematic review will also be presented in Chapter 6 as part of the conclusion and the discussion of the research.

Published reports have been classified as primary documents and are a further significant source of research evidence in education study (Cohen et al., 2014). It was mentioned by Song et al., (2003) that the systematic review of the literature will provide empirical validity to the findings in the case study. According to Reese and Rury (2008), the study of the history of education is drawn on historical, educational and social scientific methods and insights. The systematic review also, as suggested by Wragg (2012), is relative to the findings in research that can be generalised to other education contexts worldwide. The systematic review applies to this research because of the cumulative amount of existing study on practical work in STEM education in developed countries like the USA and the UK, and the source of the public report is easily accessible (Williams, 2011).

This process of documents analysis aims to explore the existing research in the field of engineering education, STEM and practical work in secondary education that have been conducted internationally. The purpose is to obtain the international perspectives of the effectiveness of practical work in STEM education for secondary education so that, the generalisation of the information toward underpinning the curriculum development in engineering education in Malaysia can be highlighted as outlined by the blueprint.

The data searching process included the keywords from all of the themes and sub-themes previously stated and the researching process also involved other term linked to practical work such as ‘experimental’, ‘workshop practice’, ‘project work’, ‘hands-on’, ‘experiential’ and ‘empirical’ with a primary focus on secondary STEM education (encompassing Sciences [science, physic, chemistry and biology], Technology [computer, design], Engineering [Mechanical, Civil, Electrical and Electronic] and the Mathematics [algebra, statistic] within the last 10 years. In order to manage these huge amounts of information, the searching process Endnote has been utilised due to its practicality and scientific reliability. This utilisation is related to what been suggested by King (2004), as the ability of software to work efficiently with complex coding schemes and large amounts of data, as well as simultaneously facilitating depth and sophistication of analysis.

It is vital to note that although computer programs are useful when organising and examining large amounts of information, it is incapable of the formation of intellectual and conceptual ideas (King, 2004 and Thorne, 2000). Due to this, the author is encouraged to utilise Endnote and as a further stage use the manual generation of data in the Microsoft Word for this process. The combination of multiple oriented analysis suggested by Crossan and Apaydin (2010) based on multiple case studies and fact-oriented in the systematic review process have derived the author's intentions to perform the cross-case analysis from the result in multiple case studies and the systematic literature reviews which is presented in 5.3.2. Table 2.1 shows the findings from the systematic review of the research and online publications on practical work in STEM secondary education for the past ten years. This table includes the information of the researcher and the publication year, the country that the study has been conducted in, the STEM subject involved as well as the focus and the findings from the study. All of the content in previous studies has been filtered, and the outcomes have been classified to suit the purpose of this study. Although there might have been more than one focus in the findings, Table 2.1 presents the significant outcomes to the contact of this study of the effectiveness of practical work which includes the challenges of implemanting practical work and possible suggestions for improvement.

The systematic literature search focused on the common issues addressed in previous research related to the achievement of the elements in the curriculum objectives. The table indicates that within the past ten years, only 23 studies have been published on the practical work for the secondary STEM education worldwide. From this amount, 20 research projects (86.95%) are related to science-based subjects, and only three were from non-scientific subjects (which included engineering education). To summarise, the findings indicated that although studies on practical work in the Sciences has been well established for several years, limited research has been conducted with regards to practical work at the secondary education level.

Table 2.1 Illustrates the available research and online publications on practical work in STEM secondary education between 2008 and 2018

	Researcher and Year	Country	STEM subject	Focus	Findings
1.	Dintsios, N. and Artemi, S. (2018)	Greece	Engineering	Students' acceptance of the implementation of remote experiments	The remote experiments are more effective than both hands on experiment and simulation experiment as students are involved actively in them
2.	Spernjaka, A. and Sorgo, A. (2018)	Slovenia	Biology	Examine differences in knowledge gained and learners' preferences for different technologies in biology laboratory work	Students achieve knowledge regardless if laboratory work is performed as traditional, computer-supported or virtual
3.	Chirikure, T., Hobden, P. and Hobden, S. (2018)	Zimbabwe	Chemistry	Assessing students' performances in practical activities to investigations the link with the quality of learning	A transformation from the traditional high stakes final examination to a school-based continuous assessment of investigations is needed to a greater emphasis on developing process skills
4.	Jones, A. L. and Stapleton, M. K. (2017)	United States	Science	Mobile laboratory programs provide active engagement by K–12 students in hands-on science activities that use authentic science tools promote student learning and retention	The access to hands-on science activities and exposure to authentic tools are key factors in improving student achievement in science
5.	Kind, P. and Kin,V. (2017)	England	Science	The investigation into the implementation of practical work regarding available resources, lesson time spent on practical work, types of activities used and	Although practical work in England is well-resourced and allocated significant lesson time, little clarity exists in reasons for undertaking it cause students experiencing little

				reasons for undertaking practical work	reflection and discussion about how science knowledge and inquiry occurs and relates to actual scientific practices
6.	Babalola, F. (2017)	Africa	Physics	Study on resenting position and an analysis of possible beneficial interventions to the teaching and learning of practical physics	Lack of practical physics in the schools, various resource constraints, ambivalent or negative teacher and pupil attitudes with prioritisation of 'theory' and a limited interest in awareness of the importance of inquiry
7.	Andersson, J. and Enghag, M. (2017)	Sweden	Physics	Investigate the relationship between the interaction and content of students' communication and outcomes of their actions during practical work	Positive significant relation appear and the suggestion a learning environment where students feel free to talk using both their everyday life language at the same time also encouraged to express themselves using physics terms in relevant activities
8.	Akuma, F. V. and Callaghan, R. (2017)	South Africa	Science	Characterise extrinsic challenges linked to the design and implementation of inquiry-based practical work	The challenges are material-related (facilities) and nonmaterial-related (such as time constraints and the lack of access to interactive computer simulations)
9.	Fan, S. C. and Yu, K. C. (2017)	Taiwan	Engineering Technology	Examine the effectiveness of the application of an integrative STEM approach within engineering design practices	Positive effect toward students acquire STEM knowledge and higher-order thinking abilities for solving complex problems
10.	Spaan, W. and Berg, V. D. (2016)	Netherlands	Science	Answer the question 'What design principles do teachers use when designing practical work?	Most teachers take great care to provide an appropriate degree of scaffolding, but they differ considerably in their view how much

					and which scaffolding should be provided. Clear differences arise when considering learning objectives
11.	Sund, P. (2016)	Sweden	Chemistry	Study of obstacles in assessing students' practical abilities	Individual and independent assessments are difficult due to the social interactions that take place and the physical sources of errors that occur in this type of setting
12.	Zezekwa, N. (2016)	Zimbabwe	Physics	The influence of practical work assessment method in developing practical work skills of advanced level physics students	Passing practical work through the assessment of practical work report did not necessarily mean that the student could have mastered the basic skills of manipulation, designing, observation and planning
13.	Martindill, D. and Wilson, E. (2015)	England	Science	Explore the use and value of practical work	Undertook practical tasks made greater gains in knowledge and understanding than those who undertook non-practical alternatives.
14.	Hinneh, J. T. and Nenty J. H. (2015)	Botswana	Science	Practical work, students' attitude and achievement in science	Practical work is important and enjoyable to students, but the experience cannot motivate them to want to learn science beyond the senior secondary level
15.	Philip, J. M.D. and Taber, K. S. (2015)	England	Biology	Exemplify the 'inquiry questions' and 'techniques' that could support minds-on practical work, by developing a scaffold that could be introduced to help learners engage with practical in	Suggest that the approach adopted here has the potential for being tested more widely in other science-learning contexts where teachers are concerned to encourage more 'minds-on' approaches to practical work

				both the domain of ideas and the domain of observable	
16.	Greulich, H. I., Flunger, B., Vollmer, C., Nagengast, B., Rehm, M. and Trautwein, U. (2015)	German	Science	The investigation into the effectiveness of a lab-work learning unit to students' motivation and achievement	Positive effects of lab-work education on state motivation, achievement (in-school learning), and although less pronounced trait measures of motivation (out-of-school learning)
17.	Abrahams, I., Reiss, M. J. and Sharpe, R. M. (2013)	England	Design and Technology, Geography, Modern Foreign Languages and Music.	The assessment of practical skills in non-science subjects for examination purposes in the UK by make use of personal communication to understand better both the practices and principles of assessment	For some subjects, notably music, modern foreign languages and design and technology, direct assessment of these skills is given much more weight than in science
18.	Abrahams, I. and Reiss, M. J. (2012)	England	Science	The effectiveness of practical work in primary and secondary schools in England	Suggest that practical work might be made more effective, regarding developing students' conceptual understanding teachers adopted a more "hands-on" and "minds-on" approach and explicitly planned how students were to link these two essential components of practical work
19.	Toplis, R. (2012)	England	Science	Students' views about the role that practical work plays in their school science lessons	The hands-on practical work can enhance students learning, able to increase a sense of ownership and effective in the role of scientific inquiry as a component of a practical activity

20.	Banu, M. S.(2011)	Bangladesh	Physics	The role of practical work in teaching and learning physics at the secondary level	The practical work is important to assist students to understand physics concepts and theories better than lecture style teaching
21.	Abrahams, I. and Saglam, M. (2010)	England and Wales	Science	Examined whether there had been any changes in the relative importance of the aims science teachers assigned to the use of practical work	Although many changes in the educational system in England and Wales during the last 46 years including the introduction of a National Curriculum teachers' views about the aims of practical work for pupils in key stage 3 have remained unchanged
22.	Abrahams, I. (2009)	England	Science	Examined whether practical work can be said to have affective outcomes	Practical work generates short-term engagement, it is relatively ineffective in generating motivation to study science post compulsion or longer-term personal interest in the subject, although it is often claimed to do so
23.	Abrahams, I. and Millar, R. (2008)	England	Science	Explored the effectiveness of practical work teaching and learning strategy	Generally effective in getting students to do what is intended with physical objects, but much less effective in getting them to use the intended scientific ideas to guide their actions and reflect upon the data they collect

Nine studies have been conducted in the UK (mostly England), six from European countries, five from African countries, two from Asian countries and one from the USA. Although many studies on STEM education was conducted in the USA, it neither focus on secondary education nor investigates the practical work element. While searching for previous research, the author found that in Malaysia, research in STEM education is minimal and indeed not widely published. This reason encouraged the author to explore the existing research on STEM education in other countries and investigate the outcome of those research which can be adapted to the Malaysia educational system. As seen earlier in Table 1.5, there are several studies on engineering education in Malaysia. However, none one of these studies have been conducted at the secondary level and furthermore, are not related to practical work.

Only three studies have been published on practical work in engineering secondary education worldwide in the past ten years (result in Table 2.1). Systematic literature reviews have indicated that there a few common researchers in practical science such as Ian Abrahams who has contributed to 5 research projects on the practical work at secondary STEM education. The author while conducted the systematic review found his established research on the practical work in higher education that not appear in the table. The study by Ian Abrahams and Robin Miller in 2008 focused on investigating the effectiveness of practical work and its link to the students' knowledge, which found that practical work successfully aided students in doing what their teacher had asked them to do, but not help them to retain what their teacher had taught them. The following year, Ian Abrahams published a study that focused on the impact of practical work on the students' motivation and interest. The findings indicated that the practical work was ineffective in generating motivation and did not promote longer-term personal interest in the subject event, although students claimed otherwise.

This study was partly based on the students' perspective, but, it took into account the observations from the researcher and the comments from the teachers in order to uphold consistency (Abrahams, 2009). However, that is not to say that the students' perspective is not relevant in education research, but merely which the findings of this study appear to contradict the students' self-claims. In 2010, the collaborative study with Saglam had evaluated the change of teacher's view on the aims of practical work where the findings showed that the teachers' view had remained the same, even though the education system has changed in the past several years. Research conducted in 2012 suggested the need for action regarding implementing effective practical work in schools. This study recommended a few practices which included hands-on and theoretical approaches.

All this while, the research on practical work has focused on science subject until research by Abrahams et al., (2013) has been analysed practical work in conjunction with four other subjects which are the Design and Technology, Geography, Modern Foreign Languages and Music. This study depicted Science as an interdisciplinary subject and showed the significance for assessing the practical skills for non-science subjects in order to ascertain the importance of practical work for other subjects. The result indicated that the weighting of assessment for practical skill in Design and Technology, Modern Foreign Languages and Music is higher than science subjects in the UK. Design and Technology are comprised of engineering education, taught at the secondary schools in England. This subject has similar characteristics with the Mechanical Engineering Studies taught in technical schools in Malaysia (see Table 1.1).

The findings from the study by Abrahams et al., (2013) presented the importance of practical work in engineering education that can be used as part of the discussion in Chapter 6. Other studies on practical work in engineering education at the secondary level have been conducted by Fan and Yu (2017) in Taiwan and the latest by Dintsios and Artemi (2018) in Greece. Both studies have different purposes. In Taiwan, the focus was to assess the effectiveness of the application of STEM integrated within engineering design practice, whereas the study in Greece was to investigate the students' acceptance of the implementation of remote experiments. Similarly, these two studies both considered the students' perspective in generating the findings. Both studies showed a positive impact toward using the STEM integrated approach in engineering design and remote experiment in implementing the practical task.

Despite the study in engineering education, there are more studies established in sciences subjects including Biology, Chemistry and Physic that are relevant to the contact of practical work in secondary education. An example of this can be found in Banu (2011), a study in Bangladesh which indicated the importance of practical work in order to encourage students' conceptual and theoretical understanding of the concept of Physics. Another study in England by Toplis, (2012) has suggested that practical work is effective with regards to enhancing student learning, increasing their sense of ownership within their subject and developing the scientifically inquiring mind.

A study in Germany by Greulich et al., (2015) indicated that practical work has a positive effect on a students' motivation inside or outside the school environment. The same study suggested that practical work can increase students' achievement in the Science subject. Similar results have been indicated in the latest study by Martindill and Wilson (2015) in England; Jones and

Stapleton (2017) in the USA where practical work has a significant impact to the achievement of students in science. These types of studies have a specific purpose which is to test the students' knowledge before and after undergoing practical work. The research designs differed, yet their purpose is to assess the impact of practical work on the students at secondary education.

Most of the findings mentioned in this systematic literature review are related to the elements in the curriculum objectives for Mechanical Engineering Studies. There are also studies on the challenges and characteristics of practical work in certain African countries. A clear example of this is the work by Akuma and Callaghan (2017); Babalola (2017) which indicated the limitation of facilities, time, materials, the teacher and students' beliefs and their attitudes towards Science subject. All these studies indicated that current international research has acknowledged the importance of practical work in different aspects of education and most of the studies have been conducted for sciences subjects.

This systematic literature review has indicated the pattern for the latest studies in practical work, focusing on the transformation from traditional hands-on practical work to mobile laboratories or remote experiments by utilising the technology (Chirikure et al., 2018; Dintsios and Artemi, 2018; Spernjaka and Sorgo, 2018). Due to the significance of findings towards practical work in Science subjects, and insufficient research regarding practical work in engineering education, especially in secondary schools, this study will adapt and expand on the findings from Science studies worldwide to investigate the effectiveness of the implementation of practical works in achieving each element in the curriculum objectives for the Mechanical Engineering Studies subject in technical schools in Malaysia.

2.3 STEM education

STEM is an acronym which describes the study of science, technology, engineering, and mathematics (STEM), its original derivation is accredited to Judith Ramaley (Christenson 2011; Koonce et al., 2011). Research on STEM education has been widely established for several years, and the focus is varied from one to another. In Malaysia, published research on STEM education is limited. Due to that, the author has to generalise the findings from other research on STEM worldwide. The generalisation also applies to the research in engineering studies (which is part of STEM) at secondary education. Osborne, (2013) outlined that the 21st century challenges for science education are also applicable to engineering education. However, as has occurred elsewhere (Benken and Stevenson, 2014; Cavanagh and Trotter, 2008; Kelly, 2010), in the United Kingdom policy is unequal and frequently negates to consider the importance of technology and engineering's fundamental role in STEM education, focussing primarily only on mathematics and science. This issue does not only happen in economically more developed countries such as the UK and Australia, but it also occurred in Malaysia education where the engineering and technology is not the priority of STEM. Research has shown that STEM subjects are vibrant, engaging and exciting, but somewhere along the line students are being stopped in their droves because they are disengaged with study beyond compulsory schooling (Christensen et al., 2015).

The author agrees that engineering education has much to offer in STEM education and presented opportunities for practice-based activities (Moye et al., 2014), where pupils are engaged in practical problem solving, and as such is a logical subject which delivers 'True STEM education' (Gomez and Albrecht, 2013). There is a persistent failure to recognise the value of this potential (Dillon, 2008). Knezek, (2015) also suggested that multiple approaches for connecting early interest in and the pursuit of STEM careers included project-based and hands-on learning that involved personal and real world relevance that offered in engineering education. However, most research conducted on integration is focused on other STEM subjects, and less on engineering education (Barlex, 2007; Bell, 2016; Pitt, 2009; Sander, 2009; Williams et al., 2015).

The importance of engineering in STEM education is below expectations, as studied by Thomas and Watters, (2015) STEM education in Malaysia also focused on science which indicated that science teachers must be capable of changing the personal biographies of learners for developing scientific conceptual information in the teaching and learning process. The same study suggested that Malaysia and Australia need to provide opportunities for students to access different curricular programmes of knowledge based constructivist learning for different levels for learner competencies which included engineering studies. There is a study which suggested the fundamental of STEM knowledge should be utilised across the curricula to allow students to learn beyond the syllabus (Rammell et al., 2006). This idea has been used by the author to look into the research in STEM education as a core that can be represented by any related subject within the group, and the findings from the research on other fields in STEM are relevant to each other.

2.4 Engineering education

Engineering education is the component of STEM education has been recognised in many countries around the world as one of the academic streams that have been taught at different levels with a similar purpose to prepare the future engineer (English et al., 2009). Previous studies on the engineering education at university level have defined it as the presentation of knowledge, skills and attitude towards preparing students for engineering fields (Borri et al., 2007; Brophy et al., 2008; Johari et al.,2002; Rompelman and Devries, 2002; Rugarcia et al., 2000). According to Johari et al., (2002) to ensure the development of industries and infrastructures of the country, engineering education must be able to produce excellent engineers. Research estimates that by 2020, Malaysia will require 200,000 engineers compared to the current number of approximately 75,000 registered with The Board of Engineering Malaysia (Soon and Quek, 2013).

However, OECD (2013) reported that the skill based on the workforce in Malaysia had been left behind in comparison to international standards. Lockheed et al., (2015) have stated that Malaysia is one of the middle-income countries that is encouraged to take action in order to improve its education system. This aspiration aligned with the interest of the government to maximise student performance for engineering education as the government have allocated a large amount of money to fund equipment, machines, tools, materials and teacher training (Educational Planning and Research Division, 2015). Thus, engineering education has to comply with the purpose of STEM education as described by Williams (2011), to prepare a STEM skilled workforce for growing economies. STEM education strategies are designed to develop a reliable supply of scientists, engineers, technologists and mathematicians (Department for Education and Skills, 2006).

As mentioned earlier, even though the practical work is the major element in engineering education at all levels, insufficient research has been done worldwide to determine its effectiveness. This research has investigated the importance of practical work in achieving the curriculum objectives for engineering education regardless to argue or to accept previous research on STEM education that acknowledged science and engineering have their own significant congruent. The debate and discussions about the significance in both subjects have brought the studies of practical work in science as the principal reference of this study based on the command criteria which occurs within both areas and the lack of research in engineering studies at secondary education. Davies and Gilbert (2003) in connecting science and engineering education found a high degree of epistemological congruence between these two subjects has developed a consistent approach to the promotion of the thinking skills.

Kimbell et al., (1991) found that science and engineering education having suitable experiences of the phenomenon or problem. Engineering education consists of establishing the nature of the problem which needs to be solved, together with gathering any clues as to what might constitute an efficient and effective solution (UNESCO, 2010). The practical work in Malaysia engineering education involved the workshop practice for form 4 and the project design for form 5. According to the International Technology Education Association [ITEA] (2009), the engineering design involved complex decision-making and problem-solving process. It required the application of scientific, mathematical, engineering, and technological knowledge to use resources optimally for solving problems.

Additionally, during the engineering design process, higher-order thinking abilities are indispensable for analysing problem factors, predicting the feasibility of different solutions, evaluating results, and optimising the solution. In summary, the competency that engineering education seeks through the teaching of engineering design is to help students gain flexible problem-solving capabilities and STEM literacy. Based on these previous studies findings that students attained in the practical work for engineering education, this study investigates the level of effectiveness of practical work and at the same time is acknowledged the importance of practical work in engineering education in Malaysia.

2.4.1 Framework for K-12 engineering education

Engineering in K-12 classrooms has been receiving expanding emphasis in the United States which is evident from the rising number of K-12 engineering courses and the development of new K-12 engineering curricula (Valtortaand Berland, 2015). The original framework introduced by the National Academy of Engineering and the National Research Council in 2009 as a fundamental concept to guide the implementation of engineering education for K-12 students. Ever since few works have acknowledged the approaches in STEM education until Moore et al., (2014) have finally suggested a framework of quality K-12 (student age 4 to 19) for engineering education with a specific key indicator in determined the standard for engineering education at this level. The framework for quality K-12 engineering education started to implement in the USA, and the research outputs from these areas have focused on the curriculum content of engineering education (Moore et al., 2014).

The framework has 12 key indicators that, when taken together, summarised a quality engineering education for all students throughout their K-12 education. The indicators are, processes of design, problem and background, plan and implement, test and evaluation, apply science, engineering and mathematics, engineering thinking, conceptions of engineers and engineering, engineering tools, issue solution and impacts, ethics, teamwork, communication related engineering. Those are the key quality of engineering students to be achieved at the end of their study. The Mechanical Engineering Studies curriculum also outlined most of this quality of engineering education from several years (Technical and Vocational Education Division, 1994), and this is the opportunity to improve the quality of written curriculum by including relevant key indicators from the significantly related framework. The order of the key indicators within the framework was carefully chosen based on the degree to which the indicator is unique or central to engineering as compared to other disciplines. Key indicators that appeared near the beginning (e.g., Processes of Design) are thought to be defining characteristics of engineering. However, key indicators that appeared later (e.g., teamwork), although essential for engineering, are concepts that are required for success in multiple disciplines.

According to Chandler et al., (2011), clear distinctions were made between the key indicators of the framework for evaluative and knowledge building purposes, although in reality many of the indicators and their uses are overlapped. The distinctions were made to help users understand how engineering is multifaceted, not to place value or pass judgment on different aspects of engineering education (Carr et al., 2012). The framework also has used as an evaluation and development tool for policy and research regarding K-12 engineering and STEM education in the USA where the framework has been used to assess the current status of engineering in all 50 U.S. state's academic science standards (Moore et al., 2013).

It is also being applied to the national career and technical education standards to gain a picture of how engineering is currently represented in their K-12 educational system (National Research Council, 2011). This framework also, intended to ensure a quality engineering education throughout students at K-12 education. However, according to Roehrig et al., (2012) not every lesson or unit that a student encounters in engineering education needs to address every key indicator of the framework. It is the overall process that reflects the indicators depending on the focus in the engineering classroom.

Table 2.2 shows the importance of practical work either in achieving the curriculum objectives or in addressing the elements in the framework for quality K-12 engineering education. The table indicates that practical work in technical school has a quality that supports the criteria outlined in the framework for quality K-12 engineering education. The indicators compared to the achievement of the curriculum objectives for Mechanical Engineering Studies are reflected in Table 2.2 below.

Table 2.2 Illustrates the relative of a characteristic in the quality K-12 engineering with the application in practical work for Mechanical Engineering Studies to the achievement of the curriculum objectives.

Quality of K-12 engineering	Curriculum objectives (CO)	Application in practical work
1. processes of design	CO4	Experience the process of design in practical work for form 5 and undergo all the process of design until completed the project
2. problem and background	CO7	Preparing for the folio for form 5 project work regard to the background information they have and create a product in order to solve the problem
3. plan and implement	CO1	Reporting the plan of a project and implement the project work to develop the prototype
4. test and evaluation	CO2	Testing the prototypes of their product and evaluate the factors that influenced the design including the selection of material
5. apply science, engineering and mathematics	CO2	The practical work for form 4 require students to combine their knowledge of science, mathematics and engineering to prepare the workpiece that included measurement and metal
6. engineering thinking	CO3	Practical work encourage engineering thinking among students while preparing for their task
7. conceptions of engineers and engineering	CO3	The introduction of engineering concept and preparation for the demand on mechanical engineering fields
8. engineering tools	CO5	Students utilise tools, machine and engineering equipment to complete their project work
9. issue solution and impacts	CO4	Students become creative in finding for a solution to the problem when they face the difficulties in the practical task

10. ethics	CO6	Students value safety and provide their ethical consideration while designing the product
11. teamwork	CO6	Students show good teamwork in presenting their work and during the delegation of work in the workshop.
12. communication related engineering	CO4	Part of practical work allowed students to communicate with others by providing rational opinions

This table indicates that all elements in the curriculum objectives for mechanical engineering education which addressed in the investigation into practical work at technical schools have a relation to the established framework for quality of K-12 education. It shows that by experiencing practical work, students are preparing themselves to meet the criteria as a high quality engineer in the future. It has indicated that the curriculum for Mechanical Engineering Studies is highly reliable on the stage of students at the age of 16 to 17.

Additionally, the framework for K-12 engineering education indicated the link to the curriculum for Mechanical Engineering Studies on the similar characteristic that both components partake in the engineering education field. The curriculum objectives for mechanical engineering study has been developed since the year 1994, and the instruction for quality K-12 engineering education appeared in the United States 15 years later in 2009. The significance of these two documents is the content which included similar elements regarding estimation outcomes and indicators for quality engineering students at the same level. This study has concluded that the importance of practical work is to provide most of the elements in order to produce the quality of future engineers as outlined by the framework for quality K-12 engineering education and, to comply with the quality of education that has been inspired by the ministry in the Malaysia Education Blueprint.

2.4.2 Engineering education at secondary school

Previous studies suggested that engineering education should start at an early age (Oware et al., 2007; Shuman et al., 2002) and the secondary school has been identified by (Brophy et al., 2008; Tafoya et al., 2005) as a pivotal period for the development of students in mathematics and science, and mostly, their interest in engineering as a profession. The research on engineering education at school levels in countries like the USA, the UK and Australia mostly relates to the knowledge and skills to be included in the curriculum and the integration with other subjects (Brophy et al., 2008; Douglas et al., 2004; Moore et al., 2014; Pearson and Young, 2002; Tytler et al., 2008). In particular, as synthesised by the National Academy in a review of K-12, it is expected that engineering education will focus on design and problem solving, incorporating appropriate STEM concepts and promoting engineering practice (National Academy of Engineering and National Research Council, 2009). In Malaysia, Mechanical Engineering Studies subject consists of the knowledge and skill to prepare students to become a successful engineer in the future (Technical and Vocational Education Division, 1994). It was also mentioned that a stronger education system and more capable teaching force would meet the economic challenges of a rapidly changing and diverse world (Gottlieb, 2015).

The primary challenge faced by educators and experts in engineering education worldwide is to develop the quality engineering students and to prepare the effective teaching and learning process (Becker, 2010). While searching for the literature on previous studies, the author found that, it has become a global issues that much has been widely discussed in recent years about what action that needs to be taken to respond to the challenges that engineering education faces in preparing students for careers as practising engineers (Fortenberry et al., 2007; Karatas et al., 2010; Shuman et al., 2005; Wulf, 2002). It seems like the quality of engineering education fundamentally needs to be developed (this research will refer to a secondary school context). In the curriculum documentation of Mechanical Engineering Studies, the element and sub-elements in the curriculum objectives have emerged 90% of the key indicator in this framework. The statement of curriculum objectives complied with the quality for K-12 engineering education since the introduction of this syllabus in 1994. The main intentions of this study are to investigate, whether or not the actual implementation of the Mechanical Engineering Studies sincronises with the written curriculum and reflects the key indicator in the K-12 engineering education after 24 years of teaching in technical schools.

2.5 Practical work

Practical work is recognised as experiment-based, workshop, laboratory work and hands-on training (Hacking, 1983; Hodson, 1990; Lunetta et al., 2007; Millar, 2009) and practical work in engineering education is also known as design, project work, collaborative work and hands-on activity (Carlson and Sullivan, 1999; English et al., 2009; Felder et al., 2000; Moore et al., 2014). As part of the teaching and learning process, practical work is defined by Millar (2004), as any teaching and learning activity which, at some point involved the student observing or manipulating the objects and materials they are studying. Different views have been produced earlier on the role of practical work, for example, to increase the performance of students, to motivate students and to increase a sense of ownership among students (Hodson, 1991; Osborne, 1993; Wellington, 1998). A further definition is given by (Lunetta and Tamir, 1979; Millar et al., 1999) who describe practical work that is of an activity which included different types of aims and objectives. Other studies have indicated the objectives of practical work in school science in the circumstances customised to certain countries (Allsop, 1991; Bekalo and Welford, 2000; Claxton, 1991; Hodson, 1996; Millar and Driver, 1987; Nott, 1996).

Research by Holman et al., (2014) has reported that in the six countries that were visited as part of the study (in which Science subject is highly important in education systems), the practical work was fully implemented and much valued by individuals (including parents, teachers and students). This study highlighted the possible approaches for teachers, schools and ministry to encourage the engagement students with practical science. Their study involved the investigations in the USA, Germany, Australia, Singapore, the Netherlands, and Finland and was then benchmarked against data from the UK. Their study has suggested three main findings which are significant to apply in other subjects in STEM education. Firstly, the findings indicated that the construct to prepare the best practical scientific learning is dependent on the teachers' expertise, well-organised lessons plans and technical support. Secondly, this study also suggested that it is the responsibility of the government to provide a supportive environment for schools to implement practical tasks. Thirdly, sufficient allocation of budget, the supply of specialist or well-trained teachers and (most importantly) a reliable education system that promotes teaching and learning beyond exams alone are vital.

Hodson, (1990) provided a list for the effective of practical work in school science. It has been mentioned that the comprehensive learning objective is important for the success of the practical work. The design of specific task for particular objectives should be the main focus in learning practical work, and the appropriate teaching strategy is used to stimulate the students' thinking beforehand so that the practical task is answering a question that students are already thinking. The same study by Hudson suggested five purposes of practical work which are to enhance the learning, to teach the skills, to develop the attitude, to create expertise and to motivate the students by stimulating interest and enjoyment. All of these purposes have become the consent of the development of an instrument for this study where most of these items included in the demographic questions.

Dillon (2008), has classified the practical activities into three broad groups which are the core activities, directly related activities and complementary activities. The practical work in

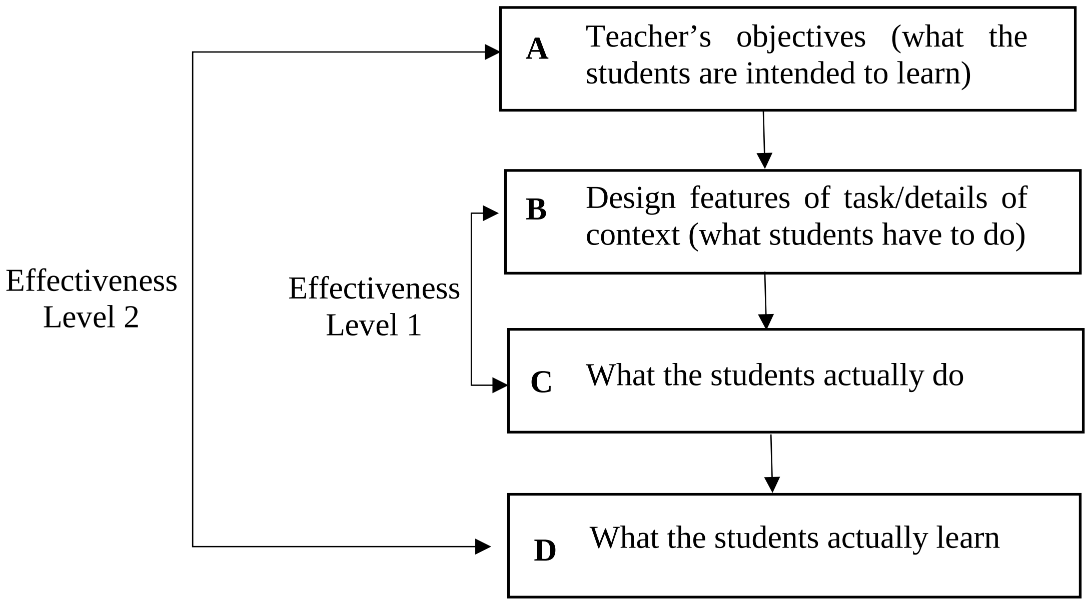
Mechanical Engineering Studies included core activities (investigations, fieldwork, workshop procedures), directly related activities (designing and planning investigations and teacher), complementary activities (presentations and role play, simulations including the use of ICT, models and modelling, group discussion and group project). Additionally, practical work has been mentioned by several studies that can promote skill in manipulating instruments and objects that cannot be achieved through other methods of schoolwork (Chen, 2014; Hofstein and Lunetta, 2004). They listed the advantages of practical work as it engaged and provided the students with real-life and genuine hands-on experiences while students can also acquire knowledge and experiences actively via individual or collaborative work.

Research by Spernjak and Sorgo, (2009) has listed the disadvantages of practical work such as the impossibility of hastening or delaying reactions, the possibility of injury, it can be time consuming with regards to collecting results and making notes, and in some instances, there can be a low level of reliability of results. Due to these strengths and weaknesses, in a certain sense, the author found that there is a gap in understanding the importance of practical work in engineering education while encountering the pros and cons of this process. Recent research on practical work that has been conducted worldwide and focused mostly on science subjects (Abrahams et al., 2013; Abrahams and Millar, 2008; Abrahams and Reiss, 2012; Bekalo and Welford, 2000; Dillon, 2008; Philip and Taber, 2015; Walsh et al., 2010). However, very little research has been conducted on practical work in engineering education even though the practical work has been identified as the most important element for this subject (Burghes et al., 1996; Halizah and Ishak, 2008; Hendley and Lyle, 1995; Moore et al., 2014).

2.5.1 Model of the effectiveness of practical work

The literature search has found limited models which contextually explained the effectiveness of practical work. Existing education models have limited the discussion on the practical work in the contact of application (Tamir, 1991). The original theory that has been explained by Abrahams (2011, p.51) on history relies on the implementation of practical work in secondary education in England. The earlier study by Abrahams and Millar, (2008) offered a comprehensive empirical analysis of the effectiveness of practical work in science education by providing the model of the process of design and evaluation of a practical task. The study attempted to assess the effectiveness in two domains (observable and ideas) during practical lessons. In the domain of observables, they compared what students were asked to do with what they did and in the domain of ideas, they sought to compare the learning the teacher intended with the actual learning that took place. Abrahams and Millar concluded that most practical lessons were conducted within the domain of observables, and thus missed the opportunity to develop a conceptual understanding to the students.

Philip and Taber, (2015) believed that the other reason for the conduction of the domain of observables is the misconception from the teachers. The teachers assumed that exposing students to the phenomena in the domain of observables would automatically lead to them developing the critical concepts in the domain of ideas which is not indicated to work that way. Figure 2.1 is the model of the process of design and evaluation of a practical task. This model shows that the effectiveness can be categorised into two Levels. Level 1 is the outcome for the domain of observable and Level 2 is the effectiveness emerges from the domain of ideas. The author found this model is significant to be adopted in this research because most of the practical work lesson conducted in Malaysia technical schools have relied on the domain of observable (see Table 1.1). It can be seen from the statement of a lesson's learning outcome for practical work session which most of the content measure the students' action at the end of the practical work lesson.



Source: Abrahams and Millar (2008)

Figure 2.1 Illustrates the model of the process of design and evaluation of a practical task by Abrahams and Millar.

2.5.2 The effectiveness of practical work in engineering studies

Some studies have found that effective teaching appeared where teachers evaluate their school of thought in order to consider the opportunity for improvement (Gurney, 2007; Hudson, 2006;

Hudson et al., 2009; Lenton and Turner, 1999; Luehmann, 2009). A study by Frekjmr et al., (2000) revealed that effectiveness could be estimated by evaluating the outcome of the process. The previous studies have found that effective teaching and learning in STEM are influenced by the active engagement of students (Felix and Harris, 2010; Gattie and Wicklein, 2007; Norton, 2008; Rogers, 2005). As Millar and Abrahams (2009) mentioned, for practical work to become more effective, a clear understanding regarding the purpose of each activity and suitability method must be applied.

Another research by Lewthwaite (2014) indicated that attractive and active student-centred strategies resulted in better achievements and higher order knowledge than passive ones. Among active teaching methods in Biology and Science education, it appeared that one of the most important teaching methods is practical work (National Science Teachers Association, 2003). According to Tiberghien (2000), practical work is the experience of helping students make links between cognitive and affective domains of knowledge which are included in most curricula. Ariosi and Frabboni,(1983) has written about specificity and objectives of engineering education and stated that cognitive objectives regarding knowledge and skills should be mentioned clearly in the curricula. The objectives of practical work are different from one subject to another depending on the policy and purposes.

Another study by Reiss et al., (2012) has shown that practical work is not confined to science alone but that there are other subjects where practical work is assessed including in engineering subjects. Recent study by Bell, (2016) indicated that engineering studies have much to offer as part of STEM education, and it presented opportunities for ‘doing’ practical based activities (Moye et al., 2014), where pupils are engaged in practical problem solving, and as such is it a logical subject area through which to deliver ‘True STEM education’ (Gomez and Albrecht, 2013). Some authors do not distinguish between attitudes towards science and engineering/ technology, treating them as a single entity (Perry and Fuller, 2002). Additionally, Karatas et al., (2016) found that engineering and science need to work together, to co-exist.

Davies and Gilbert (2003) in connecting science and engineering studies found that a high degree of epistemological congruence between these two subjects has developed a consistency approach in the promotion of the thinking skills. However, far too little attention has been given to the approach of evaluating the practical work process in achieving curriculum objectives for any engineering subject worldwide (Bekalo and Welford, 2000). As mentioned earlier, although research on the effectiveness of practical work in sciences is well established, insufficient research exists on the effectiveness of practical work in engineering education.

Practical work, as pointed out by a few studies, is a broad category that included different types of activities with specific aims and objectives (Lunetta and Tamir, 1979; Millar et al., 1999). They believed that it is impossible to generalise the overall implementation of practical work, in determining the effective teaching and learning strategy. Due to that, this study has been designed to evaluate the effectiveness of specific practical task in engineering education at form 4 and form 5 in technical schools.

2.6 The studies to measure education effectiveness

Previous research on education effectiveness showed various approaches had been used in the measurement or the process of determination of the effectiveness. Most research on educational effectiveness has been carried out has examined the changes in knowledge, attitude, behaviour or understanding in the participated respondents or control group (Abrahams and Millar, 2008; Baker, 2008; Creemers and Kyriakides, 2006; Itzek-Greulich et al., 2015; Tuan et al., 2005). The vast majority of studies on the effectiveness have been utilised pre and post-test via experimental method, and the improvement from the participants evaluated the effectiveness of the teaching and learning after the specific period (Ann and Jane, 2008; Frekjmr et al.,2000; Itzek-Greulich et al., 2015; Skourdoumbis, 2017). In a Malaysia educational context, the government defines the effectiveness of the curriculum almost all the time by presenting and comparing the students result for the terminal examination (Education Performance and Delivery Unit, 2013).

Thus, for many years, examinations are the indicator that the ministry referred to evaluate the successfulness of a curriculum. The consent in this research is, how is the education system going to move from the examination oriented to the outcome based oriented as suggested in the blueprint when the only option to measure the effectiveness is by the examination? Due to that reason, the education system has been suggested to move toward the outcome-based assessment where new methods to calculate the effectiveness of teaching and learning in achieving the educational objectives is needed (Education Performance and Delivery Unit, 2013).

Marzano, (2012) in the report of the school effectiveness suggested six criteria for the effective curriculum. The idea emphasises the need to analyse the written curriculum to ensure that it correlates with each level and adequately addresses important 21st century skills in the curriculum. Marzano's report suggested that the taught curriculum in the classrooms is evaluated to ensure that it correlates with the written curriculum, and the assessments are analysed to ensure that the processes accurately measure the written and the taught curriculum.

However, until recently none of the research on effectiveness presented a measuring scale that could consistently classify the level of effectiveness. There are no holistic indicators that can be used by the government and the curriculum maker to determine whether or not the curriculum is achieving its objectives (Educational Planning and Research Division, 2015).

This gap derived the author from investigating the holistic process of curriculum development and evaluation where all the aspects in the written curriculum, the implementation of the curriculum and the assessment of the curriculum become the focus in determining the level of effectiveness. Additionally, effectiveness as defined by Abrahams and Millar (2008), is the correlation between the teacher's expectation and student's actual actions. Several studies have reported that by involving students actively in the lesson, teaching and learning became consistently more effective (Bonwell and Eison, 1991; Felder et al., 2000; McKeachie 1999; Sutherland and Bonwell, 1996; Wankat, 2002).

Current research by Hudson et al., (2009) stated the effectiveness of learning as the chance for students to collaborate and be independent. Based on various definitions and interpretations of the effectiveness in previous research, this study has developed the scale or indicator to determine the level of effectiveness from the combinations of different perspectives (students, teachers and researcher). This level of effectiveness would classify the effectiveness of any part in curriculum development, either in the implementation of the curriculum or the assessment of the curriculum.

2.6.1 Effectiveness from students' and teachers' perspectives

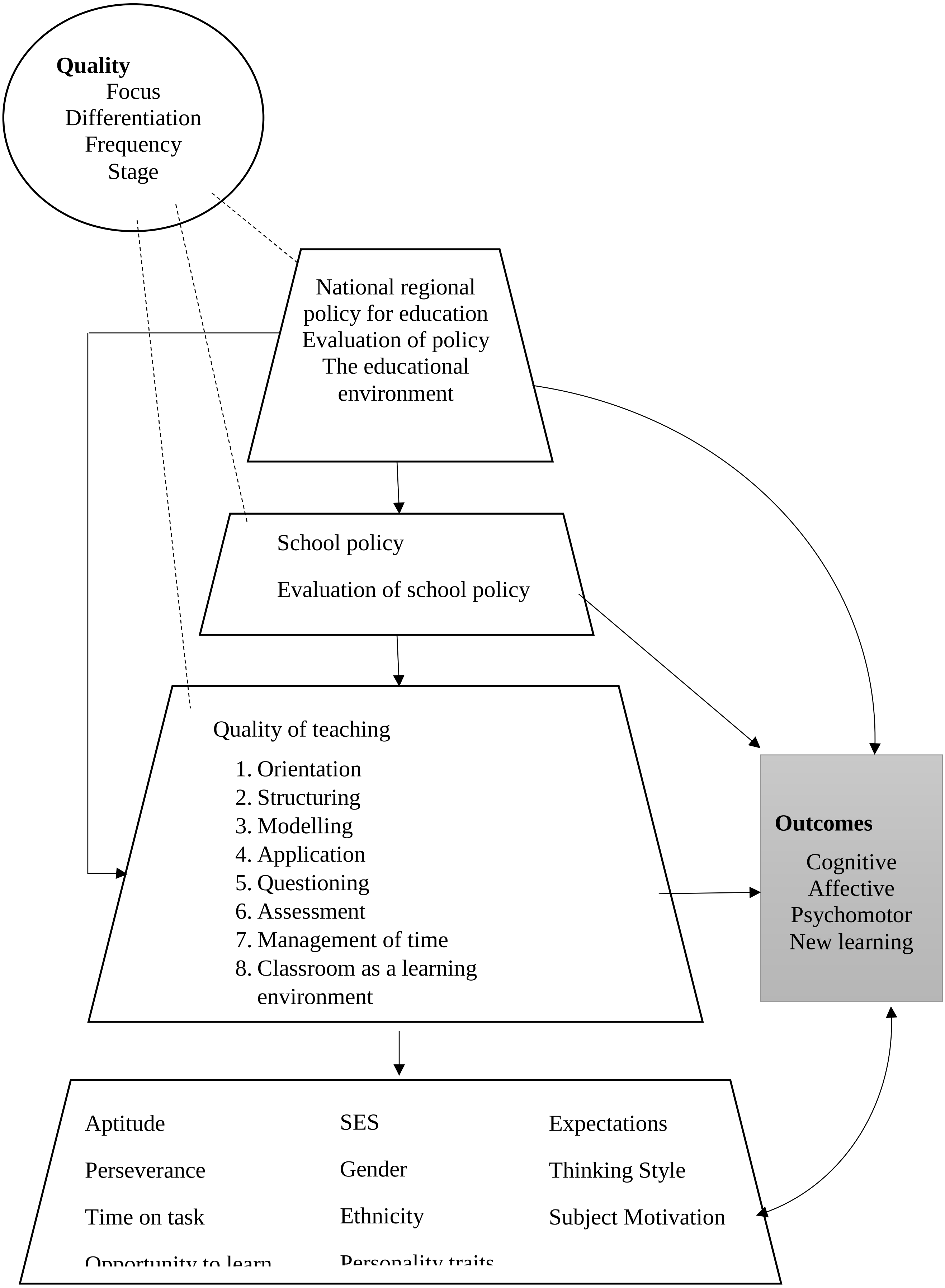
Studies on students' and teachers' perspective in many aspects of education have widely established for several years (Flick et al., 2012; Mertens and Hesse, 2012). The importance of acknowledging perceptions from teachers and students is because they involved directly with the input, the process and the educational outcomes (Tsai, 2003). Earliest studies of practical work in secondary schools (Beatty and Woolnough, 1982; Thompson, 1975) have explored the views and opinions of teachers and students without comparing such views with actual practice. The later study by Abrahams (2009), has developed a design of case study which explored the effectiveness of practical work from students' perspective against the researcher's perspectives from observation. This approach enabled the researcher to focus on the observation of actual practices and to augment these with interviews conducted in the context of these observations. Another earlier study by Wubbels et al., (1993) has combined the perception from the students, the teacher and the researcher to conclude the findings.

A study by Peter et al., (2005) has mentioned that the students' perception was strongly related to what has been observed by the researcher and consistent with the student's outcomes rather than the information from teachers. This finding showed the importance of the triangulation of perceptions, as suggested by Flick et al., (2012) to explain the relationship between reality and the idea. Some studies have included perceptions from the participant in their research design to evaluate the effectiveness (Naylor and Cowie, 1999; Pisaniello et al., 2013). It is reliable as stated by (Oware et al., 2007), to attain feedback from the stakeholders in the study of effectiveness because they are the subjects of the research and they experienced the process. Based on these reasons, this study has included the perceptions from technical schools students and teacher as well as the information from the author's observations to generate the level of effectiveness.

2.7 The Dynamic Model of Educational Effective (DMEE)

This study applies the idea of the Dynamic Model of Educational Effective by explaining the overall factor regarding the educational effectiveness which are the education system, the schools, the teachers and the students. Creemers and Kyriakides (2008), have developed a dynamic model of educational effectiveness which attempts to define the dynamic relations between the multiple factors found associated with effectiveness. This model attempts to provide a comprehensive outline of educational effectiveness by referring to factors operating at different levels such as student, classroom, school and system which were found correlated with student outcomes (Maulana et al., 2011).

Creemers and Kyriakides (2010), conducted a series of studies to test the validity of one of the most influential integrated models and provided some empirical support to the comprehensive model of educational effectiveness. The author believes that this model could contribute to establishing a theory-driven and evidence-based approach to encourage educational improvement in Malaysia. The claim for an evidence-based approach is accepted generally, and used in several policy documents (Slavin, 2002). This approach as suggested earlier is part of the outcome based assessment. The chosen of a dynamic model because it showed its devotion as a framework for developing an evidence-based approach especially given that a series of studies have provided support to its validity (Creemers 1994; Stringfield and Slavin 1992). The main characteristics of the dynamic model are as follows. First, the dynamic model takes into account the fact that effectiveness studies conducted in several countries have revealed that there are multiple factors which influence the student achievement.



Source: Kyriakides and Creemers (2008)

Figure 2.2 Illustrates the characteristic in each factor on the Dynamic Model of Educational Effectiveness.

Therefore, the model is multilevel and refers to the factors operating at the four levels begin with the education system and end with the students (Teddlie and Reynolds, 2000). Figure 2.2 illustrates the main structure of the dynamic model. This model emphasised the teaching and learning and analysed the responsibilities of the two leading roles which are the teacher and the student (De Jong et al., 2004). Above these two levels, the dynamic model also refers to school level factors. It suggested that school level factors influence the teaching and learning situation by developing and evaluating the school policy on teaching (Skourdoumbis, 2017). This factor also initiated the policy on creating a positive learning environment at the school.

This model also acknowledged a broader educational context in which students, teachers, and schools are expected to operate and influenced the teaching and learning situation (Phillips, 2010).Factors such as the values of the society for learning and the importance attached to education play an essential role both in shaping the teachers' and students' expectations as well as the development of the perceptions of various stakeholders about effective teaching practice (Slater and Teddlie, 1992). The illustration of interrelations between the components of the model presents in Figure 2.3. In this way, the model indicated that factors at the school and context level have both direct and indirect effects on student achievement since they can influence not only students' achievement but also the teaching and learning situations. This assumption supported by findings from effectiveness studies conducted by De Jong et al., (2004) and Kyriakides (2005) in order to test the validity of the comprehensive model which revealed that the relationships between factors at different levels might be more complicated than assumed in the current integrated models. This part is true for interaction effects among factors operating in the classroom and student level, which indicated the importance of investigating differential effectiveness (Kyriakides and Tsangaridou, 2008).

Considering effectiveness factors as multidimensional constructs not only provided a better picture of what makes teachers and schools more effective but may also help to develop more specific strategies to improve educational practice (Kyriakides and Creemers, 2008). This study has adopted this model in the rational on findings and the discussion because of the conceptual derives from this model is significant to represent all of the factors that emerge in the educational effectiveness and at the same time allows the author to classified the data into relevant themes. Additionally, this model complements the consideration in the pragmatism where the reality is subjective and need more than a single view (Morgan, 2007). Since the tentative of this model has clearly outlined four different aspects to achieve the effectiveness of the education, the complete utilisation of this model is relevant to the conceptual of this study. This model also originally has adopted the idea of the Bloom taxonomy of educational objectives in a more specific way that can be elaborated on the broader perspectives as discussed in 2.8.2. Due to that, the dynamic model acknowledges the effective education outcome to be in the form of transformation of either the cognitive, affective, psychomotor or the new learning (Tsai et al., 2014).

2.7.1 Education system factor

The education system factor consists of stipulations of the national, regional policy for education that control the implantation of written policy and the educational environment (Charalambous et al., 2014). The transformation process of teaching and learning is representative of a concern with managing the outcomes and outputs of education. This process mentioned by Ball, (2009) as a way of describing the modern administrative rationalities linked to political governance, where the decision by the government has profoundly influenced by the voice from population regarding fact and evidence. Similar to Malaysia context, the education system moulded by the ruled government inspired by the visions toward achieving the status of developed countries. It was mentioned in the blueprint recently, although the government has put many policies regarding work demand and has a clear vision of how to bridge the education sector with a real world, there is always the possibility of gaps between planning and delivery (Educational Planning and Research Division, 2016).

There are several criteria applied in the education policy for the practical work to be effective in schools in other countries. The annual review of these policies is necessary according to Wang (2010), to give time for the implementation of the policy and to regularly evaluate the effect. The other suggestions to enhance the effectiveness of engineering education policy is, the development of a curriculum need to involve coordination amongst the different public agency in the provision of education in various areas. There are still some issues related to equal access to quality education in engineering education Malaysia where there is a need to drive a clear policy on this learning criteria (Soon and Quek, 2013). The national examination at the same time should include in the policy with significant variations across all the elements in the practical work based subject (Aziz et al., 2005). Holman et al., (2017) suggested that the government include the sufficient allocation of budget, the supply of specialist or well-trained teachers and the most important, the reliability of the education system that promotes teaching and learning beyond exams alone.

However, the latest study has reported lack of students engaged in teaching sessions, and the learning process is still more oriented towards summative assessment rather than cultivating higher order thinking skills among students (Educational Planning and Research Division, 2017). The other aspect to be considered in the policy is the performance of teachers teaching practical subjects and whether their knowledge requires updating and they need more training (Connell, 2009). While the cost to implement practical work in engineering education is increasing for several years, the allocation of budget to technical schools never been reviewed. The amount of budget per students for each year remains the same since 1994 when this curriculum was developed.

Table 2.3 indicates the expenditure per student in USD for eight countries worldwide in 2011. The number showed that the allocation for Malaysia secondary education is the lowest among others and far too low compared to other Asian countries like Korea and Japan. Even though it might be related to the currency exchange where the USD stand higher in rate compared to Malaysia Ringgit, the figure is still too small and indicate insufficient of a budget for the student expenditure at secondary schools level. This amount also reflexes to the insufficient budget to prepare for the material for practical work lessons.

Table 2.3 Illustrates the expenditure (in USD) per students in eight countries at secondary schools in 2011.

Reference year	Finland 2013	Malaysia 2015	Japan 2014	Germany 2013	Australia 2013	Korea 2013	UK 2014	USA 2013
Secondary	17,624	1,796	9,683	10,804	11,433	5,714	9,785	11,657

Source: UNESCO Institute of Statistics (UIS)

Regard to this issue, it is suggested that the government review the budget annually so that the amount remains relevant to the needs and construct in technical schools to fully implement the practical work.

2.7.2 School factor

School factor is regards to the school authorities to determine the rule and implementation of the education within the schools (Vanlaar et al., 2016). Several studies have indicated the importance of schools policy specific to the implementation of practical work (Bekalo and Welford, 2000; Dillon, 2008; Ologo, 2014; Thompson and Soyibo, 2002). A study by Babalola, (2017) has suggested that in order to have a good practical work every school should have a written policy that explained why teachers use practical work, the outcome they expect from the practical work and how they are they going to achieve this outcome. A similar study has indicated the policy itself should explain the difference between the implementation of practical work for each subject and at every level of study. It means that the production of school policy should be part of a stakeholders team effort including the schools' management, teachers and the technician across all the departments.

Additionally, the lack of coordination across the school's divisions creates most of a missed communications among the team members (Mincu, 2015). According to Biggs (1999), it is effective school management which enforced the policy in education to focus on process and outcome. Another study by Scott (2000), suggested that the school policy should ensure as much as possible planned and purposeful practical activities in teaching by supporting the needs in the laboratories. This aspect included the facilities, tools and equipment for the implementation of practical work. The government has invested in infrastructure, and the training and recruitment of teachers to enhance the learning environment for particular concern including the practical work in engineering education (Education Performance and Delivery Unit, 2013). While preparing for the most effective educational environment for students to fully experience the teaching and learning process, the Malaysia education system has its limitation in providing and maintaining complete facilities in the technical schools.

2.7.3 Teacher factor

The teacher factor in Dynamic Model of Education Effectiveness suggested eight characteristics for the quality of teaching which included the aspect of teaching (Desimone and Long, 2010). The yearly report for Ministry of Education Malaysia, (2017) has indicated the major transformation that the government are planning to do to maximise student's outcome for every single Malaysia Ringgit. It is one of their approaches to capture efficiency opportunities with focused on relocation more funding to the critical areas such as the teacher training and upskilling. A tangible economic benefit to the nation counts and students' achievement measures increasingly circumscribe the value of teacher education. The reform of teacher education suggested by Cochran-Smith, (2005) consists of specific elements which are teacher education is now a policy problem necessitating policy responses which must be research driven, and it must be outcome based. A recent study by Gottlieb, (2015) has initiated specific teacher quality characteristics including the knowledge that a teacher possesses including of a series of best or effective teaching practice, skills development and teacher evaluation. Evidence found in psychology indicated the technique used by teachers in effective teaching practice works in enhancing students' achievement (Friedrich et al., 2015).

Additionally, the Standard for Success (SFS) for online teacher evaluation has acknowledged the impact of quality teachers as the biggest influence on student engagement and achievement (Hakansson, 2015). The previous study introduced the impact of teacher training through continuing professional development (CPD), and the sustainable of expertise in the field to brush personal exchange in teacher quality (Pitt, 2009). This aspect is due to the effectiveness as well as frequent and quality of practical work is critically dependent on the skill and confidence of teachers. This study adopted five of the characters for teacher factor in Dynamic Model of Education Effectiveness which are the applications of teacher knowledge in the classroom, teacher questioning technique, the assessment process, the management of time and the classroom as a learning environment. The selection for all of these elements is because of the approachability and suitability to the design of this study and regards to the statements in the curriculum objectives for Mechanical Engineering Studies (Technical and Vocational Education Division, 1994). These elements also included in the development of research instruments which are the interview questions and observation outlines

2.7.4 The students factor

Student factor in Dynamic Model of Education Effectiveness with regards to the characteristic of students that listed in the bottom of the model (see Figure 2.3) have the most significant influence to the educational effectiveness (Driessen and Sleegers, 2000). The integration of components in this factor with the characteristic of technical schools students for this study are the gender, time on task and subject motivation. These components had been asked in the demographic questions in the questionnaire and were statistically analysed to provide a convergent validity of the study. This study is interested in investigating further the gender aspect of the student factor where according to Margaret and Kimberley (2018), this gender aspect widely emerged in engineering education worldwide. Gender equalities as part of the student factor in Dynamic Model of Education Effectiveness that become part of the demographic factors in this study. Other factors like the SES (socioeconomic status), ethnicity, and personal traits are not a significant consideration because statistic from the Educational Planning and Research Division (2015), showed that the majority of the technical school's students has a very similar background in term of this three aspect which is not relevant to discuss further.

The broad discussion conducted for several years regarding gender equality in engineering education. One of the studies by Christensen and Knezek, (2017) indicated that middle school males generally have a higher intent to pursue a career in STEM and also showed a more favourable interest in STEM fields. However, females appear to react more positively react in project based activities. The current situation in most schools in Malaysia has shown that the gender gap is significantly decreasing as girls consistently outperform boys in many subjects including engineering (Education Performance and Delivery Unit, 2016). A study conducted by the Girl Scouts of America compared females interested in STEM fields to those who were not interested in STEM fields. The study by Modi et al., (2012) found that those who exposed to the STEM field at an early stage have a higher interest in STEM fields and were higher achievers.

Other factors that have been shown to influence females' perceptions of pursuing a career in STEM are stereotypes regarding performance in mathematics and science areas (Nguyen and Ryan, 2008; Walton and Spencer, 2009) social and cultural cues that discourage girls (Weber and Custer, 2005), as well as a lack of confidence in the ability to persevere through difficult material (Dweck, 2007). Other studies also indicated that female students in speciality areas which are most popular for females had more masculine perceptions of engineers than men did in those specialities and females in other specialities (Perez-Artieda et al., 2014; Rich, 2005; Rosati and Becker, 1996). Women who have the most robust perception of engineers as masculine preferred speciality areas with higher percentages of female students.

This selection of area showed that those women who perceive engineers as masculine seeking out speciality areas with more females as a way of increasing their level of comfort (Chu, 2007). Conversely, women in other speciality areas dominated by men possessed weaker perceptions of typical engineers as masculine, suggesting that they feel less threatened by the high percentage of males in that speciality field (Kelley and Bryan, 2018). The study of gender in this research aims to explain the challenges faced by female students in conducting their practical tasks, in mechanical engineering, a subject which is male dominant. This study will emphasise the quantity and quality of engineering students, regardless of gender, based on the teacher's perspective and the observations made by the author.

2.7.5 The outcomes of the Dynamic Model of Education Effectiveness

In Dynamic Model of Education Effectiveness, the results of effectiveness could be measured in four types of outcomes which are the cognitive, affective, psychomotor and new learning (Creemersand Kyriakides, 2010). This study has emphasised three of these outcomes (cognitive, affective, and psychomotor) in answering the research questions. The factor of selection with regards to the suitability of the outcomes to be measured and the relevance of the context in practical work. The category for these three related learning domains are cognitive which focus on thinking (Fortsch, 2017), affective on emotion and feeling (Maizamet al., 2014), and psychomotor is a physical and kinesthetic action (Zaghloul, 2001). This study, however, does not measure the students' new learning in the outcome for Dynamic Model of Education Effectiveness because the designs do not support this purposes and it would need more time and different instruments.

According to Kraiger et al., (1993) the evaluation of learning outcomes relevant to cognitive included the verbal knowledge, the skill-based outcomes (psychomotor) can be measured through the compilations of skill and the affective outcome emerge from the motivational and self-efficacy. The dynamic model also agreed that the relation of some effectiveness factors might not be linear with students' achievement (Creemers and Kyriakides, 2008). This statement supported by results of quantitative syntheses investigating the effect on some effectiveness factors upon student achievement (Clayson, 2009; Darling-Hammond, 2006; Harris, 1998; Monk, 1994). This idea made the findings in Chapter 5 more reliable, and the factor that might influence the result is more flexible and consistent with the axiology of this research (1.8.4 in Chapter 1). This study was designed to evaluate these three main outcomes through investigation into students' practical work using specific research instruments that discussed in Chapter 3, Methodology.

Models apply for the educational objectives

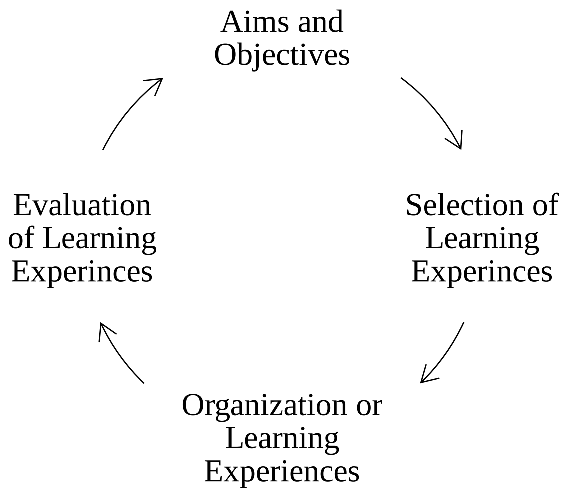
There are a few established models in the curriculum development process which provide the explanations of the objectives of education. In his latest book, “Developing the Curriculum”, 7th edition, Oliva (2001) discussed in detail about the Oliva model and its relationship with the development of curriculum. Oliva stressed that the model is based on the needs of students and society. In conjunction with the needs, the model is expected to provide a foundation for understanding its contribution to logistics curriculum (Krull, 2003). Additionally, the Olivia model acknowledged previous established curriculum models such as the Tyler model, the Saylor, Alexander and Lewis model, and the Taba model (Slattery, 1995). All of these models have a different focus, yet depending on student, society and subject matter as sources.

Tyler models, for example, is based on a cycle of goals and objectives, curriculum designing, curriculum implementation, and curriculum evaluation. The Taba model is based on producing a pilot, tertiary experimental units, revising and consolidating, developing a framework, and installing and disseminating new units. Dazmin et al., (2012) suggested that the design and development of curriculum in logistics programs are based on constructive inputs from logistics practitioners. Despite the conducive of Oliva model, this study has recognised the educational objective models from Tyler (2013) and Blooms in Krathwohl (2002) where these two models have been widely implemented in the curriculum development worldwide. Additionally, these two models provide the idea that brings the educational objective to be realistic, provide measurable outcomes and emerge the objectives from combinations of related stakeholders needs.

2.8.1 Tyler’s model of educational objectives

Tyler model is one of the most adapted models in the development of curriculum for many subjects in Malaysia since early 1980 when the government introduce a new policy to encourage the process of strengthening the education system (Education Performance and Delivery Unit, 2017). The practicality in curriculum development for this model has established for several decades. Tyler’s model ascertains the first step in curriculum planning is to develop the objectives (Tyler, 2013). The objectives are essential to guide the other activities related to the curriculum and become the focus of the outcome for the curriculum (Brady, 1990). In his model, Tyler describes learning as taking place through the changed behaviour of the students and views curriculum theory as technical. He believed that the primary stress is on the aims, evaluation and control. The model also suggested the importance of beginning the curriculum with its objectives and the need to evaluate the objectives.

Predetermined behavioural objectives serve as a driving force that controls the pedagogical and evaluative efforts that follow. Tyler's rationale has been challenged at times, but it seems to have become stronger as a result and, its elegant simplicity is engaging (Laanemets and Kalamees, 2013). Figure 2.3 is a schematic view of Tyler's Model for curriculum planning.



Source: Tyler, (1949)

Figure 2.4 Illustrates Tyler's Model for Curriculum Planning.

Tyler's model known as an objective model because the curriculum development has to begin with a serious consideration of objectives which at the end is focus on the achievement of these objectives (Christensen et al., 2015). These four steps in the model work in cyclic since evaluation gives feedback to the objectives. This model as mentioned by Walker (1971), emphasised the vitality of the curriculum objectives and the importance to evaluate the achievement of the curriculum objectives. In the Mechanical Engineering Studies curriculum, the statements of the curriculum objectives lie under the 'aims and objectives' where the beginning point derives in every curriculum. The selection of learning activities as appeared in Tyler's model emerged in the Mechanical Engineering Curriculum in the content of this knowledge which is the theoretical, mathematical and practical (Technical and Vocational Education Division, 1994).

This study will focus on the practical work element which is the major component in engineering education. Next component in Tyler's model is the organisation or learning experience which refers to the implementation of the teaching and learning of practical work. According to Kliebard (1970), this element is the process of delivering the knowledge to students after determined the type of learning experience. The final stage to complete this cycle of curriculum planning is to evaluate the learning process which became the main focus of this study, to evaluate the effectiveness of practical work. The findings from the evaluation process as stated by Lunenburg (2011), reflected the objectives and would provide a suggestion of improvement or adjustment for the new cycle. According to Hunkins and Hammill (1994), Tyler’s model incorporated in the structure of the research framework where the basis of curriculum development embedded. Tyler’s model is relevant to this study in a way that it begins with the curriculum objectives and enhances the importance of evaluating the curriculum objectives in educational effectiveness. It was mentioned widely in previous studies about the evaluation process of practical work (Abrahams et al., 2013; Jager et al., 2017; Osborne, 2013).

Most of the studies worldwide have indicated the assessment for practical work is based on an indirect assessment by the teacher, only in Singapore, the study by Li et al., (2017) indicated a formal practical examination applied for specific science practical work in secondary schools. Certain countries assess the practical skills and knowledge indirectly by mean of written questions in practical contexts. This method has been indicated without assessing the practical knowledge, especially when assessments levels are so high and the teachers are so skilled in coaching students to perform in dealing with the question (Perpignan et al., 2017). Additionally, the assessment should fit the purposes of the evaluation for practical activities which should reflect students’ practical skills and knowledge. This aspect is where the awarding grade for the subject should apply the formative assessment and evaluate students throughout the process of doing practical work (Zezekwa, 2016). The completion of the cycle in Tyler's Model indicated the complement of the education process and reflected the quality of the implementation of the curriculum. Due to this, the application of Tyler’s models in this study as the primary concept in evaluating the effectiveness of the curriculum objectives.

Tyler’s work is based on the situation that happen in the schools that emerge from the focus or objective of school (Kliebard, 1970). It was stated in the book “Basic Principles of Curriculum and Instruction” 3rd edition, Tyler (2013), that a rationale for viewing, analysing, and interpreting the curriculum and instructional program is for the purpose of achieving the school objectives. Tanner and Tanner, (1980) discussed many situation in curriculum development related to Tyler’s work which emphasised the important of curriculum documentation and the completion of the curriculum cycle which includes the evaluation of curriculum objectives. Tanner and Tanner, (1988) suggested that Tyler’s syllabus proved to be synchronised and systematic elaboration of the key elements, sources, determinants, processes, and principles that had been advanced for curriculum development and evaluation by leading experimentalists during the first half of the 20th century. Pinar, (2013) discussed the continuity of Tyler's rationale from different perspective which concludes that Tyler's rationale was evidently acknowledged for more than 50 years as a basic principle in curriculum development. Current work by Burns, (2018) indicates the conflation of curriculum and teaching and the instrumentalism associated with the institution of education operating within a broader system of disciplinary power by explaining the Tyler's rationale to demonstrate its persistence in contemporary curriculum design. It also advocates for the disentangling of curriculum from teaching, particularly as both have been subsumed under assessment, and poses questions through which curriculum scholars and teachers might consider how they can embody counter-conducts against the institutionalization of Tyler's portrayal of curriculum as a functioning instrument of education (Franklin, 2018). These previous studies show that, the Tyler Model remain relevant to current situation and the broader application of this model is well established.

2.8.2 Bloom's Taxonomy of Educational Objectives

For several years, Blooms' Taxonomy has been well-known in education as the learning domain to determine the outcomes of the learning process (Furst, 1981). The learning domains consist of three main terms which are the cognitive, affective and psychomotor. Originally, the cognitive domain was developed by Benjamin Bloom in 1948, and the affective domain was developed later (Krathwohl et al., 1964). The psychomotor domain concerns about things students physically do. Although Bloom and his co-workers compiled no taxonomy of this domain, several competing taxonomies created over the years since Bloom's original books. The one summarised here based on work by Harrow (1972) in Taxonomy of the Psychomotor Domain: A Guide for Developing Behavioural Objectives. The statements for curriculum objectives in Mechanical Engineering Studies consist of both domains of cognitive and affective, and the practical work is part of the domain of psychomotor.

The author believes that teaching and learning should attempt to construct more holistic lessons by using all three domains in constructing educational tasks. This diversity as mentioned by Honigsfeld and Schiering (2004), helps to create more well-rounded learning experiences and meets some learning styles and learning modalities. This study applied the idea of Bloom's Taxonomy of Educational Objectives for the construction of research instruments which included the component of knowledge-based (cognitive), affective-based (affective) and skills-based (psychomotor). The taxonomy has outlined a particular level of components that can be observed in multiple approaches and using different instruments (Chan et al., 2002).

The cognitive domain is a hierarchy of six levels of learning which are the knowledge, comprehension, application, analysis, synthesis and evaluation (Creemers and Kyriakide, 2010). These aspects of learning are the criteria that the practical work in engineering education would investigate. It appeared in the curriculum objectives as the measurable outcomes and emerged in every teaching lesson plan. The affective domain is a hierarchy of five levels which are receiving, responding, valuing, organisation and characterisation (Maizam et al., 2014). Few elements in this domain also appeared in the curriculum objectives for Mechanical Engineering Studies which are the students values the safety, interest (responding) and motivation (receiving). These aspects are important to be evaluated yet difficult because it considered as the unmeasurable education outcomes.

The levels categorised in a psychomotor domain are reflex, fundamental movements, perceptual abilities, physical abilities, skilled movements and non-discursive communication (Harrow, 1972). All of these components reflected the application or practical work and to be specific in regards to the outcomes of practical skills. Those combinations of elements in the domains allowed the author to develop the instrument and designed the data collection process regards of the need in the curriculum objectives. Each domain has its criteria which emerged in the curriculum objectives for Mechanical Engineering Studies and the connection with the practical work. The Bloom's taxonomy of educational objectives is best to refer for the overall construct of research instruments where the holistic outcomes from the practical work would be evaluated based on each domain in this model. The development of instruments is further discussed in 3.6.

2.9 Curriculum objectives for Mechanical Engineering Studies

There are three levels of objectives introduced by Krathwohl and Payne (1971) which are a global objective, educational objective and instructional objectives. The curriculum objective is the substitute from the educational objective, and the learning outcomes are part of the instructional objectives. It allowed the application of research on the educational objective to be the main reference in this study. Recently, Anderson et al., (2014) suggested that the general domain of objectives is best represented as an inductive continuum from quite general to very specific.

The curriculum objectives for Mechanical Engineering Studies designed with specific purposes and aims. There are seven main elements and three sub-elements in Mechanical Engineering Studies' curriculum objectives as discussed earlier in 1.4 that lied under the educational objective. Each element in curriculum objectives in Mechanical Engineering Studies syllabus has been derived from the preparation for the students to become a good engineer in the future. These elements are the heart of the curriculum objectives that become the focus to determine the approach of investigation to be used in this study. The author found that it is important to measure all of these ten elements in the practical work component for Mechanical Engineering Studies as stated by Baker et al., (2008) in order to define the effectiveness of the outcome in the teaching and learning process. All of the elements and sub-elements in the curriculum objectives for Mechanical Engineering Studies have been the focus in preparing all of the items in the instruments for this research. In the section below, this study has explained the elements in ten categories (seven main elements and three sub-elements) that have been extracted from the curriculum objectives as follows;

2.9.1 Understanding of knowledge

There are certain concepts, terminology, processes and procedures in engineering education which according to Montfort et al., (2013) students should understand during practical session. Previous studies have suggested that there should be a specifically written assessment to evaluate students' understanding after their practical work (Walsh et al., 2010). Some earlier studies have suggested that the assessment of practical work reported by students is useful to reflect on the outcome of teaching and learning practical work in schools (Rugarcia et al., 2000; Tsai, 1999; Tsai, 2003). However, later studies by Zezekwa (2016), on the influence of practical work assessment method to the students understanding in physic in Zimbabwe indicated that passing practical work through the assessment of a workshop report does not necessarily mean that the student has understood the basic knowledge of the topic. The same study has suggested that continues formative assessment conducted by the teacher during the practical lesson is the best approach to evaluate the students' understanding of concept while doing practical work.

Additionally, a study by Sund (2016), determined the obstacle in assessing students practical abilities for chemistry subject in Sweden has derived the conclusion of individual and independent assessment are difficult because the nature in practical work did not allow social interactions and it involved physical source that observable through the process. The students' understanding of the knowledge can also be obtained by observing their immediate reaction and response toward the studied subject in the session (Fuller et al., 2000). In the curriculum for Mechanical Engineering Studies subject, the achievement of curriculum objective not only focus on understanding knowledge, but also on the understanding concept, terminology, process and procedure through practical work. This study was conducted with regards to the interpretation of understanding from the students and teachers perspectives. Hence, it will investigate the effectiveness of practical work in student understanding of knowledge, terminology, process and procedure from the student-teacher perspective through their experience in teaching and learning this subject.

2.9.2 Application of knowledge

The application of knowledge is a process where students work with their project based on the engineering concept that they know (Li et al., 2017). Another study by Carbogim et al., 2000 stated that application of knowledge in engineering is when the student used either the theoretical, conceptual or their background knowledge to provide workable solutions to the task. Previous research by Kirschner et al. (2006) on the strategy to apply practical work has suggested that the students should be provided with complete demonstration and guidance before they can start their work. The same study also agreed that the teacher has to perform the correct procedure in order for the student to apply the knowledge. According to Sutherland and Bonwell (1996) application of knowledge is part of active learning where students have the opportunity to practice their learning through specific activities. In engineering, the application of knowledge or procedure can be easily seen in the final product of a practical task (Verhagen et al., 2012).

Conversely, the latest study by Tho et al., (2017) has different views of the application of knowledge in practical work since most of the activities involved lack of genuine contribution to students at the same time do not reflect students' input and ownership. It is because the teachers usually have to prepare everything for students, and this process influences most of the outcome in practical work. It was mentioned a long time ago about the practical work cookbook where it usually requires students to follow specific procedures and solve specific questions provided in the laboratory manual (Gallet, 1998). This approach might limit the actual application of knowledge compared to current practice in schools. Research by Jones and Stapleton (2017) has indicated substantial changes from the traditional hands-on to computer-based laboratories in most practical science in the USA through the use of simulation software. This new version of practical work mentioned by McGrath and Brown, (2005) allowed the students to perform virtual experiments by applying their theoretical knowledge about the topic.

The practical work for Mechanical Engineering Studies has been designed for the students to work independently to apply the knowledge, terminology, process and procedure. The demonstration from teacher involved 10% of the total practical work session while another

90% is for students to explore the task (Curriculum Development Division, 2016). This study is going to investigate the effectiveness of the practical work in acquire students to apply knowledge, terminology, process and procedure in engineering. The information gathered from students and teachers perspective and also based on observation by the author during the practical work session.

2.9.3 Create a student's interest

Student interest as defined by Hidi and Renninger (2006) as the psychological state that determines the future engagement of students toward certain criteria in school or out of school. The element of interest in this study refers to the students' interest to further their study in the engineering field in the future. This element of interest is in the domain of affective where the outcome neither easily to see nor convenient to measure (Swarat et al., 2012). Earlier research by Hodson (1996) on the practical work in sciences has defined this activity as the process is planning, finding the facts, data collecting, classifying, deriving conclusions and interpretations, sometimes with the intention of immersing students into the process of scientific inquiry. All these actions have exposed students to first-hand experiences with objects and processes which they have to engage. It appears that the practical work experienced is more interesting than the passive intake of content using instructional lectures (Hodson, 1990).

Previous studies have revealed the students' interest in STEM subjects influenced by certain factor, for example the study by Porter and Umbach, (2006) reflected on the gender, ethnicity, and socioeconomic status (SES) as the indicators of STEM interest where these variables have affected the students' interest in the STEM subjects inside or outside school. According to McGrayne (2005), students view of STEM as a predominately white, male, and middle class fields. National statistics in the USA agreed with these perceptions, with African Americans, Native Americans, and Latinos between the ages of 18 to 24 accounting for 34% of the population in this age category, yet earn only 12% of the undergraduate engineering degrees (Meyer and Marx, 2014). Additionally, the fact that women remain underrepresented in STEM fields especially engineering is real (Kelley and Bryan, 2016). The statistic of students enrol for STEM field in the local universities show a balance of the amount of these three variables except for the number of female in mechanical engineering (Ministry of Higher Education, 2016).

There are a few studies which investigated the relationship between a students' interest in Mathematics and their achievements of the subject and have found a significant relation (Lauer et al., 2006; Norton, 2008). Their results remain relevant to the current investigation given the significant relationship between interest and attitudes towards STEM and student performance (Choi and Chang, 2009; Xiao and Zhang, 2016). Another factor initiated to influence students' interest toward STEM subject is the time they spent on the subjects (Krapp, 2005). The more students spend to experience and practice, the more interest they get from their field (Martindill and Wilson, 2015). The explanation by Abrahams in his book 'Practical Work in Secondary Science: A mind-on approach' (page 26 and 27) has clarified the previous studies (above) on the factor influence the interest in STEM.

According to Abrahams (2011), there are two types of interest which are the personal and situational interest which have their particular characteristic and carry different effect to the claim that it generates interest. Other studies have found the interest in maths and science in schools as a major reason for women to enter engineering at a higher level of education (Gill et al. 2008; Smith and Dengiz, 2010). The objective of introducing the engineering study at secondary education was to stimulate the students' interest in the engineering field in tertiary education by experience practical work (Technical and Vocational Education Division, 1994). This study is going to how effective is practical work in encouraging student's interest in the field of Mechanical Engineering.

2.9.4 Develop motivation

The development of motivation among student by experience practical work is one of the universal issues across STEM education studies (Sheldrake et al., 2017). Studies in psychology have interpreted that motivation can be seen from the students' behaviour and the quality of work that they produced (Hazari et al., 2017). Similarly, other studies have suggested that the more motivation the students have, the faster they will complete the task, the earlier they will come to the session and the consistency of attendant they will commit (Dohn et al., 2016). According to Abraham (2011), motivation is the enthusiasm to perform in practical work that observable in students' action inside or outside the laboratory.

A study by Sellami et al., (2017) has correlated the motivation and interest among students where the specific practical task could generate student interest and engagement in particular lesson, a mirror to the students' motivation toward particular subject which could sustain by experience the practical work. Despite all related literature on students' motivation in practical work, this study has agreed that the element in the affective domain which is motivation is claimable by students, experienced by the teacher during their teaching and learning session and seen by the author during the observation process. This element was mentioned by Dowson and McInerney (2003) as difficult but possible to be measured. The previous study has stated that the students' motivation towards science has decreased after they enrolled in school (Tuan and Chin, 2000).

Thus this study accepted that enhancing the motivation of students with different learning styles has become a crucial area to engineering educators, and one of the approaches that they can apply is by making full use of practical work. Example, the observation process would look at how students behaviour in the practical work session and their determination to finish the task. Motivation also can be observed by the action from a student from the beginning of practical work session until the end of the process. One of the instance of motivation stated by Tuan and Chin (2000), is the students come early to the workshop and excitement showed from their facial expression while experiencing the practical task. This action defined by Krapp (2005) as the interaction of students with specific task, objects, events or ideas which are observable for a duration of time. The previous studies have indicated the students' motivation could be seen during the process of teaching and learning (in this study is during practical work session). Hence, this study is going to figure out whether or not the practical work is effective in developing student motivation toward engineering education from the students self-claimed in the questionnaire, the teachers' perspective during the interview and the author's observation.

2.9.5 Develop creative thinking

Several studies have agreed to define creativity as a naturally creative act which involved doing something that leads to a primary outcome (Piriz, 2017; Sternberg, 2005). Piaget (1962) is one of the first psychologists seek to explain creativity, started from the premise that individuals existed in a structured and the dominated action towards unpredictable change. The development of creative thinking among students is as a continual process appears inside or outside the classroom. It might have generated in the teaching and learning process where the teacher encouraged the application of creative mind among the students. Creative thinking is the process to grow the creativity and the skill to allow students to think outside their comfort zone (Ayman-Nolley, 1999). In engineering education, design work is as a general activity which entails the exercise of creativity (English et al., 2012).

Previous studies have indicated the similarities and differences between creativity in science and in engineering that reflect the aims and purposes of the subjects. In science, creativity concerned with 'creative science experiments, creative problem finding and solving and creative science activity and must depend upon scientific knowledge and skills' (Hu and Adey, 2002). Creative work in engineering education can be applied to the derivation and solution of problems derive task in project work. (Davies and Gilbert, 2003). There indeed is a strong element of individuality in creativity, whatever the social circumstances in which the individual acts. Thus, Feldman et al. (1994), recognised that to be creative, people have to believe that they can change the world and add to its knowledge themselves. According to Halizah and Ishak (2008), creative engineering students defined by their flexibilities and willingness to shift approaches when faced with a complex problem. As mentioned earlier by, McKeller (1957) that the essence of creativity consists of individuals striving to do better than did their predecessors. However, as suggested by Poulou (2007) individuals must act within supportive social frameworks if there are to be an opportunity for people to realise their creative potentials. This study will observe the implementation of practical work to evaluate its level of effectiveness in promoting creativity among Mechanical Engineering students.

2.9.6 Utilise technology/ tools and equipment

The facilities Utilise technology/ tools and equipment provided in engineering workshops at technical schools is for practical work purposes. The students are supposed to use the technology (machines/ tools/computer) during the practical work sessions to produce the final design project. Research by Thomas and Watters, (2015) has suggested the limitation in conducting science practical work in a lab due to adequate equipment and tools. According to Lewis et al. (2007), schools should have enough workshop facilities to make it possible for every practical lesson. It is also important to maintain the frequency of practical work and ensure the continuity of the task written in the curriculum (SCORE, 2008). Current studies also suggested that teachers use digital technology to support and enhance the practical experience to students (Spernjaka and Sorgoa, 2018).

Mechanical Engineering Studies has utilised the technology which available online, and the students should be encouraged to search for information about the materials that they have used during preparing for the project work and design (Li, 2012). Recently, the main focus in research has not directed towards the ability of the technologies in education, but how the technology would be used effectively in teaching and learning (Kirkwood and Price 2014; Machkova and Bilek, 2013). One of the educational transformation programmes is the initiative to maximise the use of information and communication technology for distant and self-paced learning to expand access to high-quality teaching regardless of location or student skill level include the technical school and the students for Mechanical Engineering Studies.

Recent studies have suggested contradicted perspectives on the use of the digital technology to implement practical work or back to the traditional hands-on workshop practice (Dintsios et al., 2018; Jones and Stapleton, 2017; Spernjaka and Sorgo, 2018). As yet, according to Stanton et al., (2017) there is no conclusive evidence that computer simulations are effective and commanded used to supplement rather than replace hand on activities in practical work. Additionally, hands-on activities could result in manipulative skills, such as handling instruments and objects which not achievable through other methods of schoolwork (Banu, 2011). This study focuses on the utilisation of workshop equipment, tools and computer in the implementation of practical work for Mechanical Engineering Studies. The purpose is to investigate the level of effectiveness of practical work in allowing students to utilise these tools.

2.9.7 Value safety

The value of safety in practical work is the vital element in every teaching and learning session (Pisaniello, 2013). It is important for the students to value their safety as well as their friends' and workplace safety along the process of in the workshop. The practical work is mechanical engineering subject is the hands-on process that involves three types of heavy machinery, tools and equipment that might harm the user if not appropriately operated (see 1.4). With regards to the advantages of practical work, there has been mentioned by Spernjak and Sorgo, (2009) about the disadvantages when handling the real objects which are the possibility of injuries and the time constraints. According to Kim and Tan (2011), practical work is the only practice in school where the students experience to apply the safety procedure. Research has found that by making safety as the priority in a workshop, the more effective task can be produced for long-term (Itzek-Greulich et al., 2015). At the same time, a study by Hinneh and Nenty (2015), has indicated that by embedding the value of safety among students, it prevented 70% of accidents in the workplace. The implementation of safety as vital as the reduction of risk that all subjects should consider while conducting practical work. According to Zacharatos et al. (2005), workshop safety is a participated responsibility between the school as the authority (the teachers and the students) where they adopt a balance of proportionate approach to manage risk in practical work inside or outside the workshop.

According to Brophy et al., (2008) the practical work in engineering education must all be of the highest standard of safety and teachers at the first place should ensure that they consider the best practice to manage the risk for every practical lesson, although there have been mentioned by Loeppke et al., (2015) that taking risk is part of the growing process that students have to face in experience practical work. The study on students' safety in practical activity has indicated a few criteria of lab or workshop. Some of the common criteria is the workshop should have sufficient equipment for students to work in a small group (Felder et al., 2000), a place for practical work should be flexible enough to allow students to work individually or in a pair and provided with ready access to the technology required to enable collection analysis of digital data (Itzek-Greulich et al., 2015) and it should include a preparation space, the safe storage organiser, and accessible outdoor space where practical activity can take place (Chen et al. 2014). Among all of these pieces of literature, this study focus on the investigation into the effectiveness of practical work in allows students to value their safety, their friend safety and their workplace safety. It is also will observe the criteria in technical schools which promote safety among teachers and students.

2.9.8 Promote problem solving skills

Problem solving skills are the other element emerge in most of the engineering based subjects worldwide. Other studies in education have defined the similar contact for problem solving in practical work as problem-based learning (Clark and Estes, 1999) and project-based or inquiry learning (Minner et al., 2010). It is evident that the approach used in teaching and learning has influenced the process of promoting problem solving skills among students (Zin et al., 2013). In problem-based learning, the students are expected to define and analyse the given problem and to offer solutions (Halizah and Ishak, 2008). The practical work is a type of independent learning process of solving a problem where the students have to complete the practical task (Blumenfeld et al., 1991). There is a broad acceptance on previous studies about the principles of independent learning which included values, attitudes, knowledge before a responsible decision making or any actions can be taken in regard for students to solve the problems in learning (Bates and Wilson 2002; Gorman,1998; Kesten,1987). As mentioned by Kirschner et al., (2006) that even though the application of knowledge to encourage the problem solving skill among students, complete descriptions of conducting the task remain important in providing a more effective learning environment.

A study by Baden and Major (2004), suggested the characteristic of problem solving where students decided appropriate actions needed, shared information, generate the ideas through group working and working in cooperation which allowed them to engage with the real working world. According to Tatar and Oktay (2011), the application of problem-based learning approach has a positive effect on the students' learning abilities and science process skills by providing a supportive environment to enhance continual learning. Additionally, some studies suggested the problem-based learning approach is suitable for students with common background knowledge about the concept, otherwise, the process is going to create missed conception in students learning (Hodson, 1993).

Taber (2012), also agreed that students should be appropriately guided to find solutions to the problems they come across so that it aligned with the scientific theoretical. In a similar view, Sweller et al., (2007) suggested that students should get careful guidance towards specific constructions, understandings and solutions during practical activities. However, current research found that strict guidance during practical activities has limited the students' ability to think independently to solve the problems (Cukurova et al., 2018). Regards to all these literature, this study would investigate how effective is practical work in Mechanical Engineering Studies to enhance the problem-solving skills among technical schools students and observe the problem-solving attitude during the practical work session.

2.9.9 Meet the demand

The demand in the career in engineering has been defined by Mason-Jones et al., (2000) as a new internal supply chain of resources which properly interfaced with the marketplace. Although the curriculum for engineering education focused on preparing students to become an engineer in the future, there is still an argument about the ability of this subject in preparing the students to meet the demand in a mechanical engineering field (Soon and Quek, 2013). It has been said that the knowledge of practical work in engineering education at an early stage is preparing a foundation for students on their career in the future (Berland et al., 2013). According to Soon and Quek (2013), the rapid growth of the new technology affected the advance of knowledge in engineering especially in machining and design process, and at the same time increased the demand in this skills.

The solutions provided in the practical task are never right or wrong, only better or worse, and often rely on having a feel for the marketplace (Davies, 2000). A study by Fox et al., (2015) was recognised the difference between school activity and the practitioners, and the tasks worked on by learners become part of a classroom culture significantly removed from their origins. By which the global introduction of advanced technology, it is also affecting Malaysia engineering construction where the first application of education typically and technically skilled labour is available. Despite the issue to meet the demand in engineering fields, there is a gap between the current practice in industry and perception of engineering education at the secondary level (Montfort et al.,2013).

A previous study by Mincu, (2015) has indicated an insufficiency of regular training to teach the subject and the dynamic changes in industries for the past ten years. At the same time, the Malaysia education blueprint has suggested that the collaboration with industries in the development of the engineering curriculum. Additionally, the review of the curriculum should involve the content and practice to meet industrial demand (Education Performance and Delivery Unit, 2016). These reasons indicated the importance to investigate the effectiveness of the practical work in satisfying the demand in mechanical engineering so that the Ministry can perceive the outcome of current engineering education and prepare for improvement.

2.9.10 Provide rational opinions

Rational opinions as defined by Becker, (2011) is the course of action which includes the reliable perspective from an individual about a specific issue. It was mentioned by Rugarcia et al., (2000), that the teaching and learning environment encourages the students to develop and present rational opinion by several approaches like conducting the presentation and a group discussion. A study by Andersson and Enghag (2017) indicated that practical work allowed students to communicate and provide a rational opinion to the members of the group. This process provides direction to identify empirically how specific laboratory activities have different potential strengths for learning outcomes regarding previous studies by Tiberghien et al., (2001) and Llewellyn, (2013) on possible appropriate objectives for laboratory work or inquiry.

The cumulative talk in the workshop for engineering education is the process of interaction in the group to discuss the project work or to distribute the practical task (Walsh et al., 2010). In the cumulative talk, students expressed their opinion and helped the group to progress with the task. Additionally, the discussion and presentation of ideas allow students to link knowledge and build conceptual understanding of the project work (English et al., 2009). It is consistent with Scott et al., (2011) who suggested that learning involved integrating the formalised scientific view with existing ideas in a science subject. All these while, no single study has identified similar contact of the impact of practical work on the student rational opinion in engineering education, although providing the rational opinion in the education process is one of the elements inspired by the Ministry in the blueprint (Education Performance and Delivery Unit, 2016) and also part of the element in curriculum objective for Mechanical Engineering Studies (Technical and Vocational Education Division, 1994). This study would explore the effectiveness of practical work in encouraging students to provide rational opinion through the process of practical activities.

2.10 The conceptual framework

The development of the conceptual framework consists of the combination of the Dynamic Model of Education Effectiveness (DMEE) (Creemers and Kyriakides, 2008), Tyler's model of educational objectives (Tyler, 1949), Abrahams' and Miller's model of the effectiveness of practical work (Abrahams and Millar, 2008) and the Framework for quality K-12 Engineering education (Moore et al., 2014). Figure 2.4 draws a design of the conceptual framework for this research. Despite evaluating the implementation of practical work lessons in technical schools, the focus of this study is to investigate whether the practical work is effective in achieving the curriculum objectives. This idea emerged from the factor in the Dynamic Model of Education Effectiveness which outline the four factors (education system, school, teacher and student) that influence the educational effectiveness. It is in conjunction with the model of the process of design and evaluation of a practical task where to evaluate the practical work in secondary schools. Another aspect in this conceptual framework related with the curriculum objectives is Tyler Model of Curriculum Development which suggested the cycle of curriculum development began with the objective and completed with evaluation of the objectives. Additionally, the engineering educations in Malaysia as mentioned by Education Performance and Delivery Unit, (2015) adopted the idea of the development cycle by Tyler, at the same time aligned with the framework for quality K-12 Engineering Education which was first introduced in the USA and acknowledge the content of practical work as a major focus.

There are no priority elements in the development of this conceptual framework and equally interpretation given to all of the components included in this study. Each of the components has its influence on the design of this study regarding content or reasoning the outcome. The detail of each component in this theoretical framework was presented earlier in each own sections, and this is to stimulate how the components join together to work within this study context. The main idea of the overall research is to provide a new approach in assessing the cognitive and affective learning domain in the curriculum objectives. This study aims to acknowledge the previous research on practical work in STEM education worldwide that also relevant to current secondary education. Finally, the purpose is to understand the challenges appeared in the implementation of practical work in the Mechanical Engineering Studies. The combination of the idea from the models and frameworks has developed this conceptual framework that represented each of the essential elements in the research. This conceptual framework is becoming the pillar of this study design where the baseline of the conceptual framework has stimulated the findings and directed the research conclusions. According to Robertson et al., (2018) the fundamental principle for the development of conceptual framework is to inter connecting ideas which required to understand the unique circumstances on each element in the research design. This study applied the similar concept of conceptual model where the combination of three models (Dynamic Model of Education Effectiveness, The Tyler Models of Curriculum Development and Abrahams and Millers Model of process design of practical task) and one established framework (Framework for Quality K-12 Engineering Education) were connected by the main element in this study which are the effectiveness, the practical work, curriculum objectives and engineering education (see Figure 2.4).

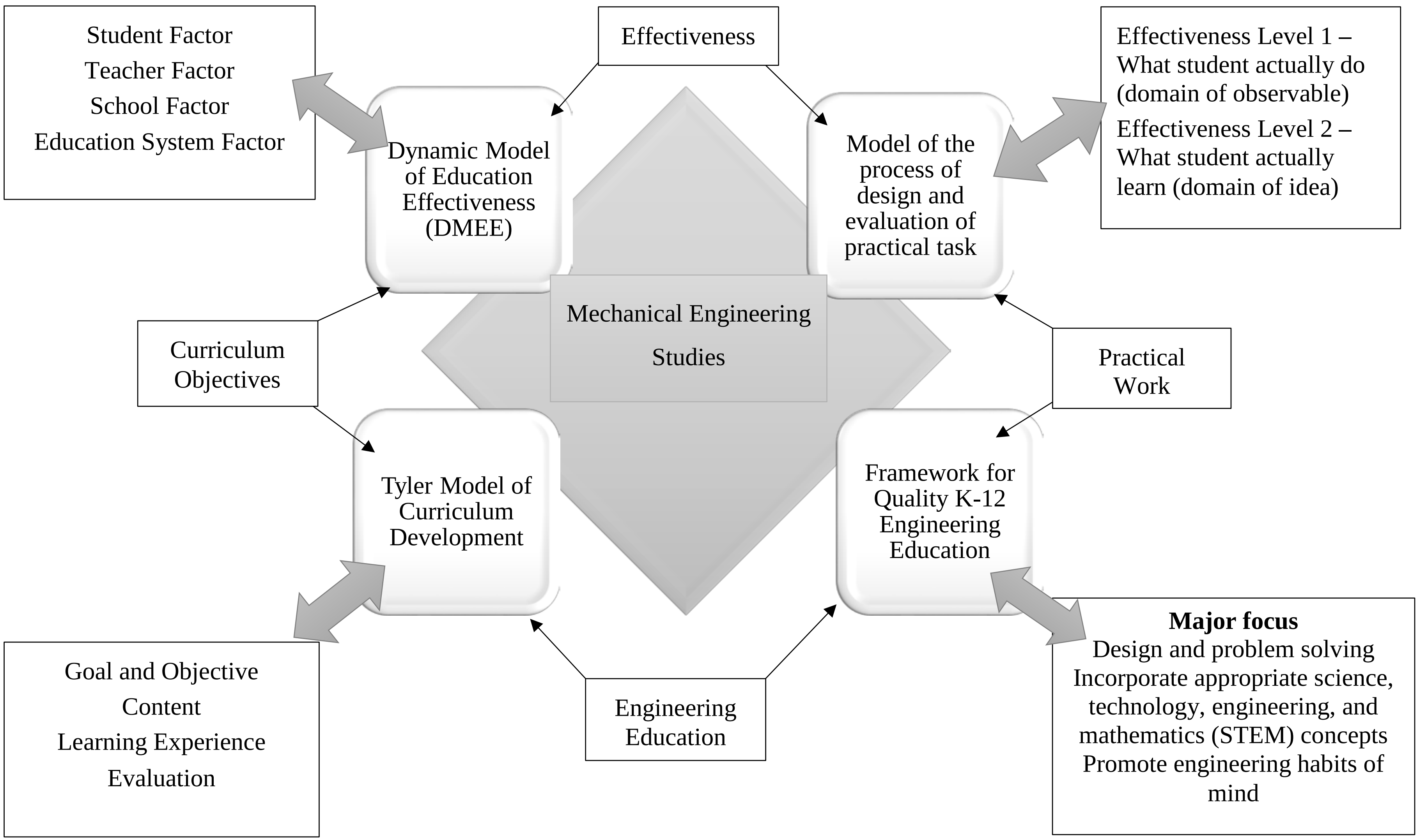


Figure 2.5 Illustrates the conceptual framework designed for this study includes the accumulations of models and frameworks.

2.11 Research questions

Regarding the reviews and identification of gaps in the related literature, this study has determined three research questions which are;

i. How effective is practical work from the students' and the teachers' perspectives in achieving the curriculum objectives for engineering studies in Malaysia?

ii. What are the international perspectives on the effectiveness of practical work in STEM secondary education?

iii. What are the challenges of implementation of practical work for engineering studies in secondary education?

2.12 The limitation of the literature review

The literature search has found few limitations that this study has encountered to obtain sufficient information to be used as a support or argument to the findings. The limitation more or less has given an impact on the design of this study and has shaped the approach taken in the overall process. The limitation of the literature review for this study are as follows;

i. This literature review focuses on acknowledging the previous research on engineering studies at the secondary education and most of the research on engineering education at a higher level is not a priority in the literature for this study. There is specific research in engineering education at a higher level has been referred to, which focused on the general information on engineering education in Malaysia and not into the practical activities. Despite the difference in ages between secondary and higher education, the approach for practical work in engineering education at higher levels are different. Engineering education at a university, for example, has less practical activities compared to the curriculum for technical schools. Their focus is to educate the engineer who supposed to acquire more theoretical and mathematical engineering knowledge rather than practical so that they would be a leader to work with skilled workers in the mechanical engineering industry.

ii. Since this literature review is focusing on the research at the secondary education, insufficient research in the engineering education at this level has become the other main limitation. The literature search found a minimal source towards studies in engineering education at the secondary level. Due to this limitation, previous studies on the other STEM subjects especially Sciences which investigate the element of practical work is significant to the context of this literature. It became a primary reference for the literature review because of the common characteristic that science and engineering have carried out in implementing the practical work. The various studies in practical work in Sciences are well established which is suitable to be adapted in this study.

iii. Limited theory and model related to the practical work in engineering education appeared in the literature search. It is difficult to find the exact model that adopted in the development of mechanical engineering curriculum at technical schools. The officer in the ministry also does not distinct on the theory or model related in this context, because the main problem with the Ministry is, for several years, the curriculum development processes are not well documented. This problem is crucial since the selection of models to be applied customised to the situation in Malaysia. In this study, the literature search on the theory regards to the existing curriculum development theory and model applies to other STEM subject and not specific to practical work in Malaysia technical schools.

iv. The studies of achieving the curriculum objectives barely appeared in a literature search at all level of education. It might be because the lack of research has been done to evaluate the curriculum objective not just to focus on the effectiveness worldwide. The most critical part of a literature search is to interpret the information on the curriculum objectives for mechanical engineering subjects. This documents in not publish to appear online, which led the author to set up an informal meeting with previous curriculum developers who developed this curriculum 24 years ago. The formal meeting is impossible for this purposes because the original curriculum developer team is no longer working in the Ministry and currently, a responsible officer has limited knowledge regarding the curriculum objectives. The previous curriculum development team consist of engineers from industry, teachers and lecturer from a university. The author asked their permission to meet them for this purpose, in order to get information about the curriculum objectives and for them to validate instruments for this study.

v. The struggle in literature search to provide the conceptual framework for this research is, to determine the elements to be included in the framework at the same time to shape the related information into workable research. The design of the framework has to accommodate existing models and include established a theoretical approach which is related to the study. While this curriculum has been teaching at technical schools for approximately 24 years, the challenge is to ensure that each element included in the framework is remain relevant. The literature search has to filter irrelevant information that is not suitable to be used in the study for each item in the framework. To read and classify each piece of information to be included in the framework is very time consuming.

vi. Another limitation in the literature search is to find the method used by previous studies in evaluating the effectiveness in education. It is difficult to determine whether or not the study correctly measures the effectiveness of the curriculum objectives. There are various studies of measuring the effectiveness mostly in medical studies which the approach is entirely different with education contact. Additionally, the evaluation into the effectiveness in education differs from one to another depending on the teaching elements that the study sought to measure. Previous studies on educational effective applied the experimental design which emphasised the used of pre-test and post-test as a research methodology, then utilised of independent and control group. It has an impact to a result of effectiveness in one aspect which is students' changed of knowledge or behaviour at the end of the process, but this setting is not suitable to evaluate the implementation of practical work that addresses to the curriculum objectives.

vii. The final limitation is the generation of information from the systematic literature review process. A massive amount of related research has emerged from the systematic literature review process and to filter the reliable information to be included in this study is a real struggle. Even though the searching process has limited to the STEM research from the past ten years, the result remains substantial. It took plenty of time to read, sort and refine the search until the finding focused on the practical work for STEM subject at secondary level only. Not to forget, the systematic review in this study based on the research that has been published online and have permitted access granted by the University of Lincoln database search. The studies apart from these online resources are not applicable in this research because it was beyond the capability of the author to excess.

2.13 Chapter summary

This chapter has presented the review of literature from previous research related to each focus element for this study. This chapter shaped the meaning of the term 'practical work' for engineering at secondary education because the practical work terminology has used in technical schools in Malaysia for the previous 24 years since the development of the curriculum. Most of the studies on the practical work, to be specific in engineering higher education, use (problem-based learning, experiential learning, experimental learning, workshop practice and hands-on activities) where the essence of all these terms is learning by doing. The first section gives an overview of the literature and the list of terminology. The next section is the description of the systematic review of the previous research on practical work in STEM education. The aim is to explore the international perspective of the practical work in achieving seven main elements and other three sub-elements in the curriculum objectives as outlined in the Mechanical Engineering Studies for secondary education in Malaysia. This section has presented the analysis from the last ten years of research in practical work in STEM education worldwide. Based on the systematic literature review process, this study has found that much of the current literature on practical work focused particular attention to the science fields. Nonetheless, this is the systematic process that emerged to answer the research question 2 and relevant to develop the discussions in Chapter 6. The other sections have discussed previous findings on the studies on students-teachers perspectives, practical work, engineering education, curriculum objectives, and educational effectiveness. All of these studies have their limitations, and they provided a gap for the generation of research questions for this study. Together, this literature has provided essential insights into each aspect of the research design and research approach. The development of a conceptual framework for this research has been described accordingly with the combination of four established education models and framework, and each of the elements related to the contact of this study. The next chapter will explain the methodological consideration for this research with further discussion on the application of research, the triangulation of methods for data collections and the mixed methods of data analysis.

CHAPTER 3: RESEARCH METHODOLOGY

Structure of the chapter

The structure of this chapter is presented as follows; the first section provides an overview of the research methodology. This section includes the explanation of the overall process of the data collection and analysis on the practical work across ten multiple case studies. While the two stages of the pilot study process were conducted at two specific technical schools, the actual data collection has included six other technical schools in the peninsular of Malaysia. However, only five technical schools (10 cases) could be reported in this research because one of the participated technical school did not implement the practical work in teaching and learning Mechanical Engineering Studies for the past five years. The main reasons for the development of the research structure were to ensure that the overall process of data collection and analysis should answer the three research questions. This next section contains a detailed explanation of the theoretical and methodological considerations that were used in the multiple cases studies and the selection of the methods (the survey, the interview and the observation) used in this research within the cases study context. The explanation includes the detail of the triangulation method of data collection, the mixed method of data analysis process, the brief review of the selection of the samples and the population including the sampling technique, construction of the study instruments, the reliability and validity of the instruments, the discussion on the adaptation of the model of observations, the technique for the data collection and the data analysis process. This chapter also demonstrates the ethical consideration applied to this research that incorporated the ethical approval from both the University of Lincoln's ethics committee and the Ministry of Education Malaysia. The last section presents the limitation of this research that influences the construction of possible best approaches that can be implemented.

3.1 Introduction to research methodology

According to Creswell (2009), most of the pragmatists focus on the 'what' and 'how' of the research problem, and this factor provided the underlying philosophical frameworks for mixed method research (Tashakkori and Teddlie, 2010). The methodological considerations are lies on believed in pragmatist paradigm through the mixed methods approaches. In additions, this study is based on a conceptual framework driven in the literature which included the framework in engineering education and acknowledged the studies in STEM education. For this research, multiple case studies have been identified as the methodology to be used through the pragmatic paradigm (discussed in 1.9). This study has been designed to accommodate the best approaches for data collection in order to answer the research questions. Based on the pragmatist paradigm, the overall process (includes data collection and data analysis) has been outlined to address the research questions by applying the most appropriate and suitable approaches. Figure 3.1 demonstrates the overall research process that was designed for this study. The process started with an intensive pilot study that conducted in two stages at two different technical schools. The adjustment of instruments and approaches has been made after the pilot studies process where the pilot studies successfully achieved the purposes. It then continued with the main data collection in 5 technical schools which involved a larger number of participants.

The overall research process shown in Figure 3.1 involves the triangulation within the three methods which includes the survey from student questionnaires, the teacher interviews, and the lesson observations. The figure shows the process involved in the triangulation of methods for the data collection and the mixed methods of data analysis by stimulating the overall process from the beginning of this study until the generation of the results. Finally, the analysis of those data implicates the mixed methods of qualitative and quantitative information before the generation of the result was presented. In this research, the single case study was used in the two stages of the pilot study and the multiple case studies was used across ten cases from the actual data collection in five technical schools.

At the beginning of the main data collection, six technical schools were involved in the data collection process, however, the data from one of the technical school was not used because they did not implement practical work in their teaching and learning process of the Mechanical Engineering Studies subject for more than five years. Thus, in order to protect the validity of the findings, only the data from five technical schools who are implementing practical work in their teaching and learning process is used in this study. The focus of the investigation practical work for form 4 and form 5 is difference (form 4 is focus on the development of practical skills while form 5 is applying the skills to provide solutions to problems). However, the approaches, the instruments and the methods of investigating the participants' responses were the same. This study utilised the pragmatism approaches of triangulation of methods in observing the reality of practical work implementation at technical schools. The used of students questionnaire, teacher interview and classroom observations is to gather the information regarding the level of effectiveness of practical work in achieving the curriculum objectives for Mechanical Engineering Studies.

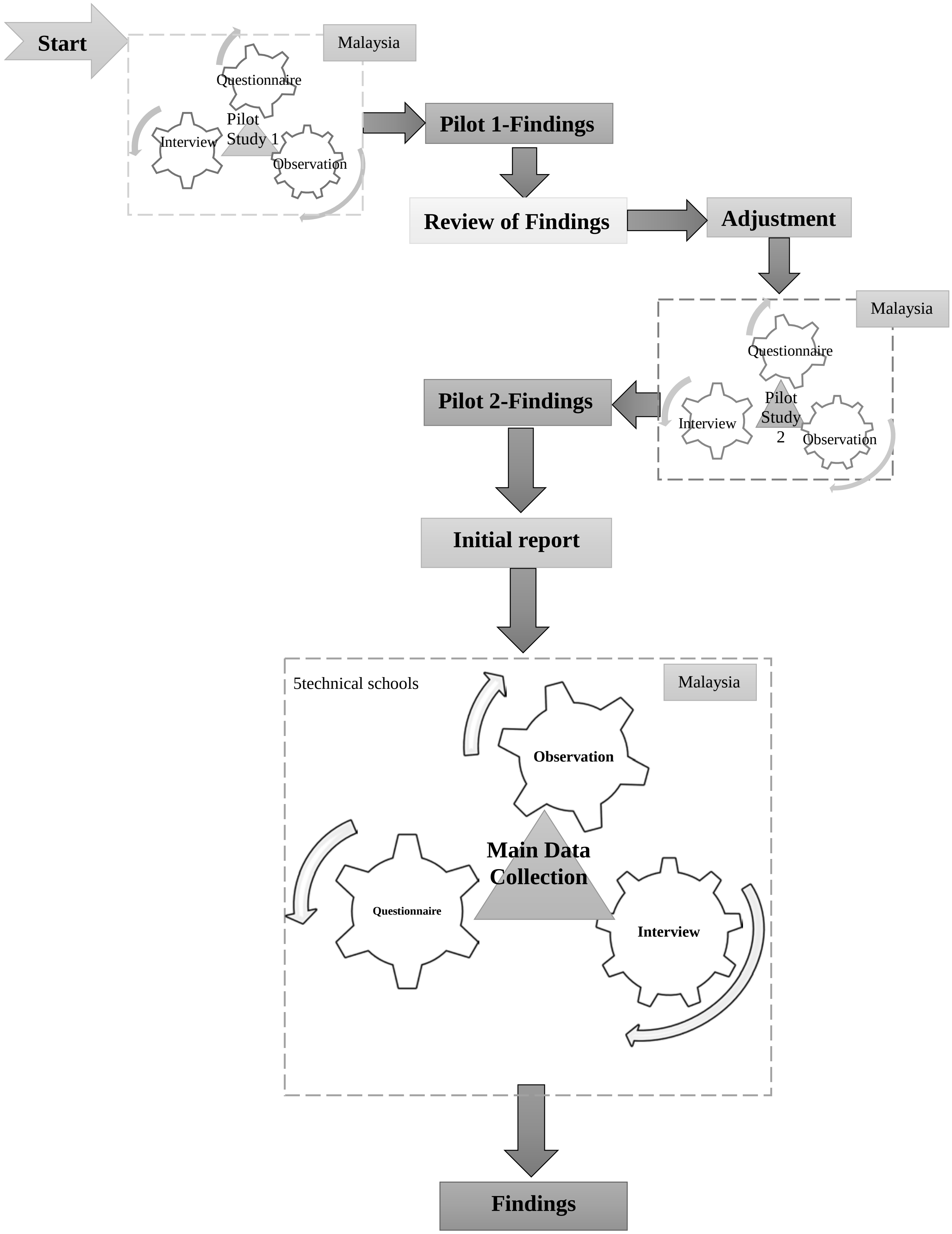


Figure 3.1 Illustrates the overall research process begins with the pilot studies, the main data collection and end with the generation of findings.

3.2 The multiple case studies

The multiple case studies design was applied in the data collection process for this research. It accumulated ten single case study (5 cases for form 4 and 5 cases for form 5) and then represented by the cross cases analysis in the multiple case studies. One of the reasons for the selection of case study design is the suitability and flexibility in a case study that matches the purpose of the research. The purpose of this research is to investigate the effectiveness of practical work in achieving the curriculum objectives, and according to (Denscombe, 2014), the case study design allows a combination of multiple approaches in a natural setting. The elements in the curriculum objectives have a variety of components that cannot be measured only in the examination or by comparing before and after outcomes of the learning process. Therefore, the best design is the case study that can be implemented in multiple cases in more than one technical schools within a certain duration of time.

Additionally, a case study allows the combination of methods that can observe the variations of effective elements in the curriculum objectives like the motivation, the interest, and the value. According to Yin (2009), the case study recognises and accepts that many variables are operating in a single case, and hence to capture the implications of these variables usually requires more than one tool for data collection and many sources of evidence. A considerable amount of literature has been published on case study methodology that combines more than one methods of data collection and the data analysis in order to illuminate cases from different angles (Gavigan, 2010; Kwok, 2017; Nowell et al., 2017; Selin and Olender, 2015). As mentioned by Yin (2009), a compilation of information to achieve the principle of mix methods research with multiple sources of evidence can provide convergent and concurrent validity on a case.

Figure 3.2 shows the structure of multiple case studies that have been specifically designed to investigate the effectiveness of practical work in achieving the curriculum objectives for Mechanical Engineering Studies in secondary education. It indicates that the overall process of multiple case studies begins with a single case study in one class at one technical school. The combination of ten classes allows the triangulation process works within the individual case that addressed to the specific learning outcomes. In this study, the methods applied were a student questionnaire, a teacher interview and a practical work classroom observation. The overall process of data collections in all participated technical schools brought the author to the journey across peninsular of Malaysia where the technical schools were located in different states (illustrated in Figure 1.2).

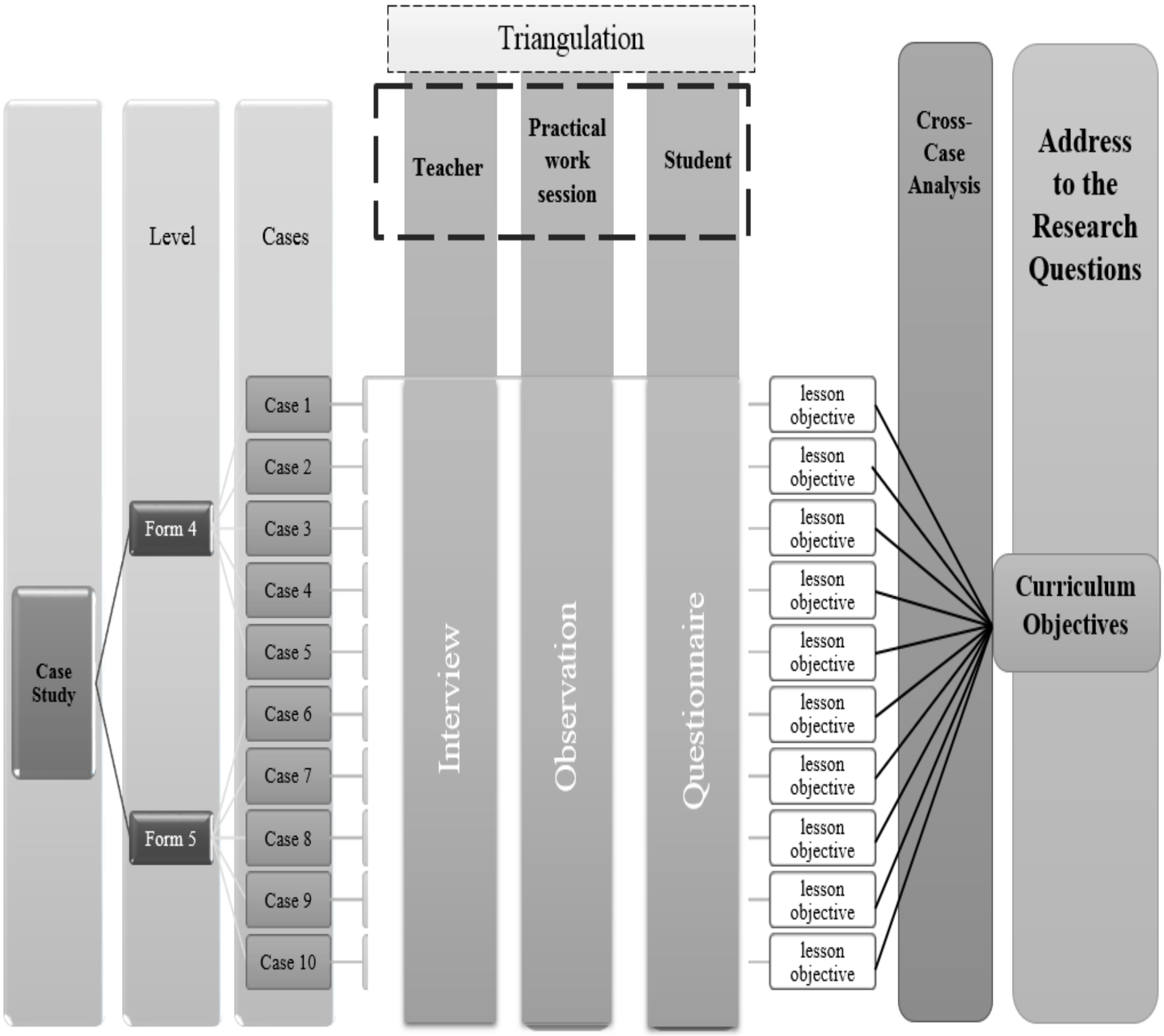


Figure 3.2 Illustrates the structure of the multiple case studies design which includes triangulation of methods from the questionnaire, interview and observation.

This structure allows this research to be generalised into the populations of technical schools in Malaysia because of the overall research design included participants from eight out of nine technical schools (90% of total population) while the reports included seven technical schools (five for actual data collection and two for the pilot study). According to Seawright and Gerring, (2008) the cross-case analysis is an analysis that examines themes, similarities, and differences across cases. The evaluation process in cross-case analysis produced the new findings that would be explained in a certain theme or criteria depends on the interpretation within the case. Cross-case analysis, defined by Khan and Wynsberghe, (2008) as mobilisation of information for a single case study to multiple cases that can generate new knowledge by comparing and contrasting cases.

This research has investigated 10 different cases at two different levels of studies in order to answer to the curriculum objectives. It has generated the findings from the cross-case analysis where each of the cases was addressed to the specific lesson objectives which at the end, addressed to the curriculum objectives. Figure 3.2 illustrated how the triangulations of mixed methods work in the multiple case studies which address to the specific lesson objectives for each case, and at the end, the combination emerged to the achievement of the curriculum objectives. The process of data collection included 10 cases in two levels of education which 5 cases for form 4 and other 5 cases for form 5 in the similar setting of multiple case studies. The main idea is to show how each case is relevant to finally answer the research questions in a setting that this study was successfully conducted.

3.3 The triangulation of methods for data collection

The triangulation is the combination of data derived from the use of different methods in the pursuit of certain objectives. This study applied the triangulation of mixed method in multiple case studies as Denzin (1970) has acknowledged as the methodological triangulation. According to (Campbell and Fiske, 1959 in Cohen et al. 2014), triangulation is a powerful way of demonstrating concurrent validity by looking at different perspectives and utilising both qualitative and quantitative data. This study applied the triangulation process of data collection that have been outlined in the main research framework based on the philosophy of pragmatic paradigm. Green et al., (1989), discussed triangulation as the designated usage of multiple methods, with offsetting or counteracting biases, in investigations of the same phenomenon in order to strengthen the validity of inquiring results. The studies that applied triangulation have been successfully established in education research for several decades (Campbell et al., 1966; Denzin, 1997; Greene and McClintock, 1985; Mathison, 1988).

This research involved the triangulation of methods from the surveys, the interviews and the observations in multiple case studies setting. As such, triangulation of methods optimally involved the combining of different methods that have complementary strengths and non-overlapping weaknesses as suggested by Johnson and Turner (2003) as the fundamental principle of mixed methods research. The combination of a concurrent equal status of qualitative and quantitative in mixed methods design suggested by Johnson and Onwuegbuzie (2004) has been applied in this research. This process is to measure the representation of both qualitative and quantitative data that have been treated equally important in this research. Figure 3.1 (above) has demonstrated the strategy for data collection and analysis that involved and integrated the triangulation of methods in this research. This method allows the different type of approaches to be applied in order to get the maximum information for the research and to ensure that all the information gathered would answer the research questions. The triangulation process involves a complicated design of mixed methods that has been explained in the data analysis process. The purpose of triangulation is to allow the author to get more holistic information of the reality (suggested in pragmatism) of the implementation of the practical work in the technical schools observed in Malaysia.

According to Onwuegbuzie et al. (2009), the triangulation of data will help pragmatist researcher to decide on the number of data type, the type of data analysis, the emphasis of interest, the association in the analysis and the equality of the data analysis. Working within the pragmatist paradigm gave freedom to the author in determining the research analysis process of mixed methods to be used in this study. This research outlined the data analysis process using the multiple data from the quantitative survey using student questionnaires, the qualitative analysis from the teacher interviews and the observation of the practical work session. This triangulation process gives meaning to the data that eventually will correlate the findings from different methods and cases to perform the new educational outcomes, in this case, is the degree of effectiveness. In this case, the availability of participants for data collection and the complexity of the mixed methods for data analysis regard to the pragmatism paradigm have led to the decision to apply the triangulation of data collection and the mixed method of data analysis.

3.4 The mixed methods of data analysis

The mixed methods of data analysis is the complex process that involved various substitute element in data transformation. According to Gorard and Taylor, (2004), the combination of methods in research has been acknowledged by many authorities as a key element in the improvement of social science including educational research. For this research, mixed methods of data analysis have been applied considering it works beyond qualitative and quantitative analysis exclusive in a pragmatist paradigm (Hoshmand, 2003). Indeed, many authors agreed that mixed method of data analysis allowed for the integrations between numeric and narrative approaches or data to meet the needs of research and in order to fully answer the research questions (Johnson et al., 2007; Tashakkori and Teddlie, 2010). While planning for the framework of this study, in many situations, the author found that often mixed methods research provided a more workable solution and would produce a reliable result.

The design of mixed methods of data is to combine the insights provided by qualitative and quantitative research into a workable solution. The multiple analysis processes have been applied where the process of data transformation from the qualitative data to the quantitative numerical code using the thematic scoring process. This process generates the mean scores for the participants' statements and finally determine the degree of effectiveness. Green et al., (1989: p.127) suggested several purposes of mixed method research which are to triangulate, to complement, to develop, to initiate and to expend the findings. This study applies three of these purposes which are to triangulate (the data collection process in 3.3), to complement (the process of supporting other findings in the systematic literature reviews in 2.2) and to develop (the results from multiple case studies to inform the findings from the three methods in 5.3). Previous research on mixed method has agreed that the mixed method analysis can help complement each other judgement and explanation (Onwuegbuzie and Johnson, 2004).

This research has been designed to apply the pragmatic paradigm of mixed methods where every method have been selected purposely to achieve the target while putting into consideration on the approachability and reliability of the technique. The complexity of the design for this research is based on the equal qualitative and quantitative concurrent settings as suggested by Onwuegbuzie et al., (2009). For example, the students' survey was chosen because the questionnaire can be used to attain information in a bigger scale in a short amount of time. It is impossible for the author to ask or interview every single student who was undertaking the Mechanical Engineering Studies subject to collect information about the practical work that they have experienced.

The interview with the teachers was explored their experiences by asking questions and getting immediate answers. The reasoning behind why the teachers' responses were not gathered through questionnaire is due to the limitation of the survey as well as the high probability that they will not provide elaborated written answers compared to the interview session. The classroom observation of the practical work session is for the author to bridge the gap of the response from students and teachers. This process has investigated the synchronisation between the perception from the students and teachers with the actual implementation of practical work in the technical schools as mentioned by Onwuegbuzie and Teddlie (2003), to verify the findings from other methods. The structured observation was designed as such because the focus outlined during the observation was based on the elements in the curriculum objectives.

3.5 Sample and population

According to Teddlie and Tashakkori (2009), the nature of mixed methods research allowed the study to use a different size, scope and types of sample working in one case and suggested the generalisation of samples to the group of the population. The population for this research is the mechanical engineering students and teachers at all technical schools in Malaysia. Since the case study has been designed to include different levels of a unit of analysis through mixed method approach, the most suitable sampling technique is the multilevel mixed method sampling (Onwuegbuzie and Leech, 2007). Multilevel mixed method sampling is the process for selection of samples based on the different approaches and specific to the purposes. In order to fit the research aims, the triangulation of the three methods which are the questionnaire, the interviews, and the observation have been designed and involved the students and teachers as the respondents. Based on the different approaches of data collection, the sample size for each method has been determined by the purpose of a sample in the mixed method analysis.

The sampling techniques for each method have been decided by using stratified sampling scheme for the questionnaire, convenient sampling scheme for the interview and homogeneous sampling scheme for the observation (Collin et al., 2006). The stratified sampling is the sampling frame that group the respondent that are relatively common in a certain aspect to fit the purpose of this research. In this case, the students between the age of 16 and 17 that undertake the Mechanical Engineering Studies in Malaysia were chosen.

At the beginning of this study, participants were chosen by generalising from a random sample of the population using a probability sampling principle quantitative approach (Bartlett et al., 2001). The process to determine the representative sample for this study has been conducted by using the online sample size generator for social science research (http://www.raosoft.com/samplesize.html). The result shown in Table 3.1 below is a computer generated a result that derives from the Krejcie and Morgan (1970) regards the confidence level of sample size table. The confidence level is the amount of uncertainty that this research can tolerate. In this study, the author decided to use 95% as the confidence level which brings the 5% tolerance to the sample size (Cohen et al., 2014). It indicates that the reliable acceptance number of samples could be between 5% of the generated size, in this case (5% from 270 is between 257 and 283 participants).

Table 3.1 Illustrates the calculation of recommended sample for the questionnaire based on the confidence level of the sample size table by Krejcie and Morgan.

What confidence level do you need?	95
Typical choices are 90%, 95%, or 99%	
What is the population size?	900
If you do not know, use 20000	
What is the response distribution?	50%
Leave this as 50%	
Your recommended sample size is	270

Source: http://www.raosoft.com/samplesize.html

This figure allows the research to have a range of a number of the participant while at the same time representing the total populations. After the online calculations were tabulated, out of the total population of approximately 900 mechanical engineering students per year, 270 students (30% of the total population) were the minimum recommended a size for the survey. This figure is a representative sample of the population as an ideal sample to participate in answering the survey. In the actual data collection, the author managed to collect 261 students as participants of the survey (from five technical schools). It is 96.67% of the recommended sample and it is acceptable because the figure is within the recommended sample size regards the tolerance. All of the students who participated in this research are the mechanical engineering students in two different level of study (form 4 and form 5) and have been chosen by the teachers according to their schedule for practical work sessions in the weeks that the author was visiting the school. The same students were involved during the practical work session observations conducted by the author.

The interviews were problematic to arrange due to the commitment of the teachers in the technical schools that were already busy with their teaching schedule and other routine work at school. The convenience sampling was used in selecting the participants for interviews because this sampling scheme allows the participants to be chosen depending on their availability and willingness to participate in this research. The participants for the individual interviews were suggested by the technical school principal from the list of mechanical engineering teachers at the technical schools. The factor of selection is also based on their willingness to participate in this research and the suitability of their time when they teach practical work to their students. In particular, based on Tashakkori and Teddlie (2010), there is no specific representative number of samples suggested for the interview because it is regarded to the needs in a qualitative study where this method will be analysed based on the purposes and the saturation of contents. In this study, the interview has been designed with the special purpose to evaluate teachers' perceptions of practical work in achieving curriculum objectives and the number of samples has been determined based on the design in the triangulation process for multiple case studies. For the purpose of triangulation within a single case, at least one respondent is needed to be interviewed in each case. Due to that, 10 out of 27 mechanical engineering teachers that represented each case participated in the interviews which are two teachers for each school (37% of the total population).

The observation utilised the homogeneous scheme sampling technique because it chose the sample based on similar criteria. As in this study, the practical work session for Mechanical Engineering Studies subject is the specific characteristic that the author is looking for. The average time for practical work teaching and learning sessions in an ideal setting (suggested in the mechanical engineering curriculum specification) for each form is the minimum of three sessions (240 minutes) and the maximum of five sessions (400 minutes) for one project. The author had planned the duration of time in one school in order to determine the number of the practical work session to be observed for this research. The author has decided to involve 400 minutes (the maximum duration of the practical work session) of observation for form 4 and 400 minutes of the observation for form 5. This lead to the design of the observation to be conducted twice at one school, in which one is for form 4 and one is for form 5.

3.6 Construction of the study instruments

The author has developed the instruments for this research based on the need to answer the research questions. Each item in the questionnaire, the interview questions, and the observation outline is customised to address the specific elements in the curriculum objectives for Mechanical Engineering Studies. The focus of each instrument is to investigate the participants' perception toward their experience on the practical work that will address the effectiveness of the curriculum objectives. The construction of these instruments begins with the mapping process of curriculum objectives adopted from the model in a Taxonomy for learning, teaching and assessing: A revision of Bloom's (1956) in Anderson et al., (2014). Table 3.2 is the example of a mapping process for the beginning of the development of all research instruments. This mapping process aligns the lesson outcome for practical work for form 4 and form 5 with the curriculum objectives.The process indicated that the completion of each lesson outcomes was finally addressing the curriculum objectives.

Table 3.2 Illustrates the sample of the mapping process of lesson outcomes and curriculum objectives (CO) for both form 4 and form 5.

Topic From Workshop Practice: Cutting (Form 4)							
Lesson Outcomes/ Learning Outcomes (LO)	CO1	CO2	CO3	CO4	CO5	CO6	CO7
1. Explain cutting by division principles	✓						
2. Identify and use hand tools for chipping	✓				✓		
3. Practise safety precautions while cutting						✓	
4. Identify various machine and their uses	✓						
5. Label main parts of the machines		✓					
6. State types of advanced machine							✓
7. Use the hand tools and drilling machines doing projects			✓		✓		
8. Practise safety precautions while drilling						✓	
9. State the principles, uses and advantages of advanced machining		✓					
10. Choose from catalogues suitable types of hand tools and machine for different types of work							✓
11. Supervise peers on the safe use of hand tools and drilling machine				✓		✓	

Topic From Design: Designing (Form 5)							
Lesson Outcomes/ Learning Outcomes (LO)	CO1	CO2	C03	CO4	CO5	CO6	CO7
1. Design artifacts to solve identified problems	✓						✓
2. State presentation methods in designing	✓	✓					
3. Produce creative artifacts				✓			
4. Present design output in documentation form and oral presentation			✓				
5. Evaluate and analyse the artifacts created by peers and suggest ways of improving the design in respect to it's characteristic			✓	✓	✓	✓	

6.	Evaluate and analyse the artifacts created by peers and suggest ways of improving the design in respect to the work process and materials	✓	✓	✓	✓

The mapping process included the intensive detail of every single curriculum objective and the remarks on the items in the instruments that address the curriculum objectives. Each question in the instrument has been customised suitable to the level of participants and all other factors have been placed into consideration at the early stage like the consumption of time, the length of the question, the numbers of questions and the structure of the instruments that might influence the result.

3.6.1 The items in the questionnaire

The construction of items in the questionnaire began with the layout of the statement in the curriculum objectives and the additional information needed based on the literature search from previous studies. The questionnaire consists of two sections, A and B. Section A includes six dichotomous questions where this section requires respondents to give information about their general background including age, gender, level of interest, total hours per week, motivation and enjoyment of experiencing practical work. Section B is the 30 rating scales questions that have been designed for respondents to indicate whether practical work is effective in achieving the seven curriculum objectives (see Appendix 1). Table 3.3 shows the sample for the mapping process of items in the questionnaire with the seven curriculum objectives. It indicates items number 14 to 20 where the question is addressing the specific curriculum objectives. The total of 30 items at the end would address to all seven curriculum objectives and gathering the information needed for the purpose of cross tabulations of the result (see result chapter 5.2).

The Likert scale was used as suggested by (Cohen et al., 2014) as a handy device in developing a degree of sensitivity and differentiation of response while still generating numbers. The five scores in Likert scale has been applied to determine the level of acceptance from the participant toward each item in the questionnaire. Figure 3.3 shows the example of items in the questionnaire with the five scores of Likert scale where students could choose their preference by a tick or sketch the circle.

Table 3.3 Illustrates the example for the construction of items number 14 to 20 in the questionnaire for all seven curriculum objectives (CO).

Items		CO1	CO2	C03	CO4	CO5	CO6	CO7
14.	use engineering tools effectively					✓		
15.	utilise machines in engineering effectively					✓		
16.	utilise workshop equipment effectively					✓		
17.	develop creative thinking through intellectual activities				✓	✓		
18.	demonstrate creative thinking through practice				✓			
19.	develop creative thinking through hands-on work				✓			
20.	solve problems related to mechanical engineering field				✓			✓

Thirty questions in the questionnaire were designed subject to the five Likert Scale (5-Strongly Agree, 4-Agree, 3-Neutral, 2-Disagree, 1-Strongly Disagree) to distinguish the level of acceptance among participants to each statement in the items. The items in the questionnaire in Figure 3.3 has been designed to align with the mapping process in Table 3.3 which can be seen in items number 17 to 20 (all the items are aligned instead). This process allows the conduction of a systematic strategy of instrument development where the author would go to the item back and forth during the process of adjustment of instruments in the pilot study. The mapping process at the same time helped the author to determine the specific items to address the specific curriculum objectives in a way to answer the research questions.

No.	Item	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
17.	develop creative thinking through intellectual activities	1	2	3	4	5
18.	demonstrate creative thinking through practice	1	2	3	4	5
19.	develop creative thinking through hands-on work	1	2	3	4	5
20.	solve problems related to mechanical engineering field	1	2	3	4	5

By experience practical work, I **believe** I am:

No.	Item	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
21.	interest in the field of mechanical engineering	1	2	3	4	5
22.	manage to meet the demands of a career in mechanical engineering field	1	2	3	4	5
23.	preparing myself to become an engineer in the future	1	2	3	4	5

Figure 3.3 Illustrates the example of items number 17 to 23 in student's questionnaire with five Likert scales.

3.6.2 The interview questions

For the semi-structured interviews, questions were designed to encourage participants to lead the conversation, enabling them to reflect upon their experiences, knowledge and conceptual understanding openly. Interview questions have been constructed to get the information from teachers about their experience in teaching practical work for Mechanical Engineering Studies subject. These semi-structured interview questions have been constructed by taking into consideration all the elements of the seven curriculum objectives for the Mechanical Engineering Studies. Table 3.4 shows the example of question number 13 to 21 were addressed to the specific curriculum objectives. The questions also have been designed to be conducted before the practical work session with the focus is to explore 'why' is something happen in that way. The same 40 interview questions were tested in the pilot study and then used in the real data collection.

Table 3.4 Illustrates the example for the construction of question number 13 to 21 in teacher's interview which addresses the seven curriculum objectives (CO).

Questions	CO1	CO2	C03	CO4	CO5	CO6	CO7
13. What is the expected learning from students after practical work?	✓						
14. Do you expect students to understand the terminologies concept/principle/fact/process after doing practical work? Why?	✓						
15. Do you expect students to remember the procedure? Why?	✓						
16. Do you think students can apply knowledge from doing practical work?		✓					
17. How do you think students will apply the knowledge they learn by doing practical work?		✓					
18. What kind of problems solving skills do you expect from students during practical work?							✓
19. Which part of practical work can promote creative thinking among students?				✓			
Teaching and Learning Outcomes (Effective Domain) I							✓
20. Do you feel that practical work is effective in promoting students interest in the field of mechanical engineering?			✓				
21. Do you agree that by doing practical work students manage to meet the demands of a career in the mechanical engineering field?			✓				

There are three sections of the interview questions. The first section is to investigate the teachers' educational background, their teaching experience, their interpretation of the Mechanical Engineering Studies curriculum objectives and their pedagogical approach in the teaching of the practical work. The second section was to explore their perspectives on the teaching of the practical work in achieving the learning outcomes and then, to address to the achievement of the curriculum objectives (based on the cognitive and /affective domain). The final section is a reflection of their experiences in the teaching of the practical work including the problem that arises during the teaching process, and the suggestion to improve practical work for Mechanical Engineering Studies subject in the future. All interview questions as in Appendix 2.

3.6.3 The observation outline

The observation outline consists of 20 focus items from the elements and sub-elements extracted from the curriculum objectives. The observation outline is a guiding document for the author to observe the specification and allowed the note taken in observation to be more deductive. During the observations, there are many things happening simultaneously, and because of that, the author has to focus on the specific activities of the students and teachers that reflect on the curriculum objectives. This instrument is to ensure that the observations successfully gather the maximum information within the limited timeframe. The observation outline is also the checklist for the author to observe the main criteria and the elements of the curriculum objectives that need to be addressed. All the observations used the same observation outlines, and the note-taking process was conducted during the observations by writing notes down.

The construction of observation outline is based on the need to see the actual implementation of practical work as claimed by the students in the survey and told by the teachers in an interview regarding the effectiveness of practical work in achieving each element in the curriculum objectives. Table 3.5 shows the example of action by students and teacher that became a focus in the observation outline. The main idea is similar to the construction of the questionnaire and interview where the items are addressing the specific curriculum objectives in Mechanical Engineering Studies. The practical work lesson observation allowed the author to gather the information regards to the implementation of practical work in technical schools from the author perspectives and compare with intended curriculum written in the curriculum specification. The observation outline table as in Appendix 3.

Table 3.5 Illustrates the example for the construction of observation outline from item number 6 to 13 which address to seven curriculum objectives (CO).

	Actions	CO1	CO2	C03	CO4	CO5	CO6	CO7
6.	Student apply the correct procedure	✓	✓					
7.	Student give an opinion and rational		✓					
8.	Teacher promote the real demand in the engineering field			✓				
9.	Student show interest in doing practical work			✓				
10.	Teacher promote creative thinking among students				✓			
11.	Student produce idea or product in a creative way				✓			
12.	Student show creativity in activity				✓			
13.	Teacher guide student to use computer/workshop equipment					✓		

3.7 Validity and reliability of the study instruments

The validity of the instruments is the ability to demonstrate that the instruments are measuring what it proposes to measure or encounter the feature that it is supposed to describe while the reliability is the consistency of the instruments to get the same result over a time-frame or groups of respondents (Cohen et al., 2014). According to Onwuegbuzie et al., (2009), pragmatism allowed the research in mixed method to use inferential statistics to make internal statistical generalisations. This approach could be used to facilitate productive and detailed description and also to enhance trustworthiness, dependability, confirmability, transferability, and authenticity. One of the criteria to ensure the credibility of the research is to demonstrate the trustworthiness of the instruments for the data collection. In this research, the validity of the instruments has been obtained by consulting experts in the field of Mechanical Engineering Studies.

During the process of the construction of the instruments, the author has referred to four experts in the Mechanical Engineering Studies curriculum which two of them are the Mechanical Engineering Studies curriculum developer, one is the officer in the Ministry of Education, and another person is the Mechanical Engineering Studies textbooks editor who is also a mechanical engineering teacher. The main purpose of contacting those experts is to attain their feedback on the curriculum objectives and to validate the meaning of the content of the items for all the instruments. This process is the first step that the author has taken to establish the correct interpretations of the Mechanical Engineering Studies curriculum that has been converted into items in the specific instruments. This process is vital because it is the foundation to determine the strength of the research design, the baseline to the construction of the instruments, and the alignment of the mapping process for each item in the instruments. Despite the acknowledgement from the experts, the pilot study has its own important rules in the validity and reliability of all the instruments.

According to Lancaster (2002), the pilot study is the best approach to test and ensure the methodological rigour in the research design. The purpose of the pilot study in this research is to check the validity and reliability of the questionnaire, to test the suitability of the questions for interviews, and to foresee what might be expected during observations. This pilot study successfully helped the author to plan the actual research regarding time allocation, selection of the participants, and the approachable techniques. It is important to ensure that all the instruments will answer the research questions before starting with the primary research.

This pilot study was conducted in two stages where at the first stage, all the instruments have been tested for the first time and have been analysed according to the needs. One of the needs is to achieve the reliability value (more than 0.8) of the *Cronbach alpha* test for all 30 items in the questionnaire. For the purposes of reliability, the test of *Cronbach alpha* has been applied where the alpha value for the first test is 0.892 (n = 28) and 0.881 (n = 26) for the second pilot study. These values indicate that all the items in the questionnaire are reliable to be applied in the real data collection process. Silverman (1993), suggested that the reliability of the interview can be enhanced by carefully piloting the interview schedules, training of the interviews, and the extended use of closed questions. The interview with the Mechanical Engineering Studies teachers was constructed to test the suitability of the 40 interview questions that have been designed based on the mapping of the curriculum objectives. The interviews, as well as the observation and the survey, were conducted by the author. Therefore, the issues relating to inter-rater reliability, the method used to assess the degree to which different observers consistently assess the same phenomenon was not applicable. A pilot study was conducted to ensure the validity of the observational categories are appropriate, exhaustive, discrete, unambiguous and effectively operationalise the purpose of the research (Cohen et al., 2014).

For the pilot study, the observation of practical work sessions in a form 4 Mechanical Engineering Studies teaching and learning session was constructed to test the flow of the observation outline and to give the overview to the author on the focus of observation during the real data collection process. The observation and the interview were both then transcribed and coded using NVivo 10 software. All of the instruments have been updated and has gone through some adjustment before undergoing the second stage of the pilot study. The purpose of the adjustment is to ascertain if the instruments could be conducted in a better way next time. It is important to reduce the probability of obstacles during the actual data collection because that is the only duration for the author to gather as much reliable information as possible from the participants.

3.8 Observation model of the effectiveness of practical work

Mulhall (2003), believed that the observation is a certain way to discover the reality of anything that people claim they do. However, it is subjected to the interpretation of the researcher rather than the real meaning of the situation. This reason is due to the authority of the observer who has a high degree of freedom and autonomy regarding the focus to be observed, how to filter that information, and how it is analysed. To minimise this claim, the author has outlined the observation process by adopting the model of the process of design and evaluation of the practical task by Abrahams and Millar (2008). This model allowed the author to focus on certain criteria for observation which is the students' activities during their practical work session. The use of observation outline is to help the author focus on the important information during the observation. Then, the application of the table of degree of the adverb is the systematic process of analysis that would control the interpretation from the author in the classroom observation. Abrahams' and Millar's study has investigated the effectiveness of practical work as a teaching and learning method in school science and has developed a model on how to measure the effectiveness of practical work in science. As no such model exists in engineering studies, Abrahams' and Millar's model is considered the best to be adopted and applied as shown in Figure 3.4.

The adaptation of this model suits the purpose of the research design because the focus is to see the students do what their teachers ask them to do (effectiveness Level 1) in the practical work session and did not investigate the students learning outcomes (effectiveness Level 2). A longer duration of intensive study needed at the same technical school, in a holistic approach, in the same class to measure the effectiveness Level 2. It is beyond the capability of this research as the permission from the Ministry of Education did not allow the author to interrupt the teaching and learning process, and the research should optimise the time in the school as much as possible. Besides that, the design of this research is focusing on the specific element in the curriculum which is the practical work, in order to achieve the curriculum objectives.

Meanwhile, the focus of the observation is to see the activity of the students and teachers during the practical work sessions that addressed the curriculum objectives. At the same time, the author is investigating the students' feeling and expression toward practical work that aligned with their answers in the questionnaires (affective domain). Certain elements in the curriculum objectives reflect students' actions such as their motivation, the value of safety and their interest in learning Mechanical Engineering Studies. Those elements are best to be observed during the practical work session.

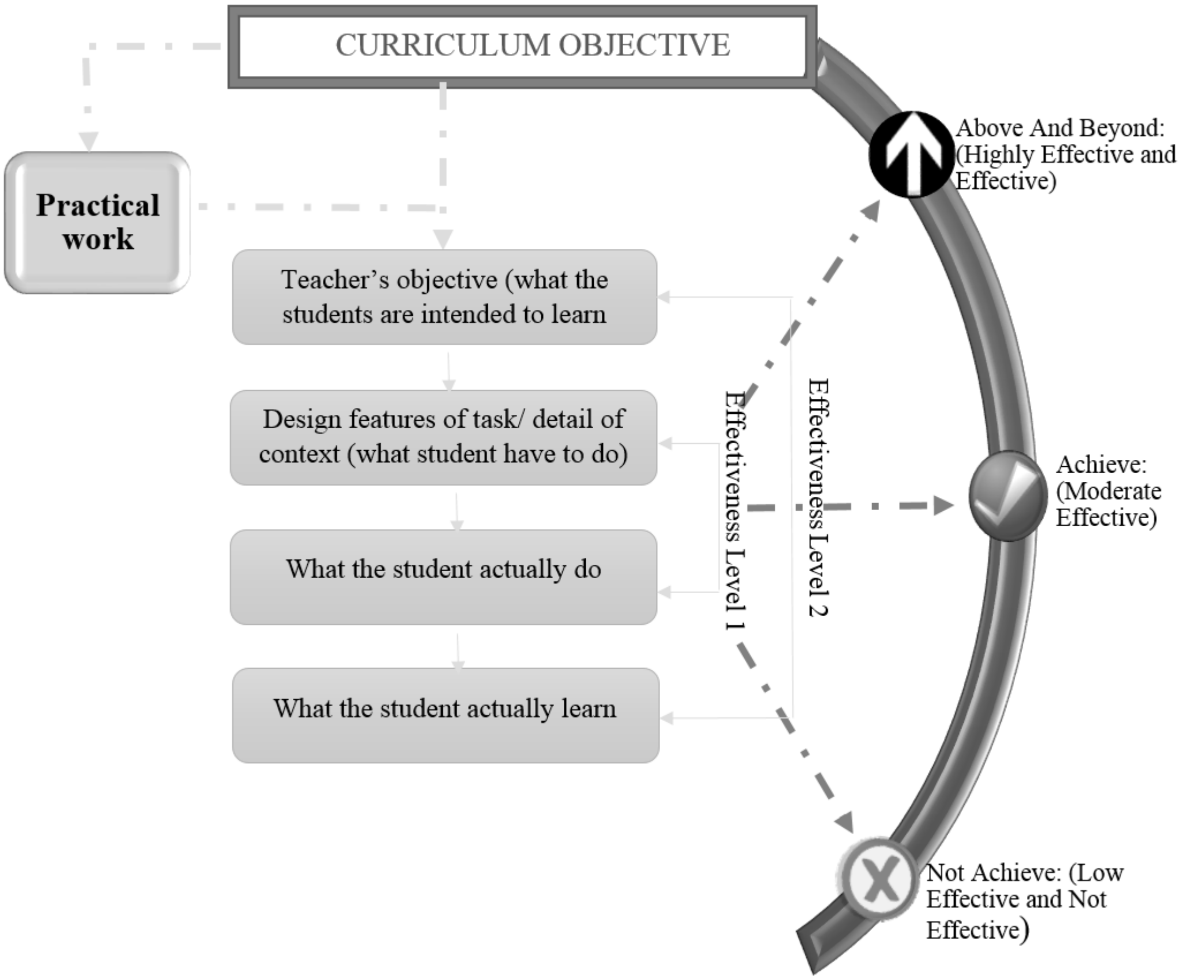


Figure 3.4 Illustrates the observation framework for the effectiveness of practical work in achieving curriculum objectives: Adaptation from Abrahams and Millar, (2008).

3.9 Multiple case studies process

The multiple case studies process has brought the author to explore eight out of nine technical schools located in the peninsular of Malaysia. Two schools are for pilot study and another six for the actual data collection. However, after the interview with the teachers, the author discovered that one of the school did not practice the practical work element in their teaching and learning this subject. There has not been any teaching of the practical work at this particular school (anonymous: Technical School Pearl) for several years due to a few reasons. In addition, during an informal conversation with the stakeholders (the curriculum developer, the Ministry of Education, and the school management), the author discovered that they did not realise this issue and until recently and since then no action has been taken to rectify this matter. As a result, to protect the reliability of the evidence and the accuracy of the finding, the author has decided to omit the particular school from the list of participants. The technical school's performance in the Malaysia Education Statistic 2015-2017 for the past three years showed that, the technical school which did not apply the practical work element in their teaching in learning have a lower rank in the Malaysia Certificate of Education (SPM) results compared to the technical schools who fully utilised the practical work (Education Performance and Delivery Unit,2017).

Assessing students work including a prototype, a drawing, a design, a workpiece and a folio is the best outcome to determine the success of a practical work session (Dillon, 2008). By evaluating the output of the practical work task, the author relates the findings and triangulate the statement from the teachers, the students and the observations to provide comprehensive evidence from various perspectives before concluding. Then, the main study has been conducted in 5 technical schools which involved 261 students from form 4 and form 5 to answer the questionnaires, 10 teachers participated in the interviews and, 10 classroom observations of the practical work sessions. There are 30 questions in the questionnaire that have been constructed in Malay and distributed to the students after the practical work session. The process went smoothly with the cooperation given by all of the participants and the teachers except from the management (discussed in 3.14). Every session began with the introduction to the purpose of the research, the role of each student in answering the questionnaire as honest as possible, the freedom to redraw from the research at any time, the explanations on the ethical part of the research and the content of the items in the questionnaire. The purpose of the briefing is to give a general overview to the students about the idea of participating in this study, and at the same time has provided a direction toward their expectations of the research. This data collection process took approximately 10 to 15 minutes, and the agreement with the teacher has been obtained to ensure that this survey did not interrupt the practical work teaching and learning process.

In the interviews, the respondents answered 40 questions (a mix of open-ended and structured questions) in the same sequence, and the process took around 30 to 45 minutes each on average. A neutral setting was used where the presence of the author is spontaneous so that the teacher has no idea what is the interview about and has prevented them from preparing for the answers. This setting was appropriate to explore the reality of the practical work implementation in the technical schools. The interviews were held at a formal place chosen by the participants, during their convenient time and were also scheduled accordingly to the teachers' availability. In addition, a voice recorder was used to record the whole process and permission from the participants have been granted before the sessions. The author starts each session with a brief introduction to the purpose of the research and the explanation about the consent form for the teachers. The author explained every single statement written in the consent form before asking for the participants' signatures. The author also created a calm ambience to ensure that participants feel comfortable to give honest answers in addressing the reality of their experience of the teaching and learning during their practical work session. This setting is important to get real information and truthful responses from the respondents. An explanation was given to the participants that the presence of the author was to conduct a research and not a representative from the Ministry of Education Malaysia. The teachers are allowed to say anything they want and their identity will remain anonymous. After signed on the consent form, the participants were subjected to an agreement to tell the truth, and the author was responsible for retaining all the information just for this research. The author, at the same time has a particular consent form to be signed in front of the teachers as a guarantee to keep all the information confidential and secure.

The observations of 10 practical work sessions (twice at each school) is to obtain a clearer view of what is expected from practical work (intended curriculum) and what happens (implemented curriculum) based on the effectiveness Level 1 in Figure 3.3 above. The involvement of the author in the process as an outside participant has been limited, purposely, to ensure that the appearance of the author does not interrupt the normal process and does not influence the final results. The author was also moving around in the classroom, interacting with the students by asking questions and for the most part, the observation was performed from far, where the whole process can still be watched. However, in order to attain the overall situations, this process required the author to observe the whole practical work session in the engineering workshop for 80 to 90 minutes for each session.

3.10 Technique for the data collection

The main data collection has been conducted on a bigger scale that included more cases after the pilot study. The detail of the pilot study process and the generation of the result by the calculation of the degree of effectiveness has been presented in Chapter 4. The main process of the data collection was the field study in Malaysia which involved the information gathering from three different methods and instruments which is the questionnaire (Appendix 1), the interview questions (Appendix 2) and the observation outline (Appendix 3). These three instruments have been developed by a mapping process of the content of the curriculum objectives for Mechanical Engineering Studies subject and the elements of the practical work, in order to suit the level of participants in each method. The actual data collection process is most likely mirroring or overcoming the weaknesses in the pilot study process. Overall, 99% of the technique for actual data collection is the continuity of the technique in the pilot study process that has been discussed in detail in Chapter 4. The author has successfully tested the technique of the data collection in the intensive series of the pilot studies and has improvised certain limitation that was mention in 4.6, (Limitation of the pilot study), in the main data collection process. Prior to the result from the pilot studies, the approaches have been modified accordingly to maximise the information gains from the participants in a convenient way. Thus the axiological consideration of pragmatism which is flexibility and fairness to the participants that has been practised in this study has influenced the selection of technique in the data collection process. This values included the flexibility of the approach to be used in the data collection and the fairness toward the participants volunteering in involving themselves as part of the research.

3.11 The data analysis process

Two types of data analysis process for the case study involved in this research are the mixed methods of qualitative and quantitative (from the questionnaire, interview and observation), and the content analysis of the interviews and the observations. The purpose of the mixed method analysis is to generate the calculation of the degree of effectiveness while the content analysis is to investigate the reasons for the problems or issues in the implementation of the practical work in technical schools. Starks and Trinidad, (2007) suggested that the author become the instrument for analysis because of the judgments that the author has to make especially in coding and thematic of the gathered information. Observing the use of language by participants as a proxy to determine the score to the statement and also, to embrace it as the evidence in supporting the findings. The data analysis process for the quantitative questionnaire used a fully statistical computer-generated process while the analysis for qualitative applied the combination of manual and software generated results. It is due to the complicated and uniqueness of each qualitative research approach that has specific techniques for conducting, documenting, and evaluating processes. This is the responsibility of the author to assure the rigorous and trustworthiness of the process by practising the systematic techniques of data analysis.

Other studies also agree that the detail process of the conduction of data analysis enables the educational stakeholder to determine whether the process is credible (Fereday and Muir-Cochrane, 2006). The interview and the observation analysis involved the process of transforming qualitative data into quantitative numerical codes by using the same five score scale (aligned with the five scores in Likert scale) based on genuine development of Table of the degree of adverb (see Table 4.2 in Chapter 4). In this study, both the statements used by the students and teachers during interviews and observations were analysed using the table of degree of adverb. Observing the use of language by participants as a proxy to determine the score to the statement and also, to embrace it as the evidence in supporting the findings.

The translation process of the 10 voice recorded interviews was first done by the author. Then, the second translator and reader were hired to check the meaning and language (Malay-English). The third reader was hired after that to apply a back work checking at random of the interviews scripts (English-Malay) that has been translated before the transcribing process. Regardless of the single researcher in this research, the purpose of hiring the second and third reader as suggested by Braun and Clarke (2006), is to perform a rigorous and systematic of analysis process that can produce trustworthy and insightful results. This process is also to ensure that the validity of the data and to avoid the missing information during translation. The detail for the data analysis process for the actual data collection is similar to the data analysis process in the pilot study that has been presented in Chapter 4: Pilot Study.

The data analysis in this multiple case studies involved the process of summarising and reporting written qualitative data from the interview and the observation known as the content analysis. The content analysis has been applied in this research to address the challenges occur in the teaching and learning practical work in technical schools based on the Dynamic Model of Educational Effectiveness (DMEE). This process acknowledges four factors that influence the effectiveness in the implementation of practical work in technical schools. The four factors are the student, the teacher, the school and the educational system.

The content analysis allowed the author to summarise the important form of content in the interview and the observation by counting various aspects of the information. This analysis enabled more objective evaluation than comparing content based on the respondents' perception of the topic. According to Flick (2009), the content analysis can be undertaken with any written material (the interview transcriptions and the observation notes) and facilitate by the systematic process (based on Dynamic Model of Educational Effectiveness) of data analysis in order to classify and reduce the large quantity of data. This process eventually produced the results of the challenges and the reasons for the limitation of implementation of practical work in the technical schools as presented in Chapter.

3.12 The degree of effectiveness

The degree of effectiveness is the indicator that this study was originally developed to provide evidence to the level of effectiveness of practical work in achieving the curriculum objectives. There is five level of effectiveness that emerged from the design of this study which is highly effective, effective, moderately effective, low effective and not effective. The calculation of the degree of effectiveness is the process where all mean score from the statement that addresses to the curriculum objectives was converted using the formula in Table 3.6 to determine the degree of effectiveness. At the end of this process, the formula for converting the mean values to the degree of effectiveness as shown in Table 3.7 was applied to present the findings for each curriculum objective. The overall process produced the degree of effectiveness as shown in Table 3.7. The equal design of qualitative and quantitative in mixed method analysis can be seen as suggested by Onwuegbuzie et al., (2009).

Table 3.6 Illustrates the formula of converting mean scores to the degree of effectiveness to determine the degree of effectiveness.

$$\frac{^{***}\text{Mean score of curriculum objective}}{5} \times 100 = \text{Degree of effectiveness}$$

**** Mean score is generated from the score given to the statement and action of a participant in interview and observation (discussed in 4.3.4)*

The mixed method of data analysis has generated the mean of each curriculum objective and the use of the formula above has produced the degree of effectiveness as calculated in Table 3.6. While Table 3.7 contains the description and explanation for the degree of effectiveness.

The purpose of this table is to give the information to the user in determining the level of effectiveness according to the overall score.

Table 3.7 Illustrates the explanation for the mean and percentage of the degree of effectiveness in five levels.

Mean Score	Score (degree of effectiveness %)	Level of effectiveness	Description
5.00 - 4.00	100 – 80.0	Highly effective	The objective is highly achieved
3.99 - 3.00	79.9- 60.0	Effective	The objective is achieved
2.99 - 2.00	59.9– 40.0	Moderately effective	The objective is moderately achieved
1.99 - 1.00	39.9– 20.0	Low effective	The objective is limited achieved
0.99 – 0.00	19.9 - 0	Not effective	The objective is not achieved

Mean score scale: 5.00 – 4.00 (Highly Effective), 3.99-3.00 (Effective), 2.99-2.00 (Moderately Effective), 1.99-1.00 (Low Effective) and 0.99-0 (Not Effective)

3.13 Ethics and research

This study has included the participants from form 4 and form 5 (16 and 17 years old) students at eight technical schools (two for the pilot study and six for the actual research with only five reported in the results) in Malaysia with the total numbers of participants of 315 students and 12 teachers. The author is aware of the ethical principles and the assessment of the vulnerability of the participants and researcher in designing this research. This study involved school children under the age of 18 and therefore are classed as vulnerable and was conducted under the ethical guidance described by the British Educational Research Association (BERA,2011). Since the technical school's students are all boarding students, written permission has been granted from the head of schools as the representative guardians.

This study has been designed to be used in the Malay Language that is understandable to the participants. The students have been guided with appropriate explanations on the first page of the questionnaire, and the written permission has been granted from the head of schools before the research has begun. Teachers had been provided with the consent form to be signed before the interview begins. The observation had been designed concerning the privacy and well-being of the participants and did not disturb the teaching and learning process. The participants have been informed of their right to withdraw from partaking in the questionnaire, interview, and observation at any time with no explanation necessary. They have also been informed that they have the right to skip or to not answer any questions that they do not want to with no explanation needed. Finally, their right for the data collected not to be used for the study has been made distinct with a clear deadline indicated for this choice to be exercised. The author was very certain in explaining that any data that is requested not to be used will be destroyed. However, there are no single refusing requests that the author has received during the data collection. All of the participants have given their commitment and cooperation in responding to the questionnaire and answering interview questions.

The interviews have been recorded through the use of a tape recorder and the author (and always will) ensures the confidentiality and anonymity of the participants. The information provided has been kept strictly confidential. All project materials will be kept for three years after the study has ended, and will be accessible only to members of the research team. As per policy, data will be stored for three years after the submission of the thesis within a password-protected computer. The access to the password is given to the supervisor after the author finishes with the study and the data will be omitted after the agreed period of retention expires. Participants' names are not going be associated with these study materials or with the research findings. The information obtained in this study may be published in scientific journals and presents at professional meetings, but only the group patterns will be described and the participants' identities will not be revealed. The data is defined as all the materials including the questionnaire, the interview and the transcribed observation, the voice recording file, the consent form and other research documents that are relevant. The data protection will also be rigorously adhered too (Data Protection Act, 1998).

This study did not involve any type of physical risk because, during interviews, the participants have been asked to answer the semi-structured questions that have been outlined under certain consideration and time estimation. The questionnaires were administrated with the presence of the teachers in the classroom and the observations were conducted during the teaching and learning process that was controlled by the. Participants have been given the right to ask questions about this study and to have those questions answered by the author before, during or after the research. It is also stated on the consent form that participants may contact the School of Education at the University of Lincoln, United Kingdom if they have any other concerns regarding their rights as a research participant that has not been answered by the author. As a qualified teacher and former education officer of Malaysia, the author has the authority to access the schools and has sufficient experience to conduct the research with children. The author is funded by the Ministry of Education Malaysia and the approvals from the Economic Planning Unit, Malaysia (EPU), the Educational Planning and Research Division, Ministry of Education (EPRD) and the Technical and Vocational Education Division (TVED) have been granted before starting with the pilot study and the approvals have been included with the primary data collection. The ethical approval from the School of Education Research Committee was officially received on 11th July 2016.

3.14 The limitation of the methodology

There are certain limitations appeared in consideration of methodology for this study. The selection of methods using questionnaires, interview and observation have their limitation where the author realised would become a consent in education stakeholders. Morrison, (1993) mentioned the issues in using questionnaire where the participants non-response to the questions or simply tick the answer without reading the questions. It is the uncontrolled human aspect that had been recognised in this study. In order to deal with this situation, the cross tabulations analysis was applied to a sample of items to determine the reliably of the answer from the questionnaire (discussed in 5.2.3).

According to Sturges and Hanrahan (2004), the problem with face to face interviews is the ability of the researcher to influence the answer from the participants unintentionally. This factor would draw bias on the interview result and as mentioned by Gadd (2004) would reduce the validity of the findings. This limitation has been overcoming by implementing the semi structured interviews with the values of flexibility and fairness in the pragmatist paradigm. This types of interviews allow the participants to give honest answers to the questions where the fairness of statement they made is protected by ethical consent form from the author and, at the same time the flexibility gave them the freedom to provide an opinion without prejudice.

In additions, to encounter these limitations appear in the methodology, this study conducted a series of intensive pilot studies before began with the main data collections. Abrahams and Millar (2008) have mentioned the limitation of case study design over the usage of the model of the effectiveness of a practical task. At the very beginning, the author sought and gained permission to observe single lesson that included practical work because it is difficult to ask for wider access to observe subsequent lessons or either create a pre and post-test (experimental) for the research. It would not have been forthcoming in many cases because of the perceived disruption to routines. Follow-up visits, or other actions, to assess students' understanding of the key points of the practical task, either shortly after the lesson observed or later, were also impossible, not least because this would have required that different diagnostic instruments be devised for each lesson observed which would have introduced many new variables and made general conclusions almost impossible to draw.

Therefore, the author decided to limit the data collection to a single visit for each practical work session with the judgements about the effectiveness are based on three pieces of evidences. The evidence from the short-term learning within the lessons observed or in-lesson student interviews in some cases on previous occasions on which they had done the same practical task as observed, comments by teachers during the interview session and the perspective of the students on their answers to the questionnaire of practical work that they have experienced. At the same time, the author views this limitation as for the opportunity to inform the government while presenting the findings to open wider access to the schools for further research purposes. The detail of the reflection of research is presented in 6.7.

3.15 Chapter summary

This chapter has presented the methodology, methods and the explanation of the research design where the focus is on the case study process, in order to answer the research questions. The application of multiple case studies process in conjunction with the triangulation of data collection and analysis in mixed method approaches has been explained in detailed. This chapter also has indicated the approach to calculate the sample size from the total population by the aid of online application via *www.raosoft.com/samplesize.html*. The construction and validation of instruments have been discussed in appropriate condition. This chapter has explained the ethical consideration applied to the whole research design. Informed consents were obtained from all participants, and assurances were given that all conversations would remain confidential and identities concealed to assure their anonymity. This chapter also stated the limitation for the selection of methodology where the author has faced to commit with the procedures outlined by the Ministry of Education Malaysia. Finally, this chapter has emphasised that the main data collection which involved the multiple case studies is the continuity of the process from the intensive series of the pilot studies. It is where the author has decided to separate the report for the pilot study in one chapter to perform the steps of each procedure that led to the final result. The example of the data collection and data analysis process for the multiple case studies is similar to the single case study in the pilot study and has been presented in detail in the next Chapter 4: Pilot study.

CHAPTER 4: PILOT STUDY

Structure of the chapter

The structure of this chapter is presented as follows; the first section gives an introduction to the pilot study by giving an overview of the participants involved in the pilot study process. Then, the detail of the pilot study procedure which included mixed methods data collection (the student questionnaire, teacher interview and the practical work classroom observations) will be presented. This section is followed by an explanation of the data analysis process which consists of the collaborative transcriptions and translations, thematic coding, scoring and verification on the reliability of the code. The next section presents the outcome of the pilot study that leads to the modification of all the instruments and the adjustment of methods and approaches. It continues with the results on the calculation on the degree of effectiveness of practical work for the Mechanical Engineering Studies' curriculum objectives. Finally, the conclusion of the pilot study is presented which address some of the limitations that have been faced along the process and the way to overcome the obstacles in order to maximise the findings in the main data collection process.

4.1 The introduction to the pilot study process

This chapter is going to report the intensive process of pilot study that has been conducted as preparation for the main data collection. Hitchcock and Hughes, (l995: p.41) suggested that conducting a pilot study is necessary to uncover some of the challenges in advance of the research proper. It was mentioned that if it appears that the research is going to come into conflict with aspects of school policy, management styles, or individual personalities, it is better to confront the issues head on, consult relevant parties, and make rearrangements in the research design where possible. In this research, two stages of the pilot study were conducted in two technical schools in Malaysia. The data collected from the schools was anonymised, and throughout this study, the technical schools were known as Technical School Silver and Technical School Lavender. The whole process of data collection involved 28 students and one teacher from the Technical School Silver, and 26 students and one teacher from the Technical School Lavender. According to Lancaster et al., (2002), and Teijlingen and Hundley (2002), a pilot study is a mini version of a full-scale study as well as a specific pre-testing of a particular research instrument.

This research used a student questionnaire (30 questions), a teacher interview (40 questions) and a classroom observation. This pilot study involved a class of students from form 4 (F4) and one teacher from each of the participating schools. The overall process of the pilot studies took approximately ten weeks (1st July 2016 to 7th September 2016). It took approximately one week at each school for data collection from the students, teachers and the practical work sessions in the classroom. Four weeks were spent to completely translate, transcribe and analyse all the instruments as well as generated the results. The data from triangulation methods of the questionnaires, interviews and classroom observations were analysed using the mixed methods process of data analysis that generated the overall means for each curriculum objective. For several decades, many studies acknowledged the idea by Lincoln and Guba (1985) that suggested the triangulation process would address the credibility in a naturalistic enquiry. According to Cohen et al., (2014) the triangulation techniques in the social sciences attempt to explain in detail human behaviour by evaluating it from more than one standpoint and, in so doing, by making use of both quantitative and qualitative data. The results from this pilot studies process have indicated the data analysis process of mixed methods was successfully generated the degree of effectiveness of practical work in achieving each curriculum objectives for the syllabus of Mechanical Engineering Studies in secondary technical schools in Malaysia.

4.2 The procedure of the pilot study

This pilot study involved the triangulation process of data collection and mixed method of data analysis in a single case study. The school's principal suggested all of the participants in this pilot study depending on their availability and willingness. A discussion was conducted with the Mechanical Engineering Studies teachers at each school to give an introduction to the research process. Since the author was previously an educational officer for the Ministry of Education Malaysia, some of the teachers at the participating schools were known to the author. It is important to explain that the presence of the author at that time as a researcher to this particular study and develop a good relationship with the participants before the commencement of this research. This step is an approach taken by the author to assure the school management, the teachers and the students, that the study was neither a representative of ministry nor an attempt to look for the flaws in the technical schools.

One of the purposes of this study was explained as to look at the opportunity for improvement in the subject of Mechanical Engineering Studies, and honest feedback from the teachers and students are crucial for the success of this research. This research was subjected to ethical approval and consideration, and thus participants were reassured about how the data would be treated confidently and encouraged to respond honestly and truthfully. Consent forms were signed by the participants (school principal, teacher and students) were evidenced that they had agreed to cooperate in giving honest information to be used in this research. The author found that this pilot study is important in forecasting the scenario and reality for the main data collection process. The pilot study also prepared the author to implement the improved version of procedures for data collection on a bigger scale.

4.2.1 The questionnaire

The questionnaire was constructed (presented in 0) in the Malay language to obtain the student's perspective on the level of effectiveness of practical work in achieving the curriculum objectives. In this particular method, the rating scale was applied, which is a useful device to build in a degree of sensitivity and differentiation of response, while still generating data (Cohen et al., 2014).

The questionnaires were distributed to students in one class of form 4 of Mechanical Engineering Studies at both technical schools after the practical work session. The author took approximately three minutes for the briefing session in front of the classroom to explain the content of the questionnaire, the purpose of the research and ethical consideration which related to the students right. The students took about 10 to 15 minutes to answer the questions. The questionnaires were collected from the students at the end of the session, and all participants gave their cooperation in answering all questions in the questionnaires.

The questionnaire was analysed using the SPSS software, and the mean scores for each item were generated. The mean score for each question which represented seven curriculum objectives for the syllabus of Mechanical Engineering Studies was calculated. The other test that had been applied for the questionnaire was the *Cronbach alpha* test. Since one of the important purposes of this pilot study was to test the reliability of the items in the questionnaire, the values of the *Cronbach alpha* were generated as an indicator. The results should be more than 0.8 for this questionnaire to be reliable and each of the items will be acceptable. At the end of this analysis process, the mean scores from the questionnaire were presented to be aligned with the mean scores obtained from the interview and the classroom observation.

4.2.2 The interview

The interview is a specific method for collecting information from the teachers of Mechanical Engineering Studies regarding practical work, curriculum objective and syllabus. The purpose of this interview is to examine the suitability of all of the questions related to practical work in achieving the curriculum objectives and, to gather the information about teaching and learning of practical work from the teachers' perspective. The interview questions were designed to address the same concern as indicated in questionnaires for students (presented in 3.6.2). In addition, the questions given during teachers' interview enabled the participants to give detail explanations and reasons for the statements that did not appear in the questionnaire. It is one of the advantages of utilising interview compared to other methods where the details information can be gathered faster and more effective.

Only one teacher at each technical school was selected to be involved in this process, and the duration for each interview was approximately between 35 minutes to 1 hour. The interview was conducted face to face with the teachers according to the suitability of their time. The teachers in both schools were highly willing to participate in this research and spent their free time to get involved with the interview session. The interview session was scheduled in the workshop preparation room of Mechanical Engineering Studies, where it was suitable and comfortable for both the author and teachers. The interview began by requesting permission from the participants to record the conversation using the voice recorder and then followed by an explanation about the consent form before retrieving signatures from both author and teachers. During the interview, the respondents answered 35 to 40 questions (a mix of open-ended and structured questions) in the same sequence. The author had to adjust the way to ask question depending on the answer given by the teacher. It happened that teacher answer one question about the creative thinking in practical work (curriculum objective 4) and then elaborate more about utilising the computer (curriculum objective 5) in design which is included in another question. Due to that, the author had to alert with the answer from the respondent and wrote a note on which questions is already mentioned. It is going to prevent the author from asking the same questions that might show the author's weaknesses for not paying attention to the previous answers from the participant.

The interview was conducted in the Malay language and then translated into the English language by the author during the data analysis process. The data from the interview was undergone the translation process before it was transcribed and analysed using NVivo 10 software. The detail process of data analysis for an interview has been explained below in 4.3: The data analysis.

4.2.3 The classroom observation

The classroom observations of practical work in the teaching and learning process is to obtain a clear view of expectation from practical work (intended curriculum) and implemented curriculum. This process was designed to fully utilise the observation outline of 20 elements, where the main focus is to address the curriculum objectives and to align with the questionnaire and interview questions simultaneously. This structured observation process is to ensure that this study would focus on specific actions or responses in the practical work session. During the observation process, the focus of observation was to see the actual implementation of practical work which had been self-claimed by the students and the teacher in the questionnaires and interview. In addition, the observation process in the workshop during practical work enabled the author to interact informally with the students. It was to ensure that direct involvement of author during the observation process was limited to prevent interruption to students and influence the final results.

The observation was carried out for 80 minutes during a practical work session of a group of students (26 to 28 pupils) and one teacher of Mechanical Engineering Studies. The author placed a laptop at the back of the workshop and observation notes were written every 5 minutes. Throughout the process, the author walked around the classroom to observe students works, watched the participants' action and occasionally talked to the students and then filled up the observation note. The data from the observations were transcribed and analysed using NVivo 10 software. The results were generated into a mean score to be aligned with the findings from the questionnaire and interview during the mixed methods of data analysis process that will be explained below.

4.3 The mixed methods of data analysis in a pilot study

The data analysis process involved mixed methods of results from questionnaires and transcription from interviews and observations. The questionnaires were analysed using SPSS (version 23) software to generate information from the raw data, while data from the interviews and observation were analysed using NVivo 10 software. At the end of the pilot study, all the data from the questionnaires, interviews and observations were gathered and analysed via a mixed method of the data analysis process. This process is convenient to cross-check the results and valuable to support other judgments. Additionally, this study was designed to undertake the content analysis of challenges in teaching and learning of practical work for the subject of Mechanical Engineering Studies. However, the content analysis cannot be performed in this pilot study as merely one technical school involved as the participant of this study. The actual data collection has utilised this analysis due to sufficient numbers of the participant to be analysed. Firstly, the analysis of the questionnaire provided the mean scores for each item by applying descriptive statistical analysis. Then, the mean scores for each item were combined in a similar group to generate the overall mean of the curriculum objectives. The data analysis involves a different layer of a complex process where each process was designed to extract the information from the different research instruments. At the end of this process, the purpose was to generate the outcome of mean scores in order to determine the degree of effectiveness.

4.3.1 The statistical analysis for the quantitative data from the questionnaire

Table 4.1 shows the generation of the overall mean for parts of the items in the questionnaire extracted from the SPSS software. The overall mean was accumulated with the result from interview and observation after translating, transcribing and coding to generate the mean values from qualitative data.

Table 4.1 Illustrates the example of generation of overall mean scores for items number 1 to 16 in the questionnaire.

Item Statistics				
	Item	Mean (SPSS generated)	CO	Overall mean
Q1	Identify term	4.10	CO1	3.88
Q2	Interpret term	3.94	CO1	
Q3	Define concept	3.94	CO1	
Q4	Explain concept	3.79	CO1	
Q5	Distinguish fact	3.98	CO1	
Q6	Relate fact	3.71	CO1	
Q7	List process	3.90	CO1	
Q8	Explain process	3.83	CO1	
Q9	Recall procedure	3.75	CO1	
Q10	Discuss procedure	3.87	CO1	
Q11	Apply knowledge	3.98	CO2	3.88
Q12	Rational opinion	3.79	CO2	
Q13	Use computer	3.75	CO5	4.15
Q14	Use engineering tools	4.33	CO5	
Q15	Utilise machine	4.29	CO5	
Q16	Utilise workshop equipment	4.25	CO5	

Adaptation from SPSS statistical result for pilot study 2

4.3.2 Collaborative transcription and translation

The translation process was performed at the same time with transcribing process using Nvivo 10 software. The recorded interviews were imported in the software and played several times so that the author could clearly capture the statement of teachers during interviews. According to Bucholtz (2007), one of the challenge in translation for transcription is the diversity of selection of words and the link between the meaning and interpretation. The main idea is not to disregard the translator works, but to minimise the difference of understanding and hence to reconceptualise one as the other is inevitable leads to what Briggs and Bauman (1992) call an 'intertextual gap' between the author and the outside reader. In order to avoid the missing information or wrong interpretation during the translation process, two external translators proficient in both Malay and English language were hired to retranslate the recorded interview. Then, the comparison of content and language terminology was made by the author to observe the difference between original and latter translation. The result shows that there was a slightly different (less than 5%) in the use of terms for both translation example the use of 'exactly' and 'absolutely' where both have the similar meaning. However, the little difference had no impact to the meaning of the sentences or statements regards to Table 4.2, the table of degree of an adverb in Table 4.2. The variation or gaps in translation was reduced by hiring external native-speaker translator to translate the interview before comparing the results with the translated version.

4.3.3 The thematic coding

Thematic coding as stated by Gibbs (2007) is a part of qualitative analysis which allowed the author to build a thematic framework from the gathered information. The common theme can be established by classifying text or data in similar categories of ideas. In identifying the result after transcription process, thematic coding was used. The purpose of this process is to align the qualitative and quantitative data in a consequential attachment. The thematic coding was applied during data analysis for interview and observation, while questionnaire generated the code/score automatically. This coding enabled the author to identify the connection of information within cases and also become a tracker for the author in categorising the data into meaningful information. Hence, this pilot study applied thematic coding process with seven codes that were placed into subcategories addressing seven curriculum objectives (see Table 4.7). The triangulation from the three methods of data collection despite all have addressed the same codes and was used to break the transcription into categories before converting the qualitative data into a numerical score. This process generated a number by given a score to any statement or action from participants that reflected the code. Table 4.2 presents the code table for the degree of adverbs of which the keyword was used to give point/score for every statement addressing the curriculum objective in an interview and observation process. The purpose of this code table is to ensure that the score to the statement was given systematically and consistent before generating the mean values in the data analysis process. The overall data analysis process using the code table for the degree of adverbs as listed in Table 4.2 was successfully simplified and connected to the huge amount of data and coding from interview and observation, while at the same time provided the score to the generation of mean.

Table 4.2 Illustrates the code for the table of degree of adverbs used as an indicator in the scoring process.

Score 1	Score 2	Score 3	Score 4	Score 5
Absolutely no	No	Not Sure	Yes	Absolutely Yes
Terribly	Bad	Not Bad	Good	Really Good / Very Good
Tiny	Small	Mmmm (Thinking)	Large	Extremely Large/Huge
Not at all	No need	Not necessary	Need	Must / Conform
Hate	Don’t Like	Neutral	Like	Love
Vanish	Missing	Some	Actual	Fully
So wrong/ totally incorrect	Wrong/incorrect	Fine	Correct	Excellent
Lost	Unsolved	Manageable	Solve	Completely Solve
Worse	Not Effective	Moderately	Effective	Highly Effective
Lowest	Low	Medium	High	Highest
Little	Less	Almost	Enough	Entirely
Awfully	Weakly	Barely	Indeed	Strongly
Hardly	Far	Least/ Just/ Quite/Well/ Nearly	Pretty Much	Much/ Greatly/ Incredibly Lots/ Most/Perfectly/ Positively/Practically/Totally/ Deeply

#Score 0 if the respondent refused to answer / no comment

4.3.4 The thematic scoring

Based on Table 4.2, the thematic coding was applied to each statement addressing the curriculum objectives in the teachers' interview and classroom observation. The calculation for the codes was based on the point where each statement or action from the teacher and students who addressed the curriculum objectives was marked from 1 to 5 points. The score was given as shown in Table 4.3 and 4.4 below, and the overall mean was calculated through the process. This is the process where qualitative data are converted into numerical codes that can be represented statistically, i.e. quantitated (Tashakkori and Teddlie, 1998).

Table 4.3 Illustrates the example of coding and transcriptions process of the interview for codes in CO3 and codes in CO6.

	Statement / Action /	Score
Codes: [CO3 Create interest and demands]		
Question 11:	How do the students respond to this (practical work) teaching approach?	
Answer:	Students love to do practical work	5
Question 20:	Do you think that practical work is effective in promoting students interest in the field of mechanical engineering?	
Answer:	Yes, it is one of the reasons, develop an interest	4
Question 21:	Do you agree that by doing practical work students manage to meet the demands of a career in the mechanical engineering field	
Answer:	No. The lesson on Form 4 and Form 5 students is just a small component	2
Question 28:	How do you feel after the practical work sessions?	
Answer:	Students love practical works	5
	Mean	4.00
Codes: [CO6 Cooperative and safety]		
Question 36:	Do you realise that students cooperate well in a team by doing practical work?	
Answer:	Yes a lot, they (the students) work really hard in groups to finish the practical task	5
Question 37:	Do you realise that students aware and responsible for their own safety by doing practical work? How?	
Answer:	Yes, they apply the safety procedure	4

Question 38:	Do you realise that students aware and responsible for their friends' safety by doing practical work? How?	
Answer:	Mmmm..(not sure) I think some of them realise	3
Question 39:	Do you realise that students aware and responsible for the workplace's safety by doing practical work? How?	
Answer:	Absolutely yes, they follow the safety procedure to avoid an incident in the workplace	5
	Mean	4.25

Adaptation from NVivo analysis result for pilot study 2- Interview

Regarding the agreeability, 1 point was marked for strongly disagree, 2 points for disagree, 3 points for neutral, 4 points for agree and 5 points for strongly agree. The cumulative points had been calculated by the aid of software developed by the author along the process so that the consistencies of the point given to the statements can be controlled. Since the number of participants is bigger, it is vital to ensure that the score given in the main data collection process represents the exact point to produce the correct accumulative of mean. Table 4.4 presents the scoring process for the thematic code in observation. The score for each statement was gathered, and the overall mean was generated accordingly.

Table 4.4 Illustrates the example of coding and transcriptions process of the observation fore codes in CO2 and CO3.

Statement / Action /		**Score**
Codes:[CO2 Apply knowledge & rational opinion]		
Focus: Student apply the correct procedure		
1.	Continue working using the correct procedure	4
2.	Moderate answer based on the learning process in the classroom	3
Focus: Student give an opinion and rational		
3.	Start to give good rational answer to what has been asked by the teacher	4
4.	Incorrect answer during application	2
	Mean	3.25
Codes: [CO3 Create interest & demands]		
Focus: Student show interest in doing practical work		
1.	She really likes to do practical works	5
2.	She enjoys the process very much	5
3.	He shows some interest in doing the practical work	3

Mean	4.33

Adaptation from NVivo analysis result for pilot study 2 – Observation

4.3.5 Verification on the reliability of codes

The reliability of code or information could be verified by the involvement of the third party which has similar background knowledge or expertise (Lincoln and Guba, 1985:315). The verification of code is important to certain the systematic score given by the author with the score by the external readers to avoid bias on the mean score given. The process of code verification or re-coding was employed by distributing the transcription to four different people who were not familiar with the code. They were the PhD students from another university, the curriculum officer from the Ministry of Education Malaysia, the school teacher and the lecturer from the Higher Education Sector. The purpose of this verification process is to ensure that the score given by the author is highly reliable and trustable. This process would determine whether the score represents by code for a table for the degree of adverb is useable in giving a consistent score to the same statement.

The result of re-coding process demonstrated that more than 95% of the score was similar and consistent to the score given by the author. A slightly different score is from the sentences that have more than one adverbs in a similar statement. The responses from an external reader indicated that they are confused to give a score to the statement in one sentence which has two contrast adverbs of judgment. Therefore, the author decided to break the statement from the respondent which included more than one adverbs in a sentence, to a few sentences in order to improve the quality of the scoring process. Small variable among the scores from re-coding process showed that the consistency of the score could be performed by referring to the table and most importantly is the interpretation by the author was highly trustworthy. It also indicated that the whole process of coding, the use of code table of adverb and the scoring were acknowledged by other users who potentially apply this method of scoring in their working contact.

4.4 Pilot study outcomes

The purpose of this pilot study is to verify the validity and reliability of the instruments, to test the suitability of the methods and to explore the selection of data analysis process. Overall, this process included the evolutions of instruments and methods (questionnaire, interview and observation) in order to maximise the information gathered in the real data collection process.

In addition, these changes focused on overcoming the weaknesses that appeared in the pilot study process, so that in the real data collection, the research can be conducted in a smoother setting. There were three major changes in the instruments and methods that have been done for certain purposes after the pilot study. The outcome of the pilot study has led to the modification of the questionnaire regarding terminology in the items. It also has resulted in the modification of the approach in conducting the teacher interview and the changes in the flexibility of the classroom observation. This pilot study has successfully tested all the instruments, and adjustment has been made in order to suit the situation in the technical schools.

4.4.1 Modification of the questionnaire

During the process of data collection in pilot study 1, a few students asked questions for item number one and two because they were not familiar with the word 'terminology'. Therefore, the author had to explain a synonym of that word in front of the class and provide an immediate solution to the students during the process. While preparing for the second pilot instruments, it was decided to change the word 'terminology' to 'vocabulary' which was more familiar to the participants. The consequence of the action showed that the second pilot study process went well without question from the participants. The questionnaires from both pilot studies were analysed using SPSS. The main focus of the analysis is to calculate the mean for each item by using the five point rating in Likert scale (example in Table 4.3) and to test the reliability of the items using the *Cronbach alpha* test.

The items were categorised into seven main objectives, and the result in the first pilot study showed that the mean values for all curriculum objective were above three. It was signified that the majority of the participants had agreed with the items. However, there were three items in the first pilot study that showed the individual mean values below three (item number 9, 13 and 22). The author decided not to change these items for two reasons; one is that the mapping process has clearly outlined the items to represent a specific element in the curriculum objective so that the changes may disturb the link of the instruments mapping. The second reason is the score in the first pilot study was an individual case that cannot be generalised as participants were not clear with the meaning of the items and it may reflect the situation in one school or one class only. Consequently, all the items remained the same for the second pilot study except for the word 'terminology'. To measure the reliability of the instrument, the test of *Cronbach alpha* was applied, and the alpha value obtained for the first pilot study questionnaire was 0.892 (alpha > 0.8) with a total number of 28 participants. Table 4.5 shows the alpha value obtained for the first pilot study, and the alpha value indicated that all of the items are reliable and acceptable.

Table 4.5 Illustrates the result from the reliability statistics *Cronbach alpha* test for the pilot study 1.

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.892	.896	30

Source: SPSS statistical result for pilot study 1

In the second pilot study, the overall mean for all seven curriculum objectives showed an average above three. The three items (item number 9, 13 and 22) mentioned in the first pilot study showed that the individual mean scored more than three. It was signified that the author decision for not changing those items in the first pilot study was correct because it was most likely an individual case rather than representing the whole situations. For the second pilot study, the *Cronbach alpha* value was 0.881 with a total number of 26 students. Table 4.6 shows the alpha value obtained for the second pilot study. Even though the value of the Cronbach alpha was less than the first pilot study, it was considered to be influenced by the decreasing number of respondents involved in this second pilot study. However, the *Cronbach alpha*'s value remained above 0.8, and it was acceptable for the measurement of the construct items in the questionnaire. The 30 items in the questionnaire were reliable to be used in the real data collection for a large number of participants.

Table 4.6 Illustrates the result from the reliability statistics *Cronbach alpha* test for the pilot study 2.

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.881	.882	30

Source: SPSS statistical result for pilot study 2

4.4.2 Modification of the interview

The interview with the teacher in the first pilot study was transcribed and coded using NVivo 10 software with the theme was to address seven curriculum objectives. 40 questions (structured and open-ended) were constructed by the author for the interview session. The perfect time to conduct the interview was discussed regarding the availability of the respondent. From the initial estimation of 30 minutes, the interview took approximately 1 hour and 15 minutes to finish. The participant has been teaching the subject of Mechanical Engineering

Studies for 14 years and has a vocational education background. The participant was one of the 27 Mechanical Engineering Studies teachers who major in training skills rather than theoretical parts (the Mechanical Engineering Studies teachers have two different academic backgrounds, namely the vocational background and engineering background). For every single question asked by the author, the respondent elaborated and explained the answers in detail which was the reason for the interview time to be longer than expected. From a positive point of view, longer interview session facilitated the information gathered during the interview session to be rich and meaningful because the respondent gave a specific answer with examples and interpretations. At the end of the interview, the author managed to address all of the curriculum objectives from the interview questions. Thus, the interview questions were reliable to be applied in the second pilot study without any adjustment. During the transcription process in NVivo, the codes were determined related to the curriculum objectives as follows:

CO1 Understand Concept/Terminology/ Process

CO2 Apply Knowledge

CO3 Create Interest

CO4 Develop Creative Thinking

CO5 Utilise Computer/ Workshop Equipment

CO6 Responsible for safety

CO7 Problem solving

The report shows that the terms used as codes assisted the author in sorting the findings into groups of categories. However, a few codes have to be rephrased because the codes did not represent some elements in the statement of the curriculum objectives. For example, in curriculum objective 2, the phrase of rational opinion was not stated, and it created some confusion during the transcription process. As a result, a few code names were adjusted during the transcription on the second pilot study while the theme remained the same (example as shown in Table 3 above). The setting for the second pilot study was similar to the first pilot, and the same questions were asked in a similar sequence. During the interview session in the second pilot study, the teacher who has been teaching the subject of Mechanical Engineering Studies for 19 years has an engineering background. The responses given by the teacher were straightforward answers for every question. The author has to change the way of asking the questions to get extra information from the respondents, for example, the addition of 'why is…'

to get the explanation of the phenomena. This interview session met the target as the duration of the interview was close to the estimation time of 35 minutes. The data were transcribed and coded using a similar process as the first pilot study. For the purpose of triangulation, the mean values were calculated to be aligned with the result from the questionnaire and observation.

4.4.3 Modification of the observation

At the beginning of the first pilot study, it initially was planned to conduct the first and second study at the same school. However, the obstacle faced by the author during the first pilot study has led to the decision of having the second pilot study at another technical school. Observation of practical work session at the first school was limited because only ten students were doing practical work at that time to finish their fitting project while the rest had already finished. The overall process of teaching and learning in practical work was not given because the teacher had already demonstrated the process in the previous class 2 weeks ago. The students only focused on finishing their work of which just approximately 20 percent left. After a discussion with the teacher, it was found that there were no more practical work sessions available at that school for the second pilot study because all form 4 and form 5 students would focus on the theoretical part and they had already covered all the elements of practical work in the curriculum specification. In the end, the author had to find a new school which was still working on the elements of practical work for the second pilot study. The observation at second school gave an opportunity for the author to understand the holistic process of practical work in the subject of Mechanical Engineering because the process of teaching and learning practical work was fully implemented. In this school, the observation outline was tested intensively, and the focus of observation was determined. Similar to the interview, the process of transforming qualitative data to quantitative numerical codes used the same scale and the same code table of degree of an adverb. In addition, no modification was done to the observation outline because the author has successfully achieved the target to address all the curriculum objectives during observation.

4.5 Results of the pilot study

Table 4.7 shows the summary of result for all methods included in this pilot study. The formula on the calculation of converting overall mean to the degree of effectiveness is shown in Table 3.6 in Chapter 3, exhibits the summary of the result of the second pilot study from the triangulation process of data analysis. The initial findings indicated that three of the curriculum objectives achieved scores between 100.0 and 80.0, followed by the other three objectives scored between 79.9 and 60.0, and one curriculum objective scored between 59.9 and 40.0.

The scores indicated that the practical work elements were ‘highly effective’ in achieving the curriculum objective 1, 3 and 6, ‘effective’ in achieving curriculum objective 2, 5 and 7, and ‘moderately effective’ in achieving curriculum objective 4. The adaptation of five scores in Likert scale for the survey was utilised in giving the score to the thematic coding from interview and observation. It was to transform the qualitative statement into numerical quantitative codes score for calculation of mean values for the curriculum objectives. For triangulation, the mean values for each curriculum objective were calculated to align results from the questionnaire to that of interview and observation.

Table 4.7 Illustrates the findings from the second pilot study by combining the mean scores from the questionnaire, interview and observation.

Curriculum Objectives	Questionnaire (Mean)	Interview (Mean)	Observation (Mean)	Overall Mean	*** Degree of Effectiveness (%)
1-Know and understand facts, concept/principle, terminologies, process and procedure in mechanical engineering	3.88	4.67	4.50	4.35	87.0
2-Apply knowledge of mechanical engineering to form rational opinions pertaining to problems related to mechanical engineering	3.88	3.23	3.25	3.45	69.1
3-Create interest in the field of mechanical engineering and able to meet the demands of a career in this field	4.20	4.00	4.33	4.18	83.6
4-Develop creative thinking through intellectual activities and practicals	3.87	3.67	0.00	2.51	50.2
5-Utilize the computer, workshop and laboratory equipment effectively	4.15	4.00	3.33	3.83	76.6
6-Be responsible, cooperative and value one's own safety and others as well	4.22	4.25	4.33	4.26	85.2
7- Able to solve problems related to mechanical engineering field	3.12	3.50	3.50	3.37	67.4

4.6 Limitation of the pilot study and the way forward

This pilot study has been considered as preparation for the main data collection, through the pilot study the author has taken every step in order to minimise the weakness in the research instruments. According to Wittes and Brittain (1990), a pilot study is a useful tool to determine the limitation toward the main data collection. It is also suggested in Cohen et al., (2014) that by piloting a study, the author would predict the possible problems and risks to be improved in the actual study. Thus, the limitations experienced by the author while conducting this pilot study and the recommendations to be considered during the main data collection are as follows:

i. The study involved only form 4 students because the author was not authorised to include form 5 students. This was due to the upcoming trial terminal examination preparation from July to September 2016 and because of the practical work sessions for form 5 had already finished by mid of June 2016. This factor has caused to the conduction of the main data collection between April and June 2017. The main data collection was rescheduled according to the appropriate time to evaluate the practical work element for both form 4 and form 5.

ii. The number of samples was limited to one class of students (n = 28 and n = 26) for the questionnaire, two teachers for an interview and two practical sessions for class observation. Due to insufficient numbers of participants for the survey, the SPSS test at this stage was limited only to test reliability (*Cronbach alpha*) and not applicable to another statistical test. Then, the main data collection process involved more participants (n = 261) in 5 technical schools, and more statistical tests were applied in order to validate or crosstab the quantitative data. At the same time, the qualitative data can be presented in a more trustworthy because of the more participants appears to support or decline the statement that addresses to the curriculum objectives.

iii. The process for gaining access to the technical schools was complicated. There were several steps that needed to be completed in order to gain access to the participants; firstly the formal letter was sent earlier to the technical school management team to inform about the presence of the author at the scheduled dates and request permission to approach teacher and students of mechanical Engineering Studies. After two weeks of waiting, a phone call was made to the school management since no response was received from the letter. Unfortunately, the phone call ended up with the uncertain status of the letter, where the management admitted that they received the letter two weeks ago, but they misplaced it. A new letter then was given to the school's principal by hand, and the principal gave immediate permission to the author to meet the teacher and the students of Mechanical Engineering Studies. This incident has changed the way the author approaches the technical school for the main data collection. Since the schedule for the main data collection is slightly tight, the author goes to each technical school and meet the principal to hand on the application letter to research that particular technical school. It is quite a distance from one technical school to another, but the author has to do it because of the short duration for practical work being teaching in the school sessions.

4.7 Chapter summary

This pilot study has successfully achieved the objectives which are verified the validity and reliability of the instruments, tested the suitability of the methods and to explore the selection of data analysis process. The overall process of data collection and analysis involved the combination of intensive qualitative and quantitative approaches in the multiple case studies. The raw information was gathered using three different methods. Then, the data were analysed separately using both qualitative and quantitative methods before transforming and combining with statistical coding using the code table of degree of the adverb. The pilot study, as planned, has prepared and tested complete instruments to be used in main data collection. The pilot study has given opportunities to the author regarding planning the work, constructing the outline and determining the method for data analysis. The initial result shows that the instruments were suitable to investigate the effectiveness of practical work in achieving the curriculum objectives for engineering studies in Malaysia. This process of the pilot study also indicated that the selected methods were acceptable to be conducted in main data collection process. This pilot study has successfully developed the code table of degree of adverb for the mixed methods analysis process of information gathered from the triangulation of methods in data collection. In addition, the reliability, validity and accessibility of the instruments, method and also data analysis process have been presented.

CHAPTER 5: RESULTS AND FINDINGS

Structure of the chapter

The structure of this chapter is presented as follows; the first section provided an introduction to the quantitative results as well as the number of participants, pseudonyms of the schools, background information of respondents and list of curriculum objectives (CO) for Mechanical Engineering Studies (MES). The analysis of items in questionnaire had begun with the normality test. This is followed by the results and series of validity tests for the quantitative data from questionnaire using the *Mann-Whitney U*-test and cross-case analysis of all curriculum objectives for form 4 (F4) and form 5 (F5) in all schools. The second section covers the individual analysis for form 4 and form 5 in achieving the Learning Outcomes (LO) for each practical work session. The findings of the effectiveness of practical work are presented in the discussions on individual mean scores for all seven curriculum objectives. The mean scores for the calculation of a degree of effectiveness in each curriculum objective are presented in tables. The level of effectiveness categorised as highly effective, very effective, moderately effective, slightly effective, and ineffective regards to their ability to achieve a particular curriculum objective. Additionally, this section discussed the qualitative findings from the teacher's interviews which coded as (A4: Answer for form 4, A5: Answer for form 5) and practical work classroom observations (C4: Classroom for form 4, C5: Classroom for form 5). The discussions addressed the related issues in the implementation of practical work in the technical schools which influenced the mean scores. This chapter discussed the difficulties occurred in the process of achieving the curriculum objectives for each technical school. The last section presents the qualitative results of the four factors (student, teacher, school and education system) as outlined by Creemers and Kyriakides (2006) in the Dynamic Model of Educational Effectiveness (DMEE). This model was tested many times in different context and has a successful impact on the effectiveness of teaching and learning (Vanlaar et al., 2016). This study had adopted the model as it complements the Malaysia Education Blueprint 2013 – 2015. These four factors of Dynamic Model of Education Effectiveness have emerged in the findings from interviews with teachers as well as the practical work session observations based on the statement from teachers, and observation of student action by the author. It ends with the conclusion, which summarised the overall findings, followed by an overview of the next chapter.

5.1 Introduction to results and findings

This chapter presents the quantitative results from the coding and scoring which were applied in the mixed method of data analysis as discussed in Chapter 4. Descriptive statistical tests were utilised and subsequently generated the combination of mean scores from triangulation methods (see 4.3). This approach enabled the determination of practical work to be either ‘highly’, ‘very’, ‘moderately’, ‘partially’ or ‘ineffective’ at achieving the seven curriculum objectives (referred to3.12, in Chapter 3 for the generation of a level of effectiveness). The purpose of this process is to provide the calculation of the degree of effectiveness of practical work in achieving the curriculum objectives by combining three different sources of data, namely from students’ perceptions, teachers’ perceptions, and author’s observations. In order to increase the validity of the result, a wide range of data was included in the case study and thus strengthened the argument of the statement created by each participated group (Thomas, 2011).

The mean scores in the tables provided in this chapter were scaled from a range of 0 to 5, (0 signifies the least effective and 5 the most effective). The mean scores were generated from the triangulation of the three methods, i.e. the students questionnaire from form 4 (F4) and form 5 (F5) (n = 261: 193 males and 68 females), ten teachers interviews (seven males and three females) and ten practical work session observations in five technical schools (pseudonyms of the schools were Technical School Jade, Khaki, Magenta, Pink and Turquoise). The overall process took approximately 18 weeks (10th April 2017 to 11th August 2017) which included the process such as data collection and transcriptions, and another 12 weeks for data analysis and reports.

The teachers of Mechanical Engineering who participated in this study have various experiences in teaching this subject, with teaching experience of 9 years to 22 years. Nine out of ten teachers have a degree in Mechanical Engineering with Education from Universiti Teknologi Malaysia (UTM), and two of these have a Master’s degree in Technical and Vocational Education (one of which studied at UTM, the other at Universiti Putra Malaysia). The form 4 students had studied Mechanical Engineering Studies for at least four months when the data collection was conducted. For form 5, they have studied the subject of Mechanical Engineering Studies for 16 months and, this was their second year experienced doing practical work where the tasks are more advanced. All of the practical work learning outcomes were designed to align with the curriculum objectives.

The seven curriculum objectives stated in the syllabus of Mechanical Engineering Studies which will be discussed in this chapter are as follows:

CO1: Know and understand facts, concepts/principles, terminologies, processes and procedure in Mechanical Engineering

CO2: Apply knowledge of Mechanical Engineering to form rational opinions pertaining to problems related to Mechanical Engineering

CO3: Create interest in the field of Mechanical Engineering and able to meet the demands of a career in this field

CO4: Develop creative thinking through intellectual activities and practical

CO5: Utilise the computer, workshop and laboratory equipment effectively

CO6: Be responsible, cooperative and value one's own safety as well as others

CO7: Be able to solve problems related to mechanical engineering field.

Syllabus Specifications of the Mechanical Engineering Studies, Technical and Vocational Education Division, (1994).

The second part of this chapter as mentioned earlier presents the qualitative results of the factors affecting the process of teaching and learning mechanical Engineering Studies subject which emerged from the interviews and observations. It is to identify the challenges and highlight the current situations in all technical schools that have been initiated during the process of data collections. These findings will also become baseline information to the detailed discussion in the final chapter.

5.2 Comprehensive results

The comprehensive result presents three main findings which are the demographic information for all participants involved in this research. The results for the main studies included the summary for all means scores for form 4 and form 5 about the seven curriculum objectives and, the quantitative validity analysis that tested the significant figures of the scores within the cases for form 4 against the cases for form 5. The demographic information in this study is defined as statistical data about the characteristics of participants, which are the participant gender and their number of years' experience in teaching the Mechanical Engineering subject (refer to the teacher). In addition, it also presents the total number of people within the population and total cases involved in the form of summary for further in-depth discussion. The overall result also shows the analysis applied in a series of tests to determine the reliability of the score for mean scores in all of the tables provided in this chapter. The *Mann-Whitney U* test has been applied based on the suitability of the data after the data distribution test that indicated the data as not normally distributed.

5.2.1 Demographic information

Table 5.1 shows the distribution of participants for student questionnaires (according to gender), teacher interviews (including gender and years of experience) and some observations (including the same participant from the questionnaire and interview for particular classes). The table shows that there are fewer female participants in the study in comparison to males. 26% of students are female (n = 68) and 30% of teachers (n = 3). The majority of participants in the field of Engineering (particularly in Mechanical Engineering) is a male. The minority of women in this study reflects the lack of female teachers in the Engineering environment. In addition, the minority of female in mechanical engineering field has been claimed by other research is caused by the nature of job scope which is harsher and the task is challenging that more suitable for a man (Powell et al., 2012).

From the 10 teachers participating in the interview, three have more than 20 years' experience teaching of this subject, and six of them have been teaching for 12 to 19 years - only one teacher has been teaching for less than 10 years. This study shows that 90% of the teachers of Mechanical Engineering Studies had much experience and are capable of teaching this subject. Experiences in conjunction with qualifications have been continuously indicated in current studies to be essential for high student achievement (Johnson, 2012; Fox, 2015). Even though 90% of the Mechanical Engineering teachers who participated in this research get their professional training from the same institution (Universiti Teknologi Malaysia), their experience and expertise are deferred from one to another depending on their involvement in education-related activities and their years of teaching this subject. From the author's observation, matured and experience mechanical engineering teacher has a good teaching approach and effective questioning technique. A young or new teacher is seen as more energetic and creative in conducting the teaching session including the practical work. In this study, the practical work teaching process has a similar construct even for students from different background and abilities across the technical schools. The pattern of teaching the practical work and the issues in implementing practical work emerged from the observations where all the teachers use demonstration as the induction set of teaching, and the students follow what mentioned by Abrahams and Millar (2008) 'do what teacher ask them to do' (the domain of observable, see 2.5.1).

Table 5.1 Illustrates the distribution of participants in the questionnaire, interview and observation in multiple case studies.

School	Jade		Khaki		Magenta		Pink		Turquoise		
Form	F4	F5	F4	F5	F4	F5	F4	F5	F4	F5	Total
Questionnaire (number of participated studentsaccording to gender)	28 (21m, 7f)	32 (24m, 8f)	26 (20m, 6f)	39 (31m, 8f)	17 (9m, 8f)	25 (20m, 5f)	32 (24m, 8f)	26 (16m, 10f)	20 (16m, 4f)	16 (12m, 4f)	261 students (193m, 68f)
Interview (teacher experience and gender)	22y (m)	21y (f)	20y (m)	12y (m)	19y (m)	19y (m)	9y (f)	15y (f)	16y (m)	15y (m)	10 teachers (7m, 3f)
Observation(number of participants and observations)	1	1	1	1	1	1	1	1	1	1	10 practical work session

F4 = Form 4   F5 = Form 5   y=year of teaching MES   m=male   f=female

The natural setting for each observation was designed to seek the reality of each practical work session and to discover the students learning experience by performing practical work which influences the learning outcome of the session. A previous study by (Booth et al., 2001) has linked between the observational and interview data where both are subjected to the interpretation of the author. It is due to the role of the observer that has a high degree of freedom and autonomy regarding what they choose to observe, how they filter that information, and how the data will be analysed (Mulhall, 2003).

Then, to reduce the autonomy of the observer in this research and to ensure the consistency of the process, an observation outline was used in each observation. The purpose of the observation outline is to guide the author in observing the specific elements of the learning outcomes in a structured way and, to look at students' experience in practical work that addresses the curriculum objectives. Ten practical work sessions were observed which involved the same participants from the questionnaire and interview. The experience of the author in teaching and managing the subject of Mechanical Engineering Studies for ten years was utilised to determine an interpretation of the output for observations by using the observation outline and observation note. On the other hand, the structured observation helped the author to focus on certain criteria (effective level 1-students'activity) to be observed based on the model of the process of design and evaluation of practical task (see 2.5.1).

In the students' survey, four additional information has been gathered based on certain criteria suggested in previous research by Onwuegbuzie and Leech (2004), to check the validity of data and suggested by Liu (2011), to investigate the influence factor of the implementation of practical work. The questions are about i) their level of interest toward practical work (to crosscheck one of the curriculum objectives, CO3), ii) the duration of time they experience practical work in a week, iii) whether they are motivated in undergo practical work (yes/no) and iv) whether they enjoy doing practical work (yes/no).

5.2.2 Students interest in practical work

Table 5.2 shows 76 % of students in all technical schools have high interest in practical work, 23% have moderate interest and only 1% show low interest. Table 5.1 has undergone cross tabulation analysis with item number 21 (Q21) in the questionnaire that asked a similar question in a bit different format about their interest level of doing practical work. The vertical format close question has been used to indicate students' response rate about the statement and assess the validity using a similar question in a different setting. This approach allowed the author to assess the validity of the answer in the questionnaire, where the participant could simply tick the answer without a read the question. It is important to the reliability of the research because it investigates the participants' perspective of the phenomena. The answers given by the students is one piece of the information that the author used to triangulate the findings with the interviews and the observations. The reliability of the data is vital and needs to be statistically proven before the analysis can continue to the next step. Table 5.2 and Table 5.3 below show the similar pattern of the answer - the majority of students have a high interest, only 8.4% to 23% has a moderate interest, and a small number of 1% to 1.9% of students is less interest in practical work.

Table 5.2 Illustrates the frequency response from students to the questions 'How interested are you in the Mechanical Engineering?'.

		Technical school					Total frequency of response
		Jade	Khaki	Magenta	Pink	Turquoise	
Interest level	High interest*	44	47	30	50	26	197
	Moderate interest	15	17	11	8	10	61
	Low interest	1	1	1	0	0	3
Total number of students		60	65	42	58	36	261

**Interest defined in 2.9.3(Chapter 2).*

Source: Cross tabulation result for interest level in all technical schools from SPSS generated

The process indicates in Table 5.3 is a grouping process of related indicators into similar contact for interpretation on the comparative chart in Figure 5.1. A 'strongly agree' and 'agree' with 'high interest, 'neutral' is 'moderately interest' and 'strongly disagree' and 'disagree' represent the low interest. This combination of frequency is part of the process to determine the reliability of students answering the survey and for this purpose only. This study at the end would classify the effectiveness into five categories relating to the mean scores.

Table 5.3 Illustrates the frequency of answer from item 21 (Q21) in the questionnaire to determine the level of students' interest. The question is 'By experience practical work, I believe I am interested in the field of mechanical engineering.

		Technical school					Total frequency of response
		Jade	Khaki	Magenta	Pink	Turquoise	
Q21 Interest*	Strongly disagree	0	1	0	0	1	2
	Disagree	0	0	3	0	0	3
	Neutral	8	2	5	3	4	22
	Agree	26	28	16	20	14	104
	Strongly agree	26	34	18	35	17	130
Total number of students		60	65	42	58	36	261

**Interest defined in 2.9.3(Chapter 2).*

- - - - - *Grouping the related indicators to similar contact.*

Source: Cross tabulation for interest level in all technical schools from SPSS generated

In the cross tabulation process, the results show statistically significant findings. Most students have a high interest in practical work in their answer at the beginning of the questionnaire. This type of question applied the three vertical close answers (high interest, moderate interest and low interest) and was linked to the item number 21-Section II in the questionnaire which used a Likert rating scale. Figure 5.1 shows the range between 9% and 25% for the degree of interest among students at participating technical schools. According to Cohen et al., (2014), the smaller the range, the more reliable students' responses are going to be and therefore, the more consistent information gathered. Figure 5.1 indicates that the most reliable students in answering the questionnaire are the students from Technical School Pink. The answers from students at Technical Schools Khaki are less consistent, because it shows a gap of 25% for this two similar meaning of questions. However, the difference is acceptable according to Carlson and Herdman (2010), because the range of percentage is below the mean (33.33%). Figure 5.1 indicates that the answers from the students followed a similar pattern and showed that simultaneously, the majority of them are highly interested in practical work.

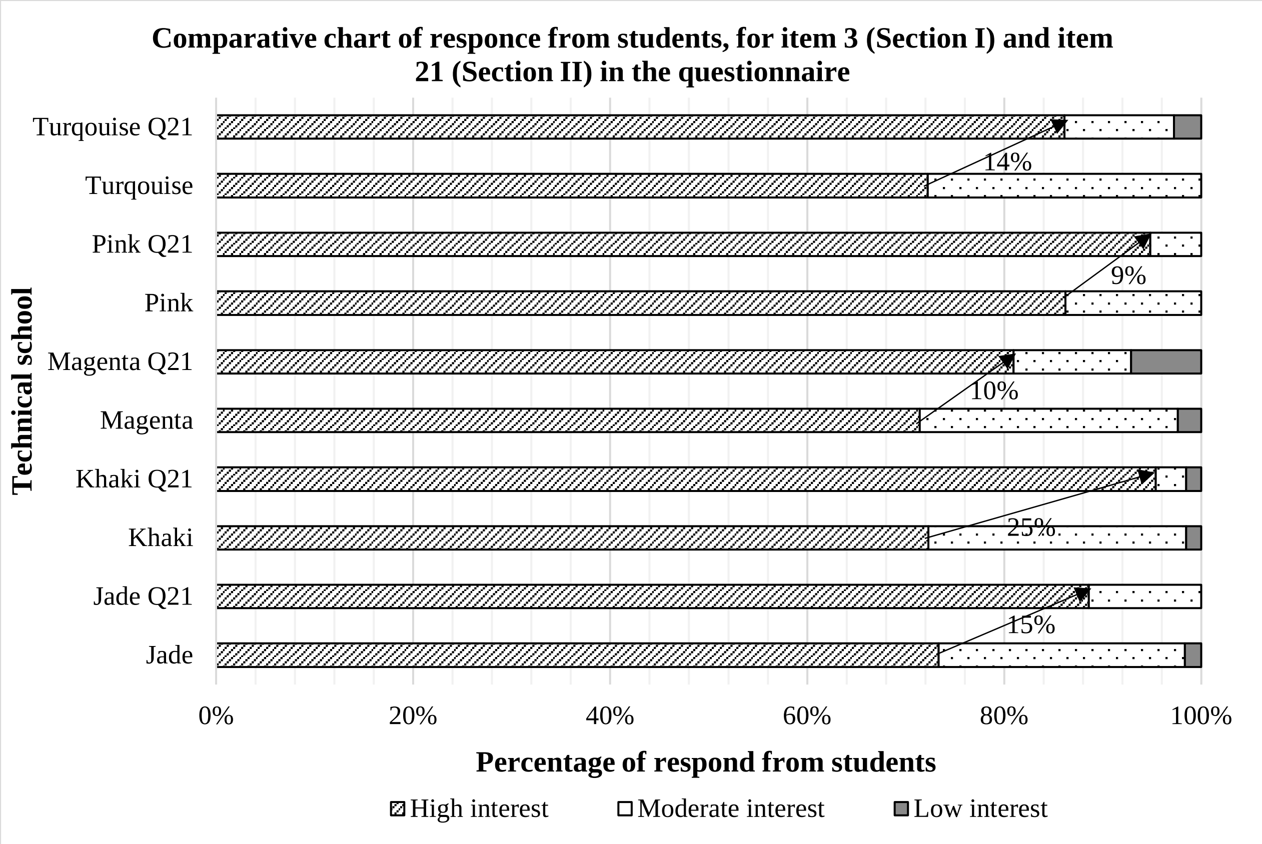


Figure 5.1 Illustrates the comparative percentage for the level of interest from two questions in the questionnaire which are the 'How interested are you in the Mechanical Engineering?' and 'By experience practical work, I believe I am interested in the field of mechanical engineering'.

Figure 5.1 indicates that the students' perception in their level of interest increased along the process of answering the questionnaire. Their interest is influenced by certain factors that will be discussed further in the result for curriculum objective 3. The author at the same time is connecting the evidence for the factor that might influence the student's interest in the practical work. This process has been conducted by connecting the findings from the level of interest among students with their time spent doing practical work, their motivation and enjoyment of experience practical work. The purpose is to see whether any of these factors related to the students' interest that can be statistically proven. The data has undergone the correlation test using SPSS and the findings show a significant explanation reflecting the factor influencing the students' interest in practical work. The correlation tests have been conducted through three different variables which are the students time spent on practical work, the students' motivation and their enjoyment of experience practical work.

5.2.3 Student time spent on practical work

Table 5.4 shows the time spent doing practical work in an hour per week and Figure 5.2 shows the cumulative percentage chart of time spent in practical work at all participated technical schools. The curriculum specification for Mechanical Engineering Studies has outlined the suggested time to implement practical work in school is 4 to 5 hours per week, and this study has indicated most of the technical schools' students had experienced an average of 2 to 3 hours of practical work per week. This time included their hours doing practical work inside and outside the formal education session. Some of the students experience practical work for more than 6 hours per week to complete their project, but the percentage is very small.

Table 5.4 Illustrates the frequency of response from students for the question 'How many hours do you normally spend on Practical Work in Mechanical Engineering Studies per week (inside and outside schedule)?'.

		Technical school					Total frequency of response
		Jade	Khaki	Magenta	Pink	Turquoise	
Time spent*	1 hour or less	6	10	15	2	3	36
	2-3 hours	31	38	13	35	17	134
	4-5 hours	20	13	9	14	13	69
	6-7 hours	1	4	3	3	2	13
	More than 7 hours	2	0	2	4	1	9
Total number of students		60	65	42	58	36	261

**Time spent defined in 2.7.2, time on task for Dynamic Model of Education Effectiveness (Chapter 2).*
Source: Cross tabulation result for time spent in all technical schools from SPSS generated.

Students at Technical School Jade, Khaki and Pink, appear within the higher percentage student who spent 2 to 5 hours of their time to experience practical work in Mechanical Engineering subject. The rationale between this evident is these three technical schools have indicated the higher level of students interest in practical work (Table 5.2). In addition, the Technical School Magenta which has a higher percentage of students who experienced practical work for one hour or less per week appears to have the lowest interest rate. These initial findings indicate the correlation between the time spent on practical work and the level of interest among students. The results shown are directly proportional to these two elements in practical work. The more students are exposed to practical work, the more they are interested in doing it. The next calculation is to evaluate the motivation factor among students where the results relate to the significant of students interest in practical work.

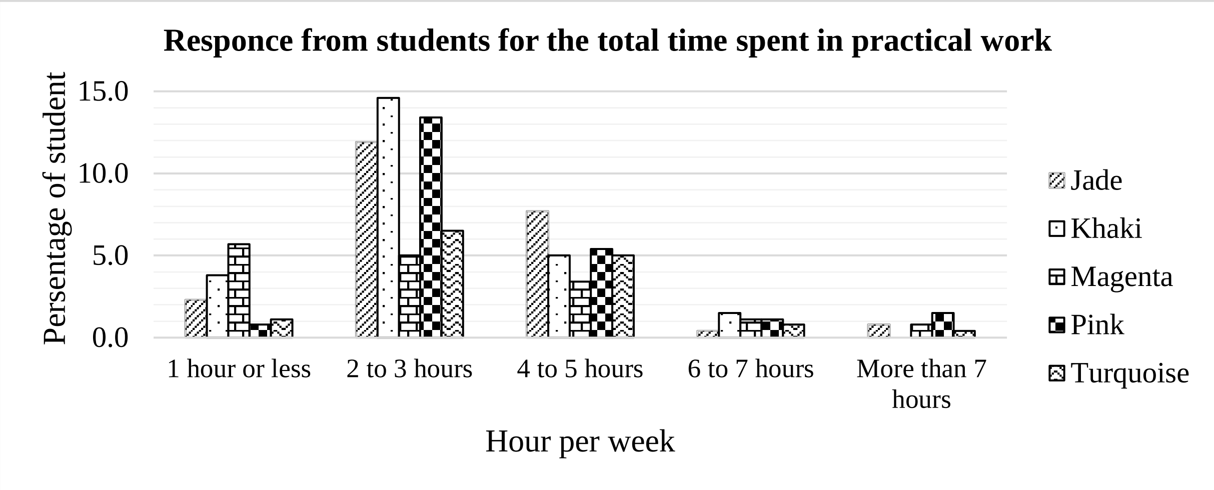


Figure 5.2 Illustrates the cumulative percentage chart on a response from students for the question ‘How many hours do you normally spend on Practical Work in Mechanical Engineering Studies per week (inside and outside schedule)?’.

5.2.4 Student motivation to do practical work

Table 5.5 indicates the result for students self-claim of their motivation to do practical work. Motivation is this research’s contact as discussed earlier in (2.9.4 in Chapter 2) is the desire or energy in the students to be continuity interested in doing practical work and being committed to complete the task. The result shows that 97.3% (n = 254) students agreed that they are motivated in experience the practical work in mechanical engineering study while 7 students disagree. The findings also indicated that all of the students who are not motivated to do practical work is the male students. A previous study by Kormos et al., (2013) found that female students in engineering at a higher level are more motivated compared to male students in completing engineering tasks. According to Alpay et al., (2008) female students are most influenced by real life orientation and motivation for their choice of becoming an engineer. Similar to that, this study indicated term of percentage, that 100% of female students are motivated to experience practical work rather than 96.37% of male students.

Table 5.5 Illustrates the frequency of response from students for the question 'Do you feel motivated doing practical work in Mechanical Engineering Studies?'.

		Technical school					Total frequency of response
		Jade	Khaki	Magenta	Pink	Turquoise	
Motivation*	Yes	59	63	40	57	35	254
	No	1	2	2	1	1	7
Total number of students		60	65	42	58	36	261

**Motivation defined in 2.9.3(Chapter 2).*

Source: Cross tabulation result for motivation in all technical schools from SPSS generated.

According to Dowson and McInerney (2003), the motivation of students might be influenced by their self-urgency to engineering education or the encouragement from friends and family who give them moral support. The cross tabulation process in this study has linked the motivation and interest where students claimed they are motivated and at the same time they are highly interested in practical work. The same process has indicated that 3% of students who claimed that they are not motivated in practical work is from form 4 male students. These findings are discussed in the student factor (in 6.3.3 Chapter 6) under the gender equalities where the female students who consider a one-third minority in Mechanical Engineering fields are more motivated compared to male. The findings as suggested by Johansson (2003), is for the cross tabulation process of respondents and not suitable for generalisation in a case study. These findings need further statistical proof to be generalised since the purpose of this question is to understand the students' background and to conduct the statistical coherent test for the responses in the questionnaire.

5.2.5 Student enjoyment in experience practical work

The purpose of this items asked in the questionnaire is to know whether the students enjoy the process of learning practical work. The previous study has suggested that enjoyment would encourage students to be motivated and certain their interest in science and engineering (Silver and Rushton, 2008). The previous study has indicated the motivation factor is closely related to the enjoyment of the practical work (Martindill and Wilson, 2015). It is the chain factor that this study has designed and mapped at the early stage to accommodate the finding at the same time investigated the factor that influenced the findings. Practical work has been mentioned as an enjoyable process where students can apply the theoretical knowledge they have learned in the classroom by using real engineering materials (UNESCO, 2010). Table 5.6 indicates almost all students enjoyed the process of practical work. Only one form 4 male student from Technical School Magenta claimed that he did not enjoy the practical work process. He is one of the student who spent one hour or less in practical work (see the result in Table 5.4) which at the same time find this process is not enjoyable. The reason behind it might be because he is not exposed enough to the practical work due to the time constraint. There are also possibilities that this particular student has misconceptions about the practical work in Mechanical Engineering because he is also the only student who has low interest in practical work (see the result in Table 5.2). He is also one of the student who has no motivation to do practical work (see the result in Table 5.5). All these factors have led to the reason of student's self-attitude (defined in student factor in 2.7.4) toward practical work, and this is a small minority that would not impact the result for entire Mechanical Engineering students' population.

Table 5.6 Illustrates the frequency of response from students for the question 'Do you enjoy doing the Practical Work element in Mechanical Engineering Studies?.

		Technical school					Total frequency of response
		Jade	Khaki	Magenta	Pink	Turquoise	
Enjoyable*	Yes	60	65	41	58	36	260
	No	0	0	1	0	0	1
Total number of students		60	65	42	58	36	261

**Enjoyable defined in2.7.3, the classroom as a learning environment for Dynamic Model of Education Effectiveness (Chapter 2).*

Source: Cross tabulation result for students' enjoyable in all technical schools from SPSS generated.

5.2.6 Demographic information summary

The demographic information shows the initial information about students' perception of practical work where most of the result indicated a positive interpretation of practical work for both form 4 and form 5 students. The connection in the demographic information has indicated that the majority of students enjoyed the process of practical work, they are motivated by the practical work, and they are highly interested in the field of engineering by undergoing practical work. The observations by the author indicated that practical work in other circumstances has a bigger impact on early student perception towards engineering education in secondary schools. This finding supported a previous study by Zin et al., (2013) which suggested that the development of students’ interest in the engineering fields is from their practical experience in the school. The data indicated that students are confident in their attitude towards practical work by giving consistency answers in the questionnaire. According to Segers and Dochy (2001), the perspective from students is vital because learners’ beliefs and perceptions are central to effective in teaching and learning. It is the reason for the further analysis in the next section enforced the perspective of students toward this subject as important as the findings from interviews and observations. The results discussed in the next section is an accumulating of mean scores from these three different methods.

5.3 The result of the main studies

Table 5.7 shows the statistical summary of the mean scores from seven curriculum objectives for form 4 and form 5 generated from the triangulation analysis in three methods which are the student questionnaire, the teacher interview and the practical work classroom observation. As illustrated in Table 5.7, practical work was ‘highly effective' in achieving three curriculum objectives, namely curriculum objective 1, curriculum objective 3, and curriculum objective 6. The rest of the curriculum objectives show overall mean scores between 3.76 to 3.93, within the range of ‘effective,' and there was no ‘moderate’ or ‘low’ effectiveness found in any of the curriculum objectives. This result shows that as a whole, the practical work for form 4 and form 5 is most effective in achieving the curriculum objectives for Mechanical Engineering Studies. However, this finding indicated that there are the elements in the practical work (which discussed further in the discussion below) that need to be emphasised in order to increase achievement of the curriculum objectives for forms.

Table 5.7 Illustrates the summary of overall mean scores for all curriculum objectives from the questionnaire, interview and observation for form 4 and form 5 in all five technical schools.

	CO1	CO2	CO3	CO4	CO5	CO6	CO7
F4	3.94	4.07	4.21	3.53	3.85	4.02	3.85
F5	4.05	3.79	4.26	3.99	3.99	3.97	3.68
Overall mean	4.00	3.93	4.23	3.76	3.92	4.00	3.76

Legend: CO = Curriculum objectives F4 = Form 4 F5 = Form 5

Mean score scale: 5.00 – 4.00 (Highly Effective), 3.99-3.00 (Effective)

Colour code: [shaded] Highly Effective [unshaded] Effective

Table 5.7 shows that, from the students and teachers perspectives, practical work was highly effective in assisting students to understand the terminologies, process, and procedure (curriculum objective 1), highly effective in creating interest in the field of Mechanical Engineering (curriculum objective 3), and highly effective in encouraging students to apply safety (curriculum objective 6). The overall results show that with the minimal time spent in practical work learning session (see findings in 5.2.3), it was 'effective' in addressing all curriculum objectives for form 4 and form 5 students. The results indicated that the implementation of practical work, even in fewer hours that is supposed to be taught in the curriculum has a substantial impact on the achievement of the curriculum objectives of Mechanical Engineering Studies. Detailed analysis on the curriculum specification document of Mechanical Engineering Studies has revealed that the time allocation of practical work was 62 % (87 hours) of the overall compositions for form 4, while 63% (88 hours) of time was allocated for form 5 compared to the theoretical and mathematical contents. However, the actual implementation in all technical schools revealed that the practical work was conducted for approximately between 25%and 30% (35 to 42 hours) for both forms. This finding was mentioned by the students in the questionnaire and teachers in the interviews. The author believed that this was the explicit finding for this study which contributed to inform the curriculum developers and policymakers about the performance of practical work in achieving the curriculum objectives for Mechanical Engineering Studies. The findings showed that the actual implementation of practical work in technical schools currently was less than half of the contact hours planned and written in the curriculum for Mechanical Engineering Studies. The insufficient practical work for both forms has caused by various reasons that will discuss in detail in 5.13 (Challenges in the implementation of practical work).

It is shown in Table 5.7 that the achievement of curriculum objective 3 was highly effective which this is the result from the triangulation process where students, teachers, and the author agreed that practical work had encouraged students' interest in the field of Mechanical Engineering. This aspect of interest was mentioned 30 times by students in informal conversation during observation that they really enjoyed (supported the finding in 5.2.5) doing practical work, and they were interested (supported the finding in 5.2.2) in the field of Mechanical Engineering by experiencing practical work. It was in agreement with the result from the students' questionnaire where the total mean score for curriculum objective 3 was 4.3 (strongly agree). The observation made by the author found that students did enjoy the process and requested for more practical works in the subject of Mechanical Engineering Studies. All teachers in the interviews strongly recommended that practical work can increase students' motivation in learning the Mechanical Engineering subject. Even though practical work requires a lot of tasks and effort as mentioned by Abrahams and Saglam (2010), students productively enjoyed the sessions and performed very well on all tasks. The data in Table 5.7 indicates the positive scores of means with the lowest score to be 3.68, and the highest score was 4.23.

The difference between the mean scores for form 4 and form 5 was between 0.05 and 0.46 (less than 0.5) for each curriculum objective. This small difference in mean scores indicated negligible differences between the perspective from all participants (including students and teachers) for both form 4 and form 5 even though they were working with different types of practical work (form 4 is focused on workshop practice and form 5 is focused on design). This difference has brought the author to investigate the statistical significance of the figures in concluding the outcomes by conducting the further statistical test (further discussed in the statistical test in 5.3.1 below). The statistical result indicated that even though the data were coded and the scores were given quantitatively (see the process in 4.3.3), the analysis by SPSS did not find any significant result for the test of overall means in Table 5.7. The overall mean scores in this study only represented the effectiveness of practical work, and no other statistical test can be performed directly or indirectly to test the mean scores.

5.3.1 Quantitative validity analysis

This study has used different statistical analysis for the purpose of increasing data validity and reliability. Previous studies have applied different research methods to demonstrate the robustness of the findings, for example, used of a statistical test to support verbal statements from the participant (Christophel and Gorham, 1995; Mark et al., 2007; Weir, 2005). Additionally, the use of various statistical analysis is to determine the validity of the findings (Carlson and Herdman, 2010). For this purpose, a further statistical test was performed in this study, and the author had to separate the students' questionnaire data (in SPSS) from observation and interview. It was due to the generated mean scores from data transforming in mixed method analysis mentioned earlier in this research which cannot be tested or treated as the original quantitative data in SPSS.

The nature of mixed method research in pragmatic paradigm has allowed this test to be run separately to gain the internal statistical generalisation (see 3.4). Firstly, the quantitative data from the questionnaire has to go through the normality test to measure the distributions of quantitative data before other significant tests are implemented. In this study, the *Shapiro-Wilk* test has been chosen because of the number of samples within individual cases is less than 100 (Cohen et al., (2014). The finding showed that the data from all participated schools are not normally distributed. The results in Table 5.8 suggests strong evidence of non-normality where the value of *p* for all listed technical schools is 0.04 which is below 0.05 (p<0.05). This result indicated that the information is accurate with several approaches needed to interpret the data and allowed the author to prepare for the next steps to be implemented in treating this type of non-normality data. One of the technique to analyse and use the non-normality data is to normalise the data by adding a certain figure to the means, and the system will generate the new layer of figures that can be used for the further test (Cohen et al., 2014). The author decided to apply the non-parametric test for the non-normality data instead of normalised the data. Table 5.8 shows the result from the normality test that has been applied through the overall measurement of data distribution using the SPSS software. The main disadvantage of choosing this nonparametric test is that it limits the forthcoming significant test to be applied for the data. This method allowed the data to be treated only as the non-normal data in a way to ensure the validity and the persistence of interpretation in the findings.

Table 5.8 Illustrates the result for normality *Shapiro-Wilk* test for overall quantitative data from students' questionnaire in all technical schools.

Technical school	*Shapiro-Wilk*		
	Statistic	df	Sig. (*p*)
Jade	.539	60	.004
Khaki	.506	65	.004
Magenta	.582	42	.004
Pink	.582	58	.004
Turquoise	.514	36	.004

**Lilliefors Significance Correction (p<0.05 the data is not normally distributed)*

Statistic= variable (auto-generated and not affect the result)df=number of participant

This non-normality result was regarded to the responses from the participants that tend to answer the question in the same direction (example, most of the participants agree to the statement, and the score is a weight on the right side of distribution graph). During the analysis process, the SPSS system has detected an imbalance of information and generate the result on non-normality. Due to that, the data flowed or skewed to one side (in this case to the right) due to most of the participants choose 'agree' and 'strongly agree' as a preference for all items in the questionnaire. It reflected in the distribution plotting and the graft becoming extreme to one part of the area. In this study, the author chooses to keep the findings as they are and use the other suitable method of analysis for non-normality. The approach chosen by the author is to apply the non-parametric test for further statistical evaluation. This is due to the axiological consideration (see 1.8.4) of this research where the author believes in the fairness of data to protect the findings without any manipulation of information needed to get the result.

The second test was conducted to measure the significant difference of the result for form 4 and form 5 by considering the null hypothesis as (N_o -there is no statistically significant difference between form 4 and form 5 in achieving the curriculum objectives). Table 5.9 shows the results of statistical tests for the measurement of the significant difference between two independent samples (in this case form 4 and form 5) toward all curriculum objectives using *Mann-Whitney U*-test (nonparametric). This test was able to be conducted because the data were not normally distributed (proved by the data distribution test above).

The purpose of this test is to calculate the result of *p*-values that can determine the significance of the finding for a selected sample. The focus of the result is the *p*-value for all curriculum objectives, where value more than 0.05 ($p > 0.05$) indicated that the null hypothesis was fully supported and there was no statistically significant difference between form 4 and form 5 in achieving the curriculum objectives. The findings showed that the *p* values for all curriculum objectives drawn between the lowest 0.182 to the highest 0.789 and far above 0.05. These *p* values indicated the acceptance of the null hypothesis and the statistical analysis for form 4 and form 5 is significant, although participants from both forms have a different experience in undergoing practical work session in technical schools. This *p* values allowed the answers from form 4 and form 5 to be categorised in a similar group and interpreted within a case in the same schools.

Table 5.9 Illustrates the result for *Mann-Whitney U* value and significant level test for overall quantitative data from students' questionnaire in all technical schools.

	CO1	CO2	CO3	CO4	CO5	CO6	CO7
Mann-Whitney U	7424.05	7984.50	7694.83	8332.50	8107.50	8193.07	8336.00
Z	-1.775	-0.833	-1.404	-0.279	-0.677	-0.548	-0.268
Asymp. Sig. (2-tailed)*p*-value	0.182	0.406	0.307	0.785	0.516	0.598	0.789

Grouping variable: form (p> 0.05 accept the null hypothesis)   CO=curriculum objective

It is also indicated that the mean scores in Table 5.7 (in Section 5.2.2 above) was highly reliable because of the mean scores indicate significant values for form 4 and form 5 that supported the result from the *Mann-Whitney U* test (the range for the null hypothesis acceptance score is high). This test additionally, has shown the statistical significance of mean score for each of the curriculum objectives in this research is highly trustworthy because it indicated a similar result with the statistical test. The statements in the curriculum objectives represented by the mean scores which align with values of the degree of effectiveness for both forms. The mean scores allowed result for this study to be presented in many ways crosscut the items (present in 5.13), the methods (present in 5.4 and 5.5, the result for form 4 and form 5) or within the case (present in 5.6 to 5.12, the result for each of the curriculum objective). In this study, the mixed method design is used in term of supporting the quantitative result from statistical data with progressive qualitative arguments from interviews and observations. The next section presents the quantitative outcomes in mean scores for each element in the curriculum objectives retrieved for practical work, supported by evidence based qualitative statements from teachers and students during the interview and observation.

5.3.2 Cross-case analysis

In this study, the cross-case analysis is used to explain the pattern appears across ten cases in five technical schools in addressing the effectiveness of practical work in achieving the curriculum objectives. The purpose is to highlight the practice applied in certain technical schools that contributed to the mean score for form 4 and form 5. The mean scores as discussed in 4.3.4, is the score given to the statements from participants which addressed to the specific element in the curriculum objectives. Table 5.10 illustrates the mean scores of all curriculum objectives for form 4 and form 5 within the five technical schools. Technical School Khaki shows a predominant mean in most of the curriculum objectives for form 4 and form 5. It indicated ten 'highly effective' means and four 'effective' means. This school also marked the highest score for seven curriculum objectives (three in form 4 and four in form 5), besides the three lowest scores (one in form 4 and two in form 5).

Technical School Jade and Magenta, shows fewer scores among others in addressing the effectiveness of the curriculum objectives. Although these schools indicated the highest score in a few curriculum objectives, they were also marked as the lowest in most of the other curriculum objectives (three highest scores and the three lowest scores for Jade, two highest scores and four lowest scores for Magenta). There were several explanations for the scores for these two schools (Jade and Magenta) which discussed in results for each curriculum objective in the next section. An observation made by the author indicated that both schools have teachers who have much experience teaching Mechanical Engineering Studies, spanning from 19 to 22 years. Besides, the workshop facilities in these schools were limited, and the internet connection was poor almost all the time.

The Dynamic Model of Education Effectiveness classified these challenges as the school factor and educational system factor which gave an impact to the educational effectiveness. In Technical School Khaki, the strength observed in this school was that the teacher has good time management skills and good questioning technique. These factors could be the two main elements of each teacher factor included in the Dynamic Model of Education Effectiveness which affected the quality of teaching (Kyriakides et al., 2013). The teachers have their own methods of questioning to the students which allowed their students to become creative thinkers (curriculum objective 4) and problem solvers (curriculum objective 7), ultimately contributing to the highest score for those curriculum objectives for form 4.

Table 5.10 Illustrates the result for mean scores for all curriculum objectives for form 4 and form 5 in all technical schools.

Form	F4							F5						
	CO1	CO2	CO3	CO4	CO5	CO6	CO7	CO1	CO2	CO3	CO4	CO5	CO6	CO7
Jade	3.70^	4.16*	4.18	3.77*	4.05	3.79	3.70	3.77^	3.63	4.45*	3.73^	4.08	3.84	3.90
Khaki	4.02	4.14	3.86^	3.71	4.18*	4.41*	4.33*	4.44*	3.37^	4.10	4.27*	4.54*	4.15*	3.33^
Magenta	3.89	4.09	4.45	3.19^	3.58^	4.09	3.98	4.02	3.84	4.00^	4.15	3.63^	4.13	3.92*
Pink	4.07*	4.07	4.09	3.68	3.85	3.59^	3.70	4.02	4.02	4.42	3.94	3.85	3.83^	3.78
Turquoise	4.05	3.87^	4.47*	3.31	3.63	4.23	3.52^	4.01	4.09*	4.34	3.85	3.83	3.89	3.46

** Highest score ^Lowest score Mean score scale is from 0 (not effective) to 5(highly effective): 5.00-4.00 (highly effective), 3.99-3.00 (effective), 2.99-2.00 (moderately effective), 1.99-1.00 (low effective) and 0.99-0 (not effective)*

Colour code: ▭ *highly effective* ▭ *effective*

Another factor emerged during observation in this school was that the arrangement of the workshop facilities allowed both form 4 and form 5 students to utilise the tools and computers during a practical session (curriculum objective 5) and enabled them to value their safety in the workshop while performing practical work (curriculum objective 6). This element could be seen in Table 5.10, where this school has the highest score for curriculum objective 5 and curriculum objective 6 for both form 4 and form 5. During observations, it was found that even though the facilities in the workshop were limited, teachers allowed the students to fully undergone practical work, and while having informal interviews with the students, they frequently mentioned that they did enjoy doing practical work. As suggested in the Dynamic Model of Education Effectiveness, the teacher factor in was one of the main reason for the effectiveness of teaching as the form 4 teachers of Mechanical Engineering Studies at Technical Schools Khaki has the most experienced of 20 years compared to others in teaching this subject.

The mean scores for curriculum objective 2 and curriculum objective 7 for form 5 at the same school were the lowest. The reason could be attributed to a less experienced teacher of 12 years for form 5 compared to the form 4 teacher. This finding was in line with the research finding reported by Wang et al., (2017) that a more experienced teacher is better in pedagogical skill and has a better questioning technique. During observation, the form 5 teachers applied traditional teaching (teacher explained while student listened) with less two-ways communication in the session and limited the opportunity for allowing students to apply the knowledge (curriculum objective 2) and solve the problems (curriculum objective 7). Overall practical work sessions exhibited that the teachers gave instructions and the students followed without any argument (domain of observable, in 2.5.1). The interview with the form 5 teacher at this school found that the teacher was not clear with the objectives of the practical work and has limited creativity in implementing practical work for the Mechanical Engineering Studies subject. As a result, the practical work session became more like a lecture session with less practice and one-way communication with the students. This practice from the author's interpretation is contradicted to the actual objectives of practical work written in the Mechanical Engineering Studies curriculum specification.

5.4 Form 4 results

Table 5.11 shows the mean scores obtained from the analysis of the questionnaire, interview and observation of practical work for form 4. The overall mean scores indicated that the practical work for form 4 was 'highly effective' in achieving three curriculum objectives and ‘effective’ in achieving another four curriculum objectives. The practical work for form 4 required students to apply the knowledge in measuring, marking, cutting and drilling using a metal plate. They were given the design and measurement to work individually in the workshop and were instructed to complete the task within three to four periods of practical work sessions (240 to 320 minutes).

Table 5.11 Illustrates the mean scores for form 4 in all technical schools obtained from the student questionnaire, teacher interview and classroom observation.

	CO1	CO2	CO3	CO4	CO5	CO6	CO7
Questionnaire F4	3.88	4.01	4.35	4.09	4.20	4.49	3.94
Interview F4	4.37	4.10	3.93	3.70	3.37	3.87	4.00
Observation F4	3.59	4.09	4.35	2.80	4.00	3.71	3.60
Mean Score	3.94	4.07	4.21	3.53	3.85	4.02	3.85

Legend: CO = curriculum objectives F4 = form 4 Mean = overall triangulations result

Mean score scale: 5.00 – 4.00 (highly effective), 3.99-3.00 (effective), 2.99-2.00 (moderately effective)

Colour code: highly effective effective Moderately effective

The learning outcomes (LO) for form 4 practical work are as follows:

- explain cutting by division principles
- identify and use hand tools for chipping
- practise safety precautions while cutting
- identify various machine and their uses
- label main parts of the machines
- state types of advanced machine
- use the hand tools and drilling machines
- doing projects, practise safety precautions while drilling
- state the principles, uses and advantages of advanced machining
- choose from catalogues suitable types of hand tools and machine for different types of work
- Supervise peers on the safe use of hand tools and drilling machine.

Syllabus Specifications of Mechanical Engineering Studies, Technical and Vocational Education Division, (1994).

These learning outcomes are used as a reference by the teachers to ensure the successfulness of practical work after teaching and learning session. The teachers also refer to the learning outcomes as a guideline in preparing their lesson plans and examination questions. Overall observations by the author in all technical schools found that nine out of eleven learning outcomes were achieved across the practical work sessions for form 4. Findings from this study indicated that only two learning outcomes were not accomplished: state types of advanced machine, and state the principles uses and advantages of advanced machining. It was due to the lack of facilities provided in the technical schools, and 80% of the conventional machines provided were either not well maintained or not safe to be used. From the teachers' perceptions, the use of simple and limited machines for a practical work session in the workshop has also minimised students' knowledge regarding the modern machine. Ever since the Mechanical Engineering Studies subject have been introduced in technical schools, the government only provided conventional machines, and from the author's observations, most of them were no longer relevant to the current technology. Interviews with teachers also indicated that the content of the curriculum of Mechanical Engineering Studies remained with the use of conventional machines and most likely not relevant to the current practice.

Table 5.11 also indicates that the three methods which were triangulated in this study shows minimal difference in mean scores from one to another except for the observation and questionnaire on curriculum objective 4 where the difference of the mean score within the curriculum objectives was 1.29 (mean score of questionnaire = 4.09, mean score of observation = 2.80). The results show a contradicting judgement between the author's perspective and students self-reporting on the ability of practical work in developing creative thinking through intellectual activities and practice in the form 4 Mechanical Engineering Studies. Students declared that they acquired creative thinking skills through practical work, while the author found this element conflicted during classroom observation.

Overall observation on form 4 practical work session in all technical schools has successfully supported the model of effectiveness of practical work level 1 (see 2.5.1) by Abraham (2008) where 'student do what teacher ask them to do' and did not perform the task to the extent of developing their creative thinking. During observation, the author realised that there was a limitation in practical work for form 4 of which the arrangement of tasks and materials was deprived the students' creativity. In this case, students were not encouraged to be creative due to a similar pattern of workpiece they have to produce during a practical task which has the customised design and measurement. Besides, three out of five (60%) form 4 teachers of Mechanical Engineering Studies also agreed that the practical work for form 4 did not allow the students to become creative. One of the reason was due to the insufficient budget that has been allocated in the technical schools, while the price of metal kept increasing for several years. As a result, all technical schools decided to minimise the use of metal by simplifying the practical task for form 4 and developing the fixed design and materials to all students. However, the range of mean scores for the rest of the curriculum objectives (between 0.09 to 0.83) showed less difference in perspective of the students, teachers and the author in portraying the result for form 4. The high achievement of curriculum objective 2 (apply knowledge of Mechanical Engineering to form rational opinions about problems related to Mechanical Engineering) in form 4 practical work session appeared relevant where the mean scores from the three methods indicated highly effective in each method. The form 4 practical work allowed the students to apply the knowledge (curriculum objective 2) in measuring, marking, cutting and drilling as stated in the learning outcomes and to relate with the problem while answering the teacher's questions during practical work sessions. In addition, the author found that overall form 4 students can form a rational opinion by experiencing the practical work (curriculum objective 2) where most of the students can give reliable answers when the teacher required them to solve the problem of the practical task.

The other element in the curriculum objectives that highly achievable is the practical work successfully increased the students' interest in the field of Mechanical Engineering [curriculum objective 3]. From the survey, the form 4 students strongly agree that by experience practical work, they are more interested in future their study in Mechanical Engineering field. Practical work has encouraged and motivated them to study this subject. This claim supported by the observation by the author where the students enjoy doing practical work and have a high enthusiasm to complete their task precisely. The mean scores for survey and observation indicated the highly effective of practical work in achieving this curriculum objective 3. Even though teacher interview indicated mean scores below 4.0, the value remains in the effective level which is reflected in the achievement of curriculum objective 3. Differ to the curriculum objective 5 (utilise the workshop equipment) where the mean score for a students' survey and classroom observation is in highly effective, but the mean for the interview is slightly low (3.37). So, the overall mean scores have accumulated to be effective rather than highly effective. This score showed that the students are utilising most of the tools during practical work, somehow the teachers regard to their knowledge and experience in engineering felt that there are more tools that students required to complete this practical lesson. Finally, the other aspects in the curriculum objectives (know and understand the knowledge [curriculum objective 1], develop creative thinking [curriculum objective 4], value students safety [curriculum objective 6] and encourage problem solving [curriculum objective 7]) were less prioritised in form 4 practical work lesson.

5.5 Form 5 result

Table 5.12 shows the mean scores obtained from the analysis of the questionnaire, interview and observation of practical work for form 5. Practical work for form 5 required students to create a prototype of the product to solve domestic problems. Even though it is a group project of three to four, the students have to provide an individual report which is the detail folio (problem statement, cost of a project, selection of materials, original sketch design, final design with dimension [AutoCAD drawing] and the development of the product). The prototype of the product is developed in a group, and the group members have to present the output to the teacher and members of the class. This presentation session is the peers' evaluation and analysis process to suggest ways of improving the design concerning the project characteristic, work process and materials. It assisted the students in developing their confidence in presenting their work in the field of Mechanical Engineering in the future.

Table 5.12 Illustrates the mean scores for form 5 in all technical schools from the student questionnaire, teacher interview and classroom observation.

	CO1	CO2	CO3	CO4	CO5	CO6	CO7
Questionnaire F5	4.03	3.97	4.25	4.13	4.22	4.44	4.02
Interview F5	4.50	3.79	4.19	4.15	4.13	3.73	3.80
Observation F5	3.63	3.61	4.34	3.68	3.60	3.74	3.22
Mean Score	4.05	3.79	4.26	3.99	3.99	3.97	3.68

Legend: CO = curriculum objectives F5 = form 5

Mean score scale: 5.00 – 4.00 (highly effective), 3.99-3.00 (effective)

Colour code: ☐ *highly effective* ☐ *effective*

These are the learning outcome for form 5 practical work session;

- design artefacts to solve identified problems,
- state presentation methods in designing process,
- produce creative artefacts,
- present design output in documentation form and oral presentation,
- evaluate and analyse the artefacts created by peers and suggest ways of improving the design with respect to the characteristic,

- evaluate and analyse the artefacts created by peers and suggest ways of improving the design with respect to the work process and materials.

Syllabus Specifications of Mechanical Engineering Studies, Technical and Vocational Education Division,(1994).

In those particular form 5 practical works, it was found that all learning outcomes were achieved during the sessions, and all elements in seven curriculum objectives were addressed throughout the process. In addition, the range of mean scores for each curriculum objective was between 0.15 and 0.87, indicating a small difference in perspective from the students, teachers and author for form 5 practical work. The mean scores also indicated that practical work in form 5 was 'highly effective' in achieving curriculum objective 1 and curriculum objective 3.This finding signified that by experiencing practical work, form 5 students will gain the knowledge and understanding of facts, concept or principle, terminologies, process and procedure in Mechanical Engineering (curriculum objective 1). According to the teachers, it is vital for them to understand the knowledge as a preparation for the terminal examination at the end of the year, and it is also useful to have a strong foundation of the terminologies and the concept for their future study at the university. The mechanical engineering students have an advantage since the basic knowledge of Mechanical Engineering is relevant in this field throughout all levels of education (Felder et al., 2000).

The result of this study indicated that practical work was highly adequate for form 5 in creating interest in the field of Mechanical Engineering, and able to meet the demands of a career in this field (curriculum objective 3). The findings show that the students highly interested in experiencing practical work and enjoyed doing practical work to the fullest. The author identified these during observations, and also mentioned by all of the teachers (100%) during interviews, and agreed by 98.85% (n = 258) of the students in the questionnaire and during informal interviews. This basic knowledge is part of the preparations for the students to meet the requirement of becoming a mechanical engineer in the future. Practical skill according to Montfort, (2013) is one of the valuable factors that most of the employers are looking for. Additionally, the result showed that the practical work was 'effective' in achieving other five curriculum objectives. In comparison with the form 4 result in Table 5.11 above, the achievement of curriculum objectives for form 5 slightly declined because the practical work was merely 'effective' in achieving the most (five out of seven) curriculum objectives. It was related to the teachers' statement in the interview where form 5 student is preparing for their terminal examination (SPM) and less focus on the practical work carried out at this stage.

During observation, the author found a significant pattern for form 5 practical work where the practical work session was conducted for the students to complete their project in the timeframe. As a result, other aspects in the curriculum objectives (apply the knowledge [curriculum objective 2], develop creative thinking [curriculum objective 4], utilise the workshop equipment [curriculum objective 5], value their safety [curriculum objective 6] and encourage problem solving [curriculum objective 7]) were less prioritised.

5.6 Result curriculum objective 1

Table 5.13 provides the breakdown of mean for curriculum objective 1 for form 4 and form 5 for the technical schools involved. The mean scores show that practical work was 'highly effective' in developing students' knowledge and understanding of facts, concept/principle, terminologies, process and procedure in Mechanical Engineering Studies at three technical schools (Khaki, Pink and Turquoise).

Table 5.13 Illustrates the mean score for curriculum objective 1 for form 4 and form 5 in all technical schools.

	Jade	Khaki	Magenta	Pink	Turquoise
F4	3.70	4.02	3.89	4.07	4.05
F5	3.77	4.44	4.02	4.02	4.01
Mean Score	3.73	4.23	3.95	4.04	4.03

Legend: CO = curriculum objectives F4=form 4 F5 = form 5

Mean score scale: 5.00 – 4.00 (highly effective), 3.99-3.00 (effective)

Colour code: highly effective effective

The findings were aligned with the teachers' statement during the interview session where all ten teachers claimed that practical work could easily make students understand rather than teaching a theoretical concept. Eight of the teachers (80%) strongly agreed that practical work helped students more understand the process and procedure in the Mechanical Engineering Studies.

Question 5.6.1: What is your learning expectation from students after practical work?

A4 Jade: Students recognise and in the know a bit of the practice

A4 Khaki: They understand the process more by doing practical work

A4 Magenta: They understand better

A4 Pink: The students quickly understand the process and procedure

A4 Turquoise: Increase their understanding

A5 Jade: They follow the instruction

A5 Khaki: They are more advanced by experience practical work

A5 Magenta: Students are more understand by doing practical activities

A5 Pink: Strengthen students' theoretical knowledge

A5 Turquoise: They experience the process and understand better

During the observation, the author found that 80% of students applied the correct procedure to complete the task for form 4 and form 5. The practical work has helped them not only to memorise but also to understand the fact, terminology, process and procedure effectively. However, the evidence showed that the action taken by the student in a practical task is highly related to the presentation by the teacher at the beginning of the session. During observation, two teachers appeared to use the correct terminology but demonstrated the wrong procedure to the students. This mistake has resulted in the incorrect steps made by the students in their project.

Observation 5.6.1: Teacher present correct terminology/concept/procedure

C4 Jade: Teacher did not place another layer of metal or wood in the demonstration

C4 Khaki: Use the correct terminology and working using the correct procedure

C4 Magenta: Use the wrong terminology

C4 Pink: Use the correct terminology but wrong in a demonstration

C4 Turquoise: Explain the correct process

C5 Jade: Explain the right procedure

C5 Khaki: Use the correct terminology

C5 Magenta: Use the correct terminology

C5 Pink: Use the terms correctly

C5 Turquoise: Use the incorrect terminology

The result shows the effectiveness of practical work in achieving the curriculum objective 1. It can be seen that the responses from the teachers in the observation and interview have a significant influence on the mean score in Table 5.13. The schools with a lowest mean score (Jade and Magenta) are the schools which teachers have not used the correct terminology and procedure during the practical work classroom observation. This action is similar to students self-claim in the survey and the statements by the teacher during interviews.

Observation 5.6.2: Student use correct terminology/concept/procedure

C4 Jade: Students start to make a mistake in procedure, and it is not a correct practice

C4 Khaki: Using the correct term, remember and list the right procedure

C4 Magenta: Some of them made a mistake did not follow the steps, but they remember and list the right procedure

C4 Pink: They did not apply correct steps- skip some of the steps

C4 Turquoise: Use the terminology correctly. Most of them can practice the right procedure and remember the process

C5 Jade: They did not follow the correct procedure, but they can remember the process.

C5 Khaki: Students follow the process correctly and more advanced than the procedure in the textbook. Share the best practices by explaining to their friend how they get the best part in the project

C5 Magenta: They use correct terminology and follow the correct procedure

C5 Pink: Use correct terminology and follow the procedure

C5 Turquoise: Sometimes use the wrong terminology but can practice the right procedure

One of the fact that was found in the interviews with the teachers was that the teaching and learning process for the subject of Mechanical Engineering Studies would eventually help the students to focus on their terminal examination. Nine out of ten teachers (90%) addressed that even though they teach students to experience practical work, the main focus is for the students to answer the questions correctly in the examination. The next aim is to provide skills of practical work to the students for their future in Mechanical Engineering fields.

Question 5.6.2: Do you expect students to understand the terminologies concept/principle/fact/process and remember the procedure after doing practical work? Why?

A4 Jade: Yes, that is really important because to prepare them for the final examination and their career in the Mechanical Engineering field.

A4 Khaki: Sure, when they do, automatically they will remember. It is for them to answer the questions.

A4 Magenta: Yes, that is correct, they should understand the terminology, because students will be accessed on this.

A4 Pink: Yes, it a must. They must remember the correct procedure for examination.

A4 Turquoise: Of course they must remember the procedure. That is the important part in Paper 2.

A5 Jade: They have to really know the procedure, they need to understand and follow the steps to pass in their SPM.

A5 Khaki: Yes, they must understand the terminology and remember the steps, so that easy for them to further study in the future.

A5 Magenta: The actual procedure in the practical task is not the same as the academic procedure. So they have to follow what written in the textbook to pass the terminal examination since the marking scheme is rigid.

A5 Pink: I can see if students remember the procedure they will know and more clear while answering the examination question.

A5 Turquoise: they must remember the procedure to seat for examination.

It has been agreed that the importance of assessment in education is indispensable the assessment has to be treated as part of the curriculum (Kasilingam, 2014). However, not all of the elements in curriculum objectives can be assessed in the terminal examination; for example, the element of an affective domain such as interest (curriculum objective 3), cooperation (curriculum objective 6), values safety (curriculum objective 6) and responsible (curriculum objective 6). These elements require in-depth observation, consistent action and continuous response to be seen, not to be only written on paper. In addition, the practical work itself is a series of activities that students have to experience to gain the knowledge and not necessary to evaluate by only answering a question to test their memories. The final products and workpiece from a practical task are measurable outcomes that require a specific type of assessment. Due to these reasons, the approach on evaluating the effectiveness of curriculum by assessing students in a terminal examination is considered inappropriate in the contact of this study and the author would suggest the specific assessment (see 6.2.3) for practical work in Mechanical Engineering Studies.

5.7 Result curriculum objective 2

Table 5.14 provides the breakdown of mean for curriculum objective 2 for form 4 and form 5 for the technical schools involved.

Table 5.14 Illustrates the mean score for curriculum objective 2 for form 4 and form 5 in all technical schools.

	Jade	Khaki	Magenta	Pink	Turquoise
F4	4.16	4.14	4.09	4.07	3.87
F5	3.63	3.37	3.84	4.02	4.09
Mean Score	3.90	3.76	3.96	4.04	3.98

Legend: CO = curriculum objectives F4=form 4 F5 = form 5

Mean score scale: 5.00 – 4.00 (highly effective), 3.99-3.00 (effective)

Colour code: [shaded] highly effective [unshaded] effective

These results show that only one school has achieved the 'highly effective' level curriculum objective 2 which was Technical School Pink, while other schools were within the 'effective' score. The practical work was mostly 'effective' in enabling students to apply knowledge of Mechanical Engineering to form rational opinions about problems related to mechanical engineering. The interview session has indicated the findings for both form 4 and form 5 technical schools pink teachers has the vision in assuring that students can apply the knowledge by experience practical work. Other technical schools in seem not having positive aims on applying the knowledge by experience the practical work. This is due to several reasons especially the condition of the Mechanical Engineering workshop to fully perform the practical work.

Question 5.7.1: How do you think students will apply the knowledge they learn by doing practical work?

A4 Jade: They remember what they learn instead of just theory but cannot fully apply because the equipment is not enough

A4 Khaki: They can, but limited

A4 Magenta: Yes they got it, but not 100% the most is 80%

A4 Pink: They can answer when we ask them in the classroom about the theory, and they can acquire the basic skill to use the machine when we observed their activities in the workshop

A4 Turquoise: They understand and know the different

A5 Jade: They will have better preparation in tackling the courses in university

A5 Khaki: Only 60% can be applied, the workshop is an inconvenience

A5 Magenta: Manage to do their project work using the skill that they learned

A5 Pink: Yes, they can apply their knowledge event faster and more than my expectation when working in the workshop

A5 Turquoise: They have to do a project so that they will apply the theoretical knowledge

From the interview, the evidence showed that teachers have their own reflection on how to achieve the curriculum objective 2. Most of the teachers have mentioned the problem with the workshop was that it bounded the student to apply the knowledge by experience practical work. Despite the Technical School Pink teachers that give their thought to maximise the application of knowledge via practical work, the other teachers provided the claims and reasons for practical work not fully implemented in the technical schools. The second sub-element in the curriculum objective 2 is students can generate rational opinion, and the interview with teachers indicate that 90% of this element is achievable.

Question 5.7.2: Do you see that students generate rational opinions after experience practical work?

A4 Jade: Yes, they are more advanced in presenting their ideas

A4 Khaki: Yes, they have to share the idea and discuss

A4 Magenta: Yes, they can give rational opinions

A4 Pink: Absolutely, they always come out with their opinions and suggestions

A4 Turquoise: Yes, they can come out with rational opinions

A5 Jade: Yes, to make sure their final product match their planned drawings

A5 Khaki: Not really, students get confused when it comes to AutoCAD

A5 Magenta: Yes, they can give rational opinions

A5 Pink: Yes, a lot of rational opinions and good arguments

A5 Turquoise: Yes, can see during the presentation of their project

Findings in Table 5.14 is synchronised with the observation where it was found that only the workshop of Mechanical Engineering Studies at Technical School Pink was well maintained and fully utilised by students. From all of the technical schools that the author has visited, this is the only workshop that occupied all students in the practical wok lesson in the conducive ambience. The environment encouraged students to apply the knowledge, and the teachers were very helpful and energetic (the teacher factor on Dynamic Model of Education Effectiveness). The teachers in this school believed that by preparing a comprehensive environment for students, it would help them to think, act and learn like an engineer and prepare them for the real engineering world. In addition, the students need to have strong support from teachers and friends in order to apply the knowledge. Example, the problem that has been mentioned by form 5 teacher from the Technical Schools Khaki (A5 Khaki) is similar to the observation in the practical work lesson (C5 Khaki) where the student was having a problem with the AutoCAD practical drawing. This evidence showed that the statement from the teacher is in this point of view is highly relevant to the situation happen in the practical work session.

Observation 5.7.1: Student apply the correct procedure

C4 Jade: Work with a template and re-draw then project on top of the metal plate

C4 Khaki: They apply the knowledge

C4 Magenta: They apply the knowledge

C4 Pink: Can apply the knowledge and more understand the concept

C4 Turquoise: Most of them can apply the knowledge

C5 Jade: They cannot relate to their knowledge

C5 Khaki: Not clear about the importance of dimension in the drawing

C5 Magenta: They are not applying the knowledge very much

C5 Pink: Apply the knowledge effectively

C5 Turquoise: Can apply the knowledge

The successfulness of curriculum objective 2 should rely on the application of knowledge through practical work. Unfortunately, from the results obtained, only one school has the best practices for achieving curriculum objective 2, while other schools have their own restriction to maximise practical work in achieving this curriculum objective. In addition, the observation showed that these factors could inspire students to discuss and share their ideas with the teachers' guidance and peers support. This healthy surrounding encouraged students to provide a rational opinion to solve the problems related to Mechanical Engineering. Ten observations have revealed 90% of students manage to provide a rational opinion by undergoing practical work. The only practical task that not allowed students to give their rational opinion is during the AutoCAD design work. It is because the nature of design using a computer which did not promote students discussion.

Observation 5.7.2: Students give a rational opinion

C4 Jade: They give the opinion that the tool bit is rusty or blunt and argue on the way their friends did

C4 Khaki: React well with few suggestion and opinions

C4 Magenta: Share the best practices by explaining to their friend

C4 Pink: Manage to give a rational opinion

C4 Turquoise: Can give reasoning and can explain the figure

C5 Jade: They are having a problem with manage the task but can give opinions

C5 Khaki: Cannot give a rational opinion while they work with design

C5 Magenta: They can give a rational opinion

C5 Pink: Can give a rational opinion

C5 Turquoise: Can give a brilliant idea

The practical work is highly effective in encouraging most of form 4 students and some of form 5 students depending on the task, to apply their knowledge and give rational opinion toward the Mechanical Engineering field. The findings derive from this study is for the teachers and policy maker to place into consideration on the efforts to increase the percentage of an application on knowledge by demolishing the limitations occurred in technical schools as mentioned by the teachers.

5.8 Result curriculum objective 3

Table 5.15 provides the breakdown of mean for curriculum objective 3 for form 4 and form 5 for the technical schools involved. The results exhibited that majority of the schools acknowledged that practical work was ‘highly effective’ in creating interest in the field of Mechanical Engineering and able to meet the demands of a career in this field. Only School Khaki showed an overall mean score below 4.0, but the score was still within ‘effective’ score. The point to be emphasised is the overall mean score for Technical School Khaki was affected by the scores for form 4 which has particular reasoning and explanation.

Table 5.15 Illustrates the mean score for curriculum objective 3 for form 4 and form 5 in all technical schools.

	Jade	Khaki	Magenta	Pink	Turquoise
F4	4.18	3.86	4.45	4.09	4.47
F5	4.45	4.10	4.00	4.42	4.34
Mean Score	4.31	3.98	4.22	4.25	4.40

Legend: CO = curriculum objectives F4=form 4 F5 = form 5

Mean score scale: 5.00 – 4.00 (highly effective), 3.99-3.00 (effective)

Colour code: highly effective effective

The results in Table 5.15 suggests that the practical work element is strongly beneficial in creating interest among the Mechanical Engineering Studies students, and by experiencing practical work, the students of Mechanical Engineering Studies have been prepared to meet the requirement as an engineer in the future. The findings from the interviews with the teachers of Mechanical Engineering Studies and also the informal interview with the students during observations showed that the overall response to this question was very positive except for the Technical School Khaki (A4 Khaki). A statement in 5.8.1 below shows the answer given by all the teacher when they have been asked about the effectiveness of practical work in promoting students interest.

Question 5.8.1: Do you feel that practical work is effective in promoting students interest in the field of Mechanical Engineering?

A4 Jade: Students always get excited when it comes to practical work and willing to come in the evening to do workshop activities

A4 Khaki: They like it

A4 Magenta: Student love to do practical work

A4 Pink: They love practical work so much

A4 Turquoise: They really love to do practical work

A5 Jade: Students are really enthusiastic when it comes to practical work

A5 Khaki: Yes, they are really interested and show high interest in AutoCAD

A5 Magenta: Extremely encouraging

A5 Pink: The practical works have successfully built the confidence level among students

A5 Turquoise: practical work encouraging student’s interest in mechanical

The responses indicated that 90% of students is highly interest in Mechanical Engineering by experience practical work. In addition, their answer to the question regarding practical work preparing students to meet the demand in this field indicate multiple reactions. 70% of teachers strongly agree with this statement while the other 30% disagree including 2 teachers from Technical School Khaki. These perspectives have come across the author attention to investigate or observe on the teachers believe while implementing practical work to students.

Question 5.8.2: Do you agree that by doing practical work students manage to meet the demands of a career in the mechanical engineering field? Why?

A4 Jade: Yes, some of it, but not really related to the job scope

A4 Khaki: The practical work cannot make them become a highly skilled worker

A4 Magenta: Yes, so true. It was proven for several years

A4 Pink: It prepares a basic or foundation to be a good engineer

A4 Turquoise: We need practical work to prepare them to become a good engineer. It a must and has been proven.

A5 Jade: prepare them with basic knowledge. They need a strong foundation to help them to become mechanical engineers in the future

A5 Khaki: Not to prepare them to become skilled workers

A5 Magenta: All technical school students have been trained to become an engineer, and the best engineer is the one who can do the task

A5 Pink: The job opportunities in this field is wider if they have a practical skill

A5 Turquoise: Yes, it prepares them for the real work demand and prepares students to become engineers in the future

During the observations, the author found that the mean score in the Technical School Khaki for form 4 was highly influenced by the school factors, as the workshop facilities in this school did not support the practical work session for form 4. The workshop was not well maintained, and the tools were not sufficient for every student. The computers in the AutoCAD lab were also insufficient whereby four students have to share one computer during the practical work for design. Cross tabulation has been performed to the teachers’ background for this school to identify whether the situation is related to the teacher factor. The results indicate that both teachers in this school are experienced and knowledgeable teachers, but became demotivated because of the environment and the surroundings of the workshop were not pleasant. The form 4 teacher has been teaching this subject for 20 years and has contributed a lot to the development of this subject. However, the teacher has mentioned frustration on the education system and the school itself for not allow the improvement and maintenance to the workshop. Despite the workshop condition, the author has observed students enjoy the process and show their interest during practical work sessions. All of the students highly participate in the activities and tried their best to complete the task.

Observation 5.8.1: Students show interest in doing practical work

C4 Jade: Students enjoy every single second

C4 Khaki: Students interested to do practical work but the computer is not enough

C4 Magenta: They really determine to finish the task and tried their best to complete the process

C4 Pink: Students show serious concentration and focus

C4 Turquoise: Students really enjoy doing practical work

C5 Jade: Too excited about completing the project and they are so certain that they can be a good engineer in the future

C5 Khaki: They are so interested to do design task but have a limited idea of job demand

C5 Magenta: They show their interest can relate with their future as a mechanical engineer

C5 Pink: They are excited to do present their work and show interest in doing the activities

C5 Turquoise: So determine to prepare the prototype and really enjoy preparing the product

Eight out of ten of the teachers who were interviewed indicated that the practical work gave high impact to the students' interest and 100% of students stated that their interest in the mechanical engineering had been influenced by experiencing the practical work in school. The author, for certain reasons, has strongly agreed with both the teachers and students that practical work really encouraged students' interest in the mechanical engineering field. One of the reasons was due to the reaction and expression shows by the students during practical work sessions which displayed their interest in the mechanical engineering field. According to

Carmichael (2017), the interest of students can be assessed by their enjoyment and personal value.

5.9 Result curriculum objective 4

Table 5.16 provides the breakdown of mean for curriculum objective 4 for form 4 and form 5 for the technical schools involved. The results indicated that none of the school demonstrated that practical work was 'highly effective' in developing creative thinking among students through intellectual and practical activities. Only practical work in School Khaki and Magenta for form 5 show 'highly effective' score, while the rest only show 'effective' scores.

Table 5.16 Illustrates the mean score for curriculum objective 4 for form 4 and form 5 in all technical schools.

	Jade	Khaki	Magenta	Pink	Turquoise
F4	3.77	3.71	3.19	3.68	3.31
F5	3.73	4.27	4.15	3.94	3.85
Mean Score	3.75	3.99	3.67	3.81	3.58

Legend: CO = curriculum objectives F4=form 4 F5 = form 5

Mean score scale: 5.00 – 4.00 (highly effective), 3.99-3.00 (effective)

Colour code: highly effective effective

The interview indicated that 90% of teachers agreed that there is a certain element in the practical work that encourages creative thinking among students which is the element of product design. This element to be specific is a major component in mechanical engineering for every level of education. The Mechanical Engineering Study curriculum specification has outlined this topic to be taught in form 4 and form 5 practical work, however, it appears only 40% of this task is successfully implemented in all technical schools for certain reasons.

Question 5.9.1: Do practical work promote creative thinking among students? How?

A4 Jade: Yes, but depending on their way of thinking

A4 Khaki: Yes, by prepare the design folio

A4 Magenta: Maybe by creating something to solve the problem

A4 Pink: Yes, during the brainstorming session to discuss project and ideas

A4 Turquoise: Yes, students have to produce the product and have to be creative

A5 Jade: Yes, by performing the designing process they could design something

A5 Khaki: Students are really creative especially in design

A5 Magenta: Design can encourage students to become a creative thinker

A5 Pink: Yes, we can see from the best sketch that can innovate by other designs, it does encourage the creativity among students until I have to limit their imaginations

A5 Turquoise: They are creative in design their project

The observation has indicated that student factor has contributed to the highest mean score for form 5 in Technical School Khaki and the teacher factor is the main influenced to the score for form 5 in Technical School Magenta. As mentioned in 5.8, insufficient facilities at School Khaki have made the students be more creative in ways to complete their practical work tasks with the limited sources. For School Magenta, the teachers for form 5 were good in asking questions which triggering creative thinking among students. The observation has revealed actions on how mechanical engineering students become creative in completing their practical task and some of the creative element that can be improved especially for form 4 practical task.

Observation 5.9.1: Student produce idea or product in a creative way/ show creativity in activity

C4 Jade: Students being creative by using the scrap from the bin to test the machine for the second time

C4 Khaki: They are creative enough to prepare the report but not too creative to relate the question asked by teachers

C4 Magenta: Students are not creative to relate the question with what they experience in practical work

C4 Pink: They are not creative to think outside the box

C4 Turquoise: There is too little creative element during the process because of limited two-way communication in the workshop

C5 Jade: They are creative to develop the task but less creative in finishing the product

C5 Khaki: They are so creative to produce few good designs and tidy drawings

C5 Magenta: They are creative to relate the task to the current situation, presenting their work and prepare the product

C5 Pink: Creative in presenting their work but not too creative to relate with a current situation

C5 Turquoise: They are creative when it comes to product design but not in the finishing

Additionally, observation by the author revealed that lack of two-way communications during practical work session also discouraged creative thinking among form 4 students. It was also noticed that during practical work, students carried out their work all the way and the teacher walked around the workshop almost all the time to monitor students' work. The conversation in the session is only at the end of the process where the teacher asked questions to students to evaluate the outcome of the practical work session. Most of the teachers (90%) agreed to emphasise practical work in producing students with creative thinking, but the factors as above-mentioned may influence the effectiveness of practical work session. The triangulation process of data has indicated that the ultimate factor contributed to the lack of creativity among students was due to budget (education system factor) and time constraint (will be discussed in 5.13). The form 4 project for practical work has been planned and outlined by the teachers, and similar for all students, therefore it was difficult for the form 4 students to be creative compared to the form 5 project where they designed and produced their own ideas. In order to increase the level of effectiveness for this particular curriculum objective, the actual implementation of practical work in the technical schools has to be continuously observed, and the task has to be reviewed over time. This action would ensure the validity of the curriculum, allowing the sustainability of the activities and monitor the relevance of the content where the knowledge in engineering education is improving over time.

5.10 Result **curriculum objective 5**

Table 5.17 presents the breakdown of mean for curriculum objective 5 for form 4 and form 5 for the technical schools involved. It shows that practical work was 'highly effective' in preparing students to utilise a computer, workshop and laboratory equipment in two schools (Jade and Khaki), while 'effective' to the other three schools (Magenta, Pink and Turquoise).

Table 5.17 Illustrates the mean score for curriculum objective 5 for form 4 and form 5 in all technical schools.

	Jade	Khaki	Magenta	Pink	Turquoise
F4	4.05	4.18	3.58	3.85	3.63
F5	4.08	4.54	3.63	3.85	3.83
Mean Score	4.06	4.36	3.60	3.85	3.73

Legend: CO = curriculum objectives F4=form 4 F5 = form 5

Mean score scale: 5.00 – 4.00 (highly effective), 3.99-3.00 (effective)

Colour code: ☐ *highly effective* ☐ *effective*

The results for this curriculum objective have its own pattern where the answers for the form 4 and the form 5 for all schools were almost the same. It was because they shared the same facilities and equipment to perform the practical task. Those two workshops at School Jade and School Khaki were the top two in the list regarding lack of facilities and equipment. In other words, both schools have the most insufficient machine and workshop facilities compared to other technical schools. It was also found that the teachers in both schools used all the possible solutions to ensure that students can experience practical work even in difficult situations. The interviews have indicated 90% of teachers agreed that the practical work allowed students to use the tools, the equipment and the computer correctly (depends on the practical task either in the workshop or AutoCAD lab). These findings are significant to the observations where most of the students can utilise the tools effectively while completing their practical task.

Question 5.10.1: Can the students handle engineering tools /computer correctly by experience practical work?

A4 Jade: Yes, they can use the correct equipment for different task and materials

A4 Khaki: Yes students use the computer effectively

A4 Magenta: Yes, they can use the tools effectively, but limited tools are available in the workshop

A4 Pink: Yes they can use the tools effectively but not expert because the time allocation is limited

A4 Turquoise: Yes, but limited to certain machine

A5 Jade: Yes, I would say so because we train them to do so

A5 Khaki: Yes they are more efficient and advance

A5 Magenta: They can, but not to become expert in using a simple machine

A5 Pink: Students can finish their task, and they know the function of each tool

A5 Turquoise: Yes, they can use the computer effectively

The observations at all Technical Schools have pointed out the ability of students in utilising the workshop equipment and the computer for the design process. It shows that practical work is highly effective in allowed students to explore the tools and machine for the achievement of the curriculum objective 5. Although limited equipment provided in the mechanical engineering workshop, the practical work session has successfully reached its target. From the observation, 90% of students use the correct tools and machine in preparing the practical task. In Technical School Jade and Khaki, the practical work is highly applied by sharing the equipment most systematically. The students follow the direction given by the teacher, work in a group effectively and share the facilities within the time given. The teacher has scheduled the time for each student to use the machine or equipment within the session so that they can take turns to complete the practical task.

Observation 5.10.1: Student can use workshop equipment/computer effectively

C4 Jade: They share some of the tools and handle it correctly

C4 Khaki: Student efficiently use the right tools even though it is limited

C4 Magenta: Student chose the right equipment

C4 Pink: They use the correct tools

C4 Turquoise: They handle the machine correctly

C5 Jade: They take a turn to work and can use the machine correctly

C5 Khaki: They schedule the use the plotter and use it effectively

C5 Magenta: They can use a computer correctly to produce the design but are not using the correct tools to prepare the project

C5 Pink: Students use the right tools and machine

C5 Turquoise: Students use the tools and machine correctly

This finding from the observation has contributed to the higher mean score for this two technical schools, and the author strongly believed that the role of teachers is one of the factors that could contribute to the full utilisation of equipment for students to experience the practical work. The creativity of the teachers has allowed the students to entirely apply the limited sources until they can perform the task very well. The observation of the products that have been made by the students shows that they used the equipment correctly, completed the task with good finishing although with all the restrains. The author also agreed that the boundaries of insufficient equipment did not stop the teachers to deliver as much skill as possible particularly for the students to experience the practical work. However, the author intended to highlight the issue of the lack of facilities and equipment for further discussion so that the ministry will give priority to this issue. It is to ensure that the teaching and learning of practical work will be full 'highly effective' in the future and giving appropriate skills to the technical school students through practical work.

5.11 Result curriculum objective 6

Table 5.18 exhibits the breakdown of mean for curriculum objective 6 for form 4 and form 5 for the technical schools involved. The means indicate that the practical work is 'highly effective' in developing students to be responsible, cooperative and value one's own safety and others in the three schools (Khaki, Magenta and Turquoise), while the other two schools (Jade and Pink) indicated as 'effective'. This curriculum objective involved two elements and sub-element which are the value of safety and the development of students' cooperation.

Table 5.18 Illustrates the mean score for curriculum objective 6 for form 4 and form 5 in all technical schools.

	Jade	Khaki	Magenta	Pink	Turquoise
F4	3.79	4.41	4.09	3.59	4.23
F5	3.84	4.15	4.13	3.83	3.89
Mean Score	3.82	4.28	4.11	3.71	4.06

Legend: CO = curriculum objectives F4=form 4 F5 = form 5

Mean score scale: 5.00 – 4.00 (highly effective), 3.99-3.00 (effective)

Colour code: highly effective effective

The interviews revealed 90% of teachers agreed that the practical work has allowed the students to become cooperative by doing a group project and responsible for all the tasks that have been given to them. The idea of combining this element with a value the safety in the same curriculum objective is due to the domain of affective that these elements have shared in command. Similar to the interest in 5.8, the cooperation, responsibility and values are the elements that cannot be measured in the examination or by answering a question. This element requires in-depth observation with the specific type of assessment by the teachers.

Question 5.11.1: Do you realise that students cooperate well in a team by doing practical work?

A4 Jade: Yes indeed

A4 Khaki: Yes, I do realise

A4 Magenta: They are so good in group work

A4 Pink: Agree, I observe them during a group project

A4 Turquoise: Yes, they work together as a team

A5 Jade: Some of them

A5 Khaki: Yes, they follow the instruction and work well in group

A5 Magenta: They cooperate well in a group

A5 Pink: Yes, they cooperate well in preparing their project work

A5 Turquoise: Absolutely yes

Throughout the data collection process, the elements of responsible and cooperative among the students were noticed by the author and visible during project presentation for form 5 and during a distribution of tools in the practical work for form 4. The students working together in a group and share the tools with their friends safely. This study indicated that this combination is reliable because the element of cooperation and responsibility in the curriculum objective has given an impact on the students' safety in the workshop. From the author's perspective, the more students are responsible and cooperative in the task, the lower safety risk they were faces, and this could minimise the accident in the workshop. The next element to be discussed in this curriculum objectives is the element of safety where it has been stated in the curriculum specification that the students should be able to value their own safety, their friends' safety as well as the workplace safety. Safety is considered the most vital aspect of practical work, particularly for engineering subject because the students are working with tools and machines that can be harmful if not been handled properly. While the teachers and students have to be responsible for their own safety, they also have to be aware of their surroundings. The interview has come across various feedback from teachers about this safety issue.

Question 2: Do you realise that students aware and responsible for their own safety, their friends' safety and responsible for workplace's safety by doing practical work? How?

A4 Jade: Of course they did. They wear safety attire, and they clean the workshop at the end of the practical work session

A4 Khaki: Yes, for sure, safety is the most important element, it is a must and mandatory. Students wore suitable safety outfit and did not play along during practical work

A4 Magenta: Yes, because we teach them safety in the first place and they applied it in the workshop like wear a goggle during the drilling process

A4 Pink: Yes, they are aware but still need to be observed. They tent to easily forgot to wear a glove while cutting the metal and let the leftover metal on the floor

A4 Turquoise: Yes, that is the most important, we also have to put it as a priority because safety is mandatory. They wear safety shoes and safety jacket

A5 Jade: Yes, leaving them unsupervised is not an option because of students always careless and play around. They use the safety tools but need to remind frequently

A5 Khaki: Students alert about their safety and always work in a safe environment. They are proud to wear their safety jacket

A5 Magenta: Yes, also for the safety of equipment, students work together in preparing their project and remind each other to prioritise safety

A5 Pink: Yes, they alert, just normally they did not wear the glove because they feel uncomfortable

A5 Turquoise: Yes, the first thing that we highlight is the safety, and the students follow the safety procedure every time they enter the workshop

During the observation, it was found that the safety issue was addressed by the teachers, and the students were highly aware of their own safety. The emphasis of this topic at the beginning of Mechanical Engineering Study syllabus allowed the teacher to focus on safety issue in practical work and place the priority to the implementation of the safety as it supposed to treat. As a result, from the teachers' perspective, most of the students (nearly 100%) aware of their own safety, their friends' safety and their workplace safety by experience practical work. The observation has indicated, there were few students from School Jade and School Pink who did not use safety attire during the practical work sessions. For example, gloves were not worn by the students while cutting the metal and goggles were not used while drilling. These actions were extremely dangerous and can lead to serious accidents in the workshop. It is the students' factor that contributed to the lower mean score for these two technical schools where the safety issues are the major element that they supposed to put into consideration while entering the workshop for practical work.

Observation 3: Student aware and apply safety procedure

C4 Jade: One of the students cut off his finger and bleeding, the used metal template have been left over on the floor that affected the working area safety

C4 Khaki: Wear the safety shoes and a suitable outfit, and they wear goggle during the drilling process

C4 Magenta: They use drilling machine safely and alert on their friend safety

C4 Pink: Student wear goggle, glove and safety shoes

C4 Turquoise: They sweep the floor after the practical work session

C5 Jade: Not wearing goggle and glove before using the machine and they are careless of their friend safety

C5 Khaki: They aware of the product safety during designing the project and explain briefly

C5 Magenta: They practice the safety procedure, and the workplace is clean

C5 Pink: Wearing safety attire and practice the safety procedure

C5 Turquoise: students wear safety shoes but careless of their workplace safety

The author agreed with the teachers that there was no compromise in safety, and the teachers have to be certain in instructing the students to care about safety issue during the practical work session. The best example that was noticed by the author in the Technical School Khaki was when the teacher checked the attire of each student before entering the workshop and before starting to use the machines. The teacher prepared a very detailed checklist, so that the students will always be aware of their safety before, during and after the practical work session. It was done with the help from other teachers of Mechanical Engineering Studies who worked together throughout the practical work session. Despite the insufficient tools and equipment in technical school Khaki that has been discussed earlier (5.8, 5.9 and 5.10), the author found it is important to share the best practice in practical work that has been applied in this school which highly effective in address most of the curriculum objectives.

5.12 Result curriculum objective 7

Table 5.19 provides the breakdown of mean for curriculum objective 7 for form 4 and form 5 for the technical schools involved. The results show that none of the school is highly recommended that practical work can produce students who can solve problems related to the mechanical engineering field. In other words, the mean scores indicated that the practical work was 'effective' and not 'highly effective' in promoting students to acquire the problem-solving skills. All five schools remained almost the same mean scores except for form 4 in School Khaki which indicated the score more than 4 (highly effective).

Table 5.19 Illustrates the mean score for curriculum objective 7 for form 4 and form 5 in all technical schools.

	Jade	Khaki	Magenta	Pink	Turquoise
F4	3.70	4.33	3.98	3.70	3.52
F5	3.90	3.33	3.92	3.78	3.46
Mean Score	3.80	3.83	3.95	3.74	3.49

Legend: CO = curriculum objectives F4=form 4 F5 = form 5

Mean score scale: 5.00 – 4.00 (highly effective), 3.99-3.00 (effective)

Colour code: ▢ *highly effective* ▢ *effective*

The results were significant to the interview and observation in Technical School Khaki which provided the most problem-solving situation during the practical work session for form 4. The interview with the teachers indicated that 80% of the teachers agreed that practical work could encourage students to solve problems in the mechanical engineering field. The point that teachers address is deferred from one to another regarding how practical work can prepare students with the problem-solving skills. This view is based on their understanding of problem-based learning and the projection of how students would encounter this skill mostly by experience practical work. The author agreed with form 4 teacher from Technical School Khaki and form 5 teacher from Technical Scholl Pink that the practical task itself provide the problem for students to be solved. Only form 5 teacher from Technical School Turquoise has a different perspective of this element, and his opinion is not significant with the findings from survey and observation.

Question 5.12.1: Do practical work train students for problems solving skills? How?

A4 Jade: Yes, they help each other, they have to do practical work by themselves

A4 Khaki: Students must have the problem-solving skills because students must complete the practical task, the task itself is the problem

A4 Magenta: Yes, they have to face the problem and find the solutions they use suitable tools for different process

A4 Pink: We want them to think before doing the work, they will find out the best way to solve the problem

A4 Turquoise: Yes, they can solve the problems along the way to complete their work, they will face the difficulties and find the solution

A5 Jade: They will have to adjust and yes, they have to adapt to succeed

A5 Khaki: Students already applied the problem solving by doing the project, and we embedded the problem-solving skills among students

A5 Magenta: Yes, we discuss problem-solving theoretically, and they apply while preparing their project

A5 Pink: The nature of the practical work itself is about to solve the problem, we want them to think and solve the problem logically

A5 Turquoise: Not that much problem solving, produce something to solve the problem

During the observations, it was found that the element of problem-solving among students can be improved by the encouragement from the teachers. The teachers play the most important roles in developing problem-solving skills among students, and it is the teachers' responsibility to guide the students to find solutions. Observation in a practical task that involved computers like during AutoCAD design has indicated a lack of problem-solving and students relied on the direction from the teacher. The domain of observable has emerged clearly in this kind of practical work which not encourage students to solve the problem. They are too dependent on the computer and the teacher. The author found that the problem-based questions asked by the teacher during practical work session have forced students to think which at the same time encouraged them to use their previous knowledge and experience of practical work to solve the problem.

Observation 5.12.1: Student can solve a problem during activity

C4 Jade: They solve the problem and start using manual tools to cut the metal, they suggest to the teacher if possible to put the lubricant oil

C4 Khaki: They give opinions to solve the problems, they answer the problem-based questions ask by teacher correctly

C4 Magenta: Use the suitable tools for different process

C4 Pink: Students solve the problem by using the scrap from the bin to test the machine before starting to cut the actual plate

C4 Turquoise: They can complete the task with lack of problem-solving

C5 Jade: They can solve the problem regarding get the smooth metal cutting

C5 Khaki: Lack of problem-solving skill while working with computer

C5 Magenta: They can solve the problem appear on their presentation of the project

C5 Pink: They follow what teacher ask them to do in drawing and less of the problem solving

C5 Turquoise: Students can solve the problem regarding the design and selection of material in their project

The previous discussion with the curriculum developer has revealed that the design of practical work for Mechanical Engineering Studies itself is about solving the problem and creating the solutions. For example, the form 5 project work requires the students to prepare the task that begins with the statement of a problem until they create the product to solve the problem. To a certain extent, the author believes that there are opportunities to prepare the condition that will allow students to solve the problems during practical work session even though the result is not highly effective. It has been done by the teacher from Technical School Khaki where he asked the questions and required students working together to solve the problem. This approach is more effective compared to the other technical schools where the teacher gives the direction and students do the task. The practical work setting is for the student to experience and solve the problem, but this study has indicated that the actual implementation in most technical schools is not promoting this problem-solving skill among students because of certain limitations that will discuss further in 5.13 below.

5.13 Challenges in the implementation of practical work

The challenges were identified by the author based on two different views: 1) the answers from the respondents during the interview sessions, and 2) the situation occurred during practical work classroom observations. The information was sorted out to become the meaningful data, and classification of each category was identified by conducting a systematic content analysis process. According to Selin and Olander (2015), content analysis is used to extract the data in the form of codes, and in this case, it was sorted into most frequent order to feature the importance of each factor in the curriculum objectives. Codes were applied to classify the findings into a few categories, and the challenges were sorted out based on the most frequent problem addressed in the study. The process of data retrieval as suggested by Weber (1990), in Cohen et al., (2014) was preferable to set based on category rather than a single word because it provides an indication of their significance. This section will discuss the identified factors of the less effectiveness of practical work and the reasons for not fully implementing practical work at the technical schools. The challenges were classified using the Dynamic Model of Education Effectiveness as the baseline as suggested by Creemers and Kyriakides (2010) on the validity of this model in evaluating the educational effectiveness. There were four factors in the Dynamic Model of Education Effectiveness that will be discussed in the next sub-sections, namely student factor, teacher factor, school factor and education system factor. These limitations then become the reasons for teachers not to fully utilise the practical work in teaching and learning the Mechanical Engineering Studies subject or limit their ability to teach the lesson to their full potential.

5.13.1 The difficulty of the curriculum [education system factor]

One of the main challenges mentioned by the teachers was the difficulty of the curriculum of Mechanical Engineering Studies for secondary school students. As one interviewee said, the content and level of the curriculum are always inconsistent. About seven teachers (70%) also agreed that the syllabus of Mechanical Engineering Studies at the moment is lagging behind the technology, and the current practice of teaching and learning process is rigid to the textbook provided by the government where the content is outdated. Looking at this issue, most of the teachers (80%) referred to the curriculum of Mechanical Engineering Studies which began in 1994 where the content included the detail element of physic and chemistry. It was also the time when the practical work was fully implemented, and the workshop was highly utilised (from 1994 to 2004). Some interviewees (20%) argued that the reduction of physic and chemistry component in the syllabus had made Mechanical Engineering Studies less challenging to students, while others (80%) said that the reduction of the element had made the syllabus of Mechanical Engineering Studies to broader and difficult for students.

The crosstab analysis run by the author revealed that 80% of the teachers who emphasised the difficulty of the current curriculum for present students were among the most experienced teachers. They involved in the transformation of the curriculum of Mechanical Engineering Studies from the very beginning and felt the impact of the revolutions toward the practical work and teaching and learning process. New teachers (20%), have their own expectation of students due to a different perspective on their own towards the curriculum of Mechanical Engineering Studies compared to senior teachers. On the author's point of view, the current situation is different from ten years ago were technical schools received enrolment mostly from excellent students. Statistic on the technical schools' enrolment for the past five years showed fewer distinction grades such as 'A' (refer to the PMR result) for students enrolled in technical schools compared to the previous years (Educational Planning and Research Division, 2016). From the teachers' perspectives, present students have a lack of basic technical knowledge and some learning topics are beyond their capabilities.

Another issue is that the curriculum is not updated, where it has been more than 14 years since the curriculum of Mechanical Engineering Studies has been revised. Some of the contents are no longer relevant to current situations. Observation by the author on the curriculum content in the textbook found a similar answer as evidence that the curriculum of Mechanical Engineering Studies needs to be reviewed since the author involved in managing the curriculum of Mechanical Engineering Studies and dealing with the technologies in industries. The curriculum should be aligned with current technologies and industries.

In addition, the updated syllabus of Mechanical Engineering Studies curriculum will enable students to achieve all the curriculum objectives. The students should be exposed to current knowledge in engineering to enable them to apply the learning process inside and outside the classroom. At the same time, the difficulty of the curriculum has bounded the students to explore and solve the problem while they are still preparing a foundation in an engineering field. In addition, 90% of teachers mentioned that the learning outcomes are also irrelevant to the current situation, for example, the use of hand tools in the workshop during the practical work for cutting and marking the metal is currently invalid because the industry already applied modern machinery for that purpose. This is the issue that the curriculum makers have to take into consideration while reviewing the content of the curriculum of Mechanical Engineering Studies in the future.

5.13.2 Insufficient budget [education system factor]

Finances are another issue that all teachers (100%) agreed to be the limitation to implement the practical work in a few years back. They said that the allocated budget to technical schools had been declined constantly and eventually restrained teachers to prepare various materials for students to experience the practical work. This has limited the creativity of students as proven in curriculum objective 4 and also addressed in curriculum objective 2, where students were bounded by the limitation of tools to apply the knowledge. The price of metals is higher that urges the teachers to reduce the size of form 4 project and limits the source of materials for form 5 prototypes. This is the particular reason for the schools to encounter the quantity of metal used in order to ensure that the budget would be sufficient for every student. It is a restriction to the teachers to multiply their approach in teaching and learning practical work due to money constraint. Eight out of nine teachers (80%) mentioned that they have to work within the limited budget and have to make some adjustment to the students' project in order to minimise the use of raw materials. This limits the ability of the students to apply the knowledge (curriculum objective 2), become a creative thinker (curriculum objective 4) and problem solver (curriculum objective 7).

This issue has to be addressed by the government each time during the provision of budget allocations to all technical schools. This was one of the main factors which prevented Technical School Pearl from conducting practical work for several years. The teachers have to maximise the use of budget for the most important element in the curriculum and to prioritise the development of students in the subject of Mechanical Engineering Studies by providing the students with the best teaching and learning tools in the classroom rather than applying practical work in the workshop. The observation made by the author toward the materials in the workshop deduced that teachers had tried their best to provide the teaching and learning of practical work to the students. They have limited material, and the teachers have to be as rigid as possible in distributing the metal to ensure that all students have the opportunity to experience the practical work.

5.13.3 Unclear objective and policies [education system factor]

Another problem that needs to be considered is the direction of engineering education according to hierarchy from top to bottom. The Ministry of Education together with policy maker and curriculum developer have their own vision while creating the curriculum objectives which are not delivered effectively to teachers in technical schools. Four teachers (40%) at different schools stated that they were not clear about the objective of the technical school, and the curriculum objectives for Mechanical Engineering Studies was no longer relevant at present. It is somehow surprising that there were technical schools that have not conducted practical work for the last five years. Most likely, 60% of the teachers had a negative perspective toward ministry and concluded that attention has not been given to the technical schools. The collaboration between the Ministry of Education (secondary education) and Ministry of Higher Education (tertiary education) is seemed vague because students of technical schools need to repeat the same subjects that they had learned in technical schools when they pursue higher education. At this point, the technical certificate or the subject of Mechanical Engineering Studies apparently presented no values when the students further their studies even in the same engineering field.

Three teachers mentioned the pressure received from the ministry to implement new policies drastically in technical schools that often end up with insufficient sources and dissatisfaction of outcomes. Teachers are not given enough information about the implementation. Besides, the importance of practical work is less highlighted because there is no assessment for practical work. Teachers have to focus on the terminal examination which the major target is to ensure that students get a good result. In this situation, according to Dynamic Model of Education Effectiveness, it is not appropriate to blame the teachers because the Malaysia education system is custom made for a long time to place the examination result as the major focus in measuring the successfulness of the teaching and learning.

5.13.4 Lack of facilities and technology [school factors]

The majority (90%) of teachers revealed that the main problem with the implementation of practical work in engineering education was due to insufficient facilities at the technical schools at present. It is getting worse when the current integrated technology that has been applied in technical schools was already lagged compared to the industry. Most of the teachers claimed that the tools and equipment provided for practical work were limited, and most of the machines were outdated. Students have to share the tools during the practical work session, including computers for design work. Most of the conventional machines stated in the curriculum to be taught to students were not provided or not well maintained. The teachers have to use the YouTube application as a medium of presentation for viewing the real process of certain practical work. Students have no opportunity to experience certain process, and this has been considered as a theoretical explanation rather than practice.

The author also found the same issue during the observations. In almost all schools, the machines were rusty and not working properly. Some of the tool bits were blunt and not safe to be used by students. Compared to current technologies and industrial needs, the facilities and hand tools in technical schools were way outdated. It was assumed that technical schools did not prepare the students to be skilled workers in the industry, and at the same time, the curriculum objective 3, stated the target to prepare the students for real demand in mechanical engineering fields, while curriculum objective 5 assessed the students to utilise the tools and workshop equipment. Based on that, the overall implementation of practical work and facilities have to be reliable and supportive to achieve the curriculum objectives. Another interviewee revealed about the internet connection provided in the workshop of Mechanical Engineering Studies.

Occasionally, access to the internet was not available, and this has interrupted the teaching and learning process including the practical work. The teacher cannot demonstrate a certain task using the online application before the practical work session if the internet is not working. In addition, 60% of the teachers agreed that the software for AutoCAD design was already outdated. Even the computers provided in the laboratory did not undergo maintenance and insufficient for every student. This could be the reason that hinders maximum achievement for curriculum objective 5 (to utilise the computer and the workshop equipment effectively) due to the facilities provided is not supportive. Although the technology moves fast and the students are advanced, but the tools provided for the students to learn in technical schools are not synchronised with the current situation. The equipment was probably valid when the Mechanical Engineering Studies curriculum started in 1994, but as for now, it is no longer relevant. It was found that most of the students have been exposed to the current technology from the internet, and the way they use AutoCAD to design their project work was faster than the traditional version in the textbook. However, the curriculum has limited the student's credibility with the old version of the software (using a command to draw), as if students are taught about the history of a computer while they have already exposed to advance technology.

5.13.5 Limited training and human resources [teacher factor]

The issue on teacher workload has been derived since the author's first day in the education field, and it seems like a never-ending story. This issue becomes even worse when it comes to conducting practical work for the engineering subject without laboratory assistance in contrast to practical work in sciences subject. The teachers have to prepare everything, including materials, tools and equipment by themselves. Teachers have full responsibility for the safety of students in the workshop and at the same time have to ensure the successfulness of the practical work session. It is contrary to practical work in sciences subject that has a lab assistant to prepare the materials and act as co-instructor or helper during the practical work sessions. The lab assistant is also responsible for taking care of the lab before and after the session. This was a concern from one of the teachers who stated that the challenge is not about teaching the practical work, but it is to manage the process before and after the practical work because they have to encounter everything. Teachers have too many management works because no technical assistance is given to them either to prepare the materials for practical work or to maintain the tools. It jeopardises the practical work sessions as teachers are not given specific training in previous years for teaching practical work. This was the issue that emerged so often in the interview where 60% of teachers claimed that the governments had not provided enough funding to train teachers particularly for certain skill of practical work. All of the teachers (100%) admitted that they lost their practical skills since the lathe and milling machines were omitted, and they kept repeating the old style of teaching because no new training has been given to them on the current teaching approach especially, for practical work. Only one technical school provided internal training for teachers to improve their practical skills and one technical school allowed the teachers to undergo their training outside the schools. In Malaysia, the Teacher Training Department carry the responsibility to prepare suitable and sufficient training to all teachers in schools (Ministry of Education Malaysia, 2018). With regards to the current list of training provided by this department, none of it focused on teacher training in practical work, nor the training on mechanical engineering subject.

5.13.6 Time constraint and capability of students [student factors]

Time is the other issues that have been addressed by the majority of teachers (80%) in the interviews. The allocation of time for practical work was too short (80 to 90 minutes per week) that eventually led to the limitation of activities during the practical work session. Practical work is a major component in STEM subjects, especially engineering and it can be defined in engineering contact as students experience by manipulating a real object or materials (hands-on) inside or outside the classroom to enhance engineering knowledge (Dillon, 2008). The practical work is a process for students to explore and experience certain skills that require times. In this case, the time factor is crucial to ensure that practical work can achieve the objectives.

As mentioned earlier, the implementation of practical work in all technical schools was approximately between 25 to 30% (35 to 42 hours) maximum for both form 4 and form 5. The finding indicated that the students had less time to experience the practical work of the Mechanical Engineering Studies subject and resulted in the disadvantages of the number of skills that the students were supposed to attain. The other issue mentioned by the teachers was the capability of students to undergo the process of learning the Mechanical Engineering Studies through practical work and the challenge to face with a different capability of students (some of them are too fast, and some are too slow). About 70% of teachers admitted that they struggled to guide students in preparing their work regarding designing the project particularly the male students. However, all teachers agreed that the female students have the same level of effort and willingness while completing a task in the practical work session.

Observations by the author have supported the teachers' statement where an extensive range of students was evaluated in the same class. About 10% of the students finished the practical task within two weeks where the rest of the students took more than four weeks to complete the project. The author also agreed that the time allocation for practical work was limited for both form 4 and form 5. During the informal interview with the female students, it was found that they have no difficulties to finish the task, but they demanded for more time to apply for practical work.

5.14 Chapter summary

This chapter has discussed the findings which answered the research question 1, where practical work was 'highly effective' in achieving three of the seven curriculum objectives and 'effective' in achieving another four objectives. This chapter also has answered to the research question 3 which addresses the challenges accursed in the implementation of teaching and learning practical work for Mechanical Engineering Studies subject based on the Dynamic Model of Education Effectiveness (Kyriakides and Creemers, 2008). The next chapter will discuss the conclusion and recommendations based on the results from this chapter, as well as reviews of the literature in Chapter 2. Chapter 6 will also present the contribution of this research to the educational knowledge and answer the three research questions in this study. Finally, these findings have allowed the author to provide a tentative suggestion to the Ministry of Education Malaysia, curriculum developer, teachers and technical school as the practical work could be highly effective in achieving the curriculum objectives for the engineering study.

CHAPTER 6: DISCUSSION AND CONCLUSION

Structure of the chapter

The structure of this chapter is presented as follows; the first section gives an introduction to the overall content in the discussion and conclusion and the aims of this research. The second section attempts to answer all three research questions followed by the original contributions and the implication of this study. The final section explains the limitation of this study and provides further research and recommendation. Overall, this chapter provides a conclusion to the study by presenting the evidence-based result from the findings and acknowledge the previous related research from the review of the literature. This chapter explains the results and shows how the study is answering all the research questions and contributes to the body of knowledge.

6.1 Introduction to the discussion and conclusion

The focus of this chapter is the discussion on answering all research questions. The first research question sought to determine the level of effectiveness of practical work. The second research question is to acknowledge the international perspectives of practical work and the third is to understand the challenges of practical work implementation in secondary engineering education. This chapter discusses these research questions based on specific settings which are research question 1 emerged from the findings in investigating the effectiveness of seven curriculum objectives. Research question 2 has been indicated from the systematic literature reviews of previous ten years research worldwide on STEM at secondary education. Research question 3 provides the challenge of practical work implementation which presented in four factors suggested in the Dynamic Model of Education Effectiveness which are the education system factor, the school factor, the teacher factor and the student factor. It ends with the recommendation to improve the curriculum development of engineering education in Malaysia emerged from the teachers' perspectives during the interview sessions. The following section is the originality of this research that contributes to the body of knowledge in a related research field. This section presents the contribution of this research in various aspects of education practice and benefits from this research to different target groups includes the important of the table of degree of adverbs. The final section is the reflection that explained the limitations of this research, its implication towards the generation of findings and for selection of practice that influences the design of this research. It has been concluded with the recommendation of further research in related fields including science and technology subjects, also the other areas of engineering which implement practical work as part of the teaching and learning at all level of education. This section also offers some tentative suggestions of the opportunity for improvement in future research.

6.2 The aims of the research

This study set out with the aim to determine the effectiveness of practical work in achieving the curriculum objectives for mechanical engineering study at secondary education. It also aims to acknowledge the previous research on practical work in STEM education worldwide that also relevant to current secondary education. Finally, the purpose is to understand the challenges appeared in the implementation of practical work in the Mechanical Engineering Studies at technical schools.

6.3 Answering the research questions

This study has outlined three research questions, and the findings have successfully answered all the research questions. The study contributes to the understanding of the method of calculating the level of effectiveness of practical work in achieving the curriculum objectives. Before this study, evidence of important of practical work in engineering education at the secondary level was anecdotal. This project is the first comprehensive investigation of the effectiveness of practical work in achieving the curriculum objectives for engineering education. The methods used for evaluating the mechanical engineering subject may be applied to other engineering and sciences subjects elsewhere in the world in which the practical work is fundamental to teaching and learning. This study has addressed each research question in different chapters. In the discussion below, the author wants to revisit each research question and by doing so, highlight the main findings of this study.

6.3.1 Research question 1: How effective is practical work from the students' and the teachers' perspectives in achieving curriculum objectives for engineering studies in Malaysia?

The results from this study have indicated that practical work is highly effective in achieving three curriculum objectives in Mechanical Engineering Studies, which are curriculum objective 1, 3 and 6. These findings show that the practical work is highly effective in assisting students to understand the terminologies, process, and procedure (curriculum objective 1), highly effective in creating interest in the field of mechanical engineering (curriculum objective 3), and highly effective in encouraging students to apply safety and cooperate in performing practical task (curriculum objective 6). On the other hand, the results indicated that practical work is ‘effective’ in achieving curriculum objectives 2, 4, 5 and 7 (for students to be able to apply their knowledge, develop creative thinking, utilise the technology and solve the challenges related to mechanical engineering). The result from this study shows that practical work is perceived (both by pupils and teachers) as the important component in the Mechanical Engineering Studies curriculum to address all the elements in the seven curriculum objectives as follow;

1. Curriculum objective 1: Understanding of knowledge/ terminology/ process and procedure

This study indicates the practical work is highly effective (with a mean score of 4.00) in developing students’ understanding of knowledge, terminology, process or procedure. These results match those observed in the latest studies as follows;

- The practical work enhanced the students’ understanding of gaining knowledge in biology (Spernjaka and Sorgo, 2018).
- Practical work appeared to promote greater understanding in the teaching lesson compared to other delivery methods of teaching and learning (Rugarcia et al., 2000).
- It was suggested that there should be a specifically written assessment to evaluate students’ understanding after their practical work (Walsh et al., 2010).
- The students’ understanding of the knowledge can also be obtained by observing their immediate reaction and response toward the studied subject in the session (Fuller et al., 2000).
- The discussion and presentation of ideas allow students to link knowledge and build conceptual understanding of the project work (English et al., 2009).

2. Curriculum objective 2: Application of knowledge and provide rational opinions

This study indicates the practical work is effective (with a mean score of 3.93) in allowing students to apply the knowledge and provide rational opinions. From the teachers' perspectives and practical work sessions observation, it was indicated that the application of knowledge in practical work is effective with the proper guidance from teachers. It was also indicated that the students could provide rational opinions when the session promote a suitable learning environment.

- A good learning environment is where students feel free to talk using in everyday life language and also encouraged to express themselves using physics terms in relevant activities (Andersson and Enghag, 2017).

- Application of knowledge in engineering is when the student used either the theoretical, conceptual or their background knowledge to provide workable solutions to the task (Carboni et al., 2000).
- Research on the strategy to apply practical work has suggested that the students should be provided with complete demonstration and guidance before they can start their work (Kirschner et al., 2006).
- Practical work allowed students to communicate and provide a rational opinion to the members of the group (Andersson and Enghag, 2017).

3. Curriculum objective 3: Create a student's interest and meet the demand

This study indicates the practical work is highly effective (with a mean score of 4.23) in creating interest among students and highly effective to meet the demand in the engineering field. This finding supports the previous studies as follows;

- Teacher questioning techniques could increase students' interest in learning science including students from different learning styles. It appears a positive outcome of their study conducted in Sweden to evaluate the interaction and content of students' communication and outcomes of their actions during practical work (Tuan et al., 2005).
- There is a significant relationship between interest and attitudes towards STEM and student performance (Choi and Chang, 2009; Xiao and Zhang, 2016).
- The knowledge of practical work in engineering education at an early stage is preparing a foundation for students on their career in the future (Berlandet al., 2013).
- Insufficiency of regular training to teach the subject regards to the dynamic changes in industries for the past ten years (Mincu, 2015).

Consistent with the literature, the results from this study indicated that practical work is 'highly effective' in promoting interest for students to further their study in the engineering education field. However, these findings contradicted with previous research below;

- Although the students claim that they are interested in pursuing their study in science, practical work is ineffective in generating longer personal interest to study science in the future (Abrahams, 2009).
- In engineering education, it was statistical evidence that 90% of students from technical schools have successfully pursued their tertiary education in the engineering field (Educational Planning and Research Division, 2016).

4. Curriculum objective 4: Develop creative thinking

This study indicates that practical work is effective (with a mean score of 3.76) in developing creative thinking among technical schools students. This study suggests the interactive teaching conducted in practical work session which involving two-way communication and discussion that encouraged creative thinking among mechanical engineering students.

- School laboratory activities have a unique role as a medium for student learning (Hofstein and Lunetta, 2004).
- Practical work might open the opportunity for students to participate and interact physically with objects, which is valuable but not enough because laboratory experiments need to be integrated into a pedagogical structure to trigger reflection (Kluge, 2014).
- Creative work in engineering education can be applied to the derivation and solution of problems derive task in project work. (Davies and Gilbert, 2003).
- Creative engineering students defined by their flexibilities and willingness to shift approaches when faced with a complex problem (Halizah and Ishak, 2008).

5. Curriculum objective 5: Utilise technology/ tools and equipment

This study indicates the practical work is effective (with a mean score of 3.92) in allowed students to utilise technology tools and equipment in engineering education. These findings aligned with previous studies below;

- The advantageous nature of practical work is that it utilised hands-on tasks, promoted a classroom atmosphere which is rich in variety, semi-autonomous learning and self-discovery, which students found intrinsically interesting (Martindill and Wilson, 2015).
- Teachers use digital technology to support and enhance the practical experience to students (Spernjaka and Sorgoa, 2018).
- The main focus in current research has not directed towards the ability of the technologies in education, but how the technology would be used effectively in teaching and learning (Kirkwood and Price 2014; Machkova and Bilek, 2013).

6. Curriculum objective 6: Encourage the value safety

This study indicates the practical work is highly effective (with a mean score of 4.00) in encouraging students to value their safety. It was also appeared in the practical work classroom observations and mentioned by the teachers' interviews. As it aligned with the study below;

- Practical work is the only practice in school where the students experience to apply the safety procedure (Kim and Tan, 2011).
- By recognise safety as the priority in a workshop, the more effective task can be produced for long-term (Itzek-Greulich et al., 2015).
- By embedding the value of safety among students, it prevented 70% of accidents in the workplace (Hinneh and Nenty, 2015).
- The practical work in engineering education must all be of the highest standard of safety and teachers at the first place should ensure that they consider the best practice to manage the risk for every practical lesson (Brophy et al., 2008).

7. Curriculum objective 7: Promote problem-solving skills

This study indicates the practical work is effective (with a mean score of 3.76) in promoting problem-solving skills among technical schools students. It was mentioned in the teacher's interviews and the practical work observation that practical work is effective to promote problem-solving skills among students.

- It is evident that the approach used in teaching and learning has influenced the process of promoting problem solving skills among students (Zin et al., 2013).
- Even though the application of knowledge to encourage the problem solving skill among students, complete descriptions of conducting the task remain important in providing a more effective learning environment (Kirschner et al., 2006).
- The application of problem-based learning approach has a positive effect on the students' learning abilities and science process skills by providing a supportive environment to enhance continual learning (Tatar and Oktay, 2011).

6.3.2 Research question 2: What is the international perspective on the effectiveness of practical work in STEM secondary education?

The systematic literature review from previous research in practical work for STEM subjects for the last ten years has successfully found 23 related pieces of research, and the findings have been summarising in Table 2.1 (Chapter 2). This study agreed that most of the findings in the research on the effectiveness of practical work in engineering education in Malaysia are aligned with the international perspective on the effectiveness of practical work in STEM education. This indicated that there are common issues in implementing practical work which faced by other countries and could be adopted in Malaysia contact as the opportunity for improvement in the future. The common issues that appear are as listed below:

- Specific assessment for practical work is required to ensure that the assessment process is evaluating the correct outcomes. Studies in Sweden (Sund, 2016), Zimbabwe (Chirikure et al., 2018) and England (Kind and Kin, 2017) have suggested that transformation from terminal examination to school-based continued assessment would give more impact to evaluate practical work. This type of evaluation is aligned with the inspiration in the Blueprint toward the implementation of the outcomes-based assessment in Malaysia education system. Perhaps, the findings from this study may help the government to understand the importance of outcome-based assessment especially for the practical based subjects including sciences and engineering.
- Practical work is claimed to increase the students' motivation in learning science and increase their interest in pursuing higher education in this field. Only the study in Germany by Greulich et al., (2015) fully supports this claim, while the other studies in England (Abrahams, 2009) and Botswana (Hinneh, and Nenty, 2015) show contrary results. Most of the findings indicate that practical work is effective in promoting students motivation to learn the subject in secondary school but did not maintain their interest to continue in the same field. Conversely, the findings from this study indicated that practical work is highly effective in promoting student interest in the field of engineering. These results should be interpreted with caution because it has been generated from the students and teachers perceptions. It might be other elements beyond the focus of this research that influence students' interest which requires further investigation.
- The studies in the United States (Jones and Stapleton, 2017), Taiwan (Fan and Yu, 2017) and Greece (Dintsios and Artemi, 2018) emphasised the importance of integrating technology in teaching practical work. These studies have their strength where the findings showed that the application of the latest technology in practical work had resulted in a positive impact toward students learning outcomes. Research conducted in Slovenia (Spernjakaand Sorgo, 2018) has found no significant difference whether the practical work is performed traditionally or with technology integrated into the achievement of students. The author would suggest that the government should focus on this issue since the use of technology in practical work has been recognised to increase the achievement of students' learning outcomes in many countries.
- Most studies in England have indicated that the role of a teacher in promoting mentally challenging approaches for practical work lesson is significant to the students' performance to understand the knowledge (Abrahams and Millar, 2008; Abrahams and Reiss, 2012;

Philip and Taber, 2015). Teaching and learning should focus on the combination of theoretical and practical education to increase the effectiveness of students' work (Philip and Taber, 2015). It should focus on the domain of ideas (minds-on) to cooperate with the domain of observable (hands-on) to ascertain the outcome of practical work (Abrahams and Reiss, 2012). In engineering education, this approach is possible to be implemented by encouraging creative thinking among students while experiencing practical work. The outcomes can be seen through interactive ways of teaching and learning and the teacher questioning technique. This aspect is also part of the inspiration that highlighted in the blueprint where the teaching and learning along the process should develop the higher order thinking skills.

- For the practical work to become highly effective, the facilities and equipment for this purpose have to be relevant. The studies in South Africa (Akuma and Callaghan, 2017) and the Netherland (Spaan and Berg, 2016) have listed the material related and the challenges in designing the practical task. They indicated that the facilities and tools to implement practical work in sciences are costly and difficult to acquire. Similarly, the main obstacle for the situation in engineering education Malaysia is the effort from the government to provide more expensive tools and equipment to implement the high technology in practical work lessons. This study has suggested that the importance of providing up-to-date facilities and equipment for engineering education not only to prepare the students for the introduction into an engineering working environment, also for their safety during practical work sessions. It should gain serious attention from the government especially regards to the students' safety while implementing practical work.

6.3.3 Research question 3: What are the challenges in the implementation of practical work for engineering studies in secondary education?

Ten interviews with teachers and ten practical work observations have initiated specific challenges regarding the implementation of practical work in technical schools as reported in 5.13 which are;

- The difficulty of the curriculum [education system factor]
- Insufficient budget [education system factor]
- Unclear objective and policies [education system factor]
- Lack of facilities and technology [school factors]
- Limited training and human resources [teacher factor]
- Time constraint and capability of students [student factors]

This study provides a suggestion to overcome the challenges, and the discussion is based on the Dynamic Model of Education Effectiveness (Kyriakides and Creemers, 2008). There are a number of changes suggested to improve the engineering education environment at technical schools including to strengthen the policies, to establish financial and training support from local university and industry, to review the curriculum and the assessment system and, to increase time allocation for the practical work session in all technical schools.

1. A recommendation to the challenges in the education system factors

The education system factor is the top level in the dynamic model of education effectiveness that emphasised the rule of government, policy maker and the curriculum developers in the success of education. The findings from this study corroborate the results of previous works by Kyriakides and Creemers (2008), by considering the factor of effectiveness as multidimensional constructs. These views not only provided a better picture of what make teachers and schools more effective but also help to develop specific strategies for improving educational practice.

i. Strengthen the education policies

The curriculum of Mechanical Engineering Studies delegated under the education policy where the written curriculum needs to be approved by the ministry before implement in technical schools. While the policy has stated that Mechanical Engineering Studies curriculum is about to prepare students for the higher level of education and aid students with the basic skills needed in a mechanical engineering field, this study has indicated a few elements in the current policy need to be reviewed.

- The important to consistently measure the weaknesses that occurred in a school so that at the end the policy on teaching and actions can be improved (Kyriakides and Creemers, 2008).
- The ability of education system to identify the weaknesses and develop their policy on aspects associated with teaching and the school learning environment is also able to improve the functioning of classroom-level factors and their effectiveness status (Kyriakides and Creemers, 2008).
- As outlined by the dynamic model, by strengthening the policy (top rank of education effectiveness), it allowed the accumulation of changes in other factors that make practical work highly effective (Wang, 2010).

ii. Financial and expertise support from local universities and industries

The financial aspect is the most sensitive issue that the government have aimed to address. The government has allocated a certain amount of budget for students to experience the teaching and learning process including the practical work. It is important to develop a support system that allowed students to explore the practical work in engineering education which is close to the nature of work in engineering fields. All of the teachers have mentioned that the allocation of a budget is insufficient to implement practical work, This study agreed that this is part of the responsibility of the policy maker and the curriculum developer to decide and allocate the reasonable budget for schools to conduct the practical work since the problem of the budget is frequently mentioned (18 times in 10 interviews).

- Policy-makers are expected to adapt their general policy into the specific needs of groups of schools including the technical schools by involving the industry as the funder of students practical work project (Fox et al., 2015).
- The blueprint has mentioned that the school collaboration with industry regarding sharing the expertise and experience. These approaches are well known in developed countries as apprenticeships, or the K-12 engineering education is perceived as real-world collaboration (Moore et al., 2014).

iii. Reviewing the curriculum and assessment system

This study analyses the importance of the Mechanical Engineering Studies curriculum and argues that assessment should include more requirements for extended projects in an interactive application in the latest engineering knowledge.

- For the school to be effective, the taught curriculum must be checked and connected with the written curriculum. Although students have to do many tasks in practical work for form 4 and form 5, the assessment does not count in terminal examinations (Marzano, 2012).
- The study in evaluating the relationship between qualities of learning and the students' performance in practical task has suggested that a shift from the traditional high stakes final examination to a school-based continuous assessment of investigations might be a viable move towards a deep approach to investigations and greater emphasis on developing process skills (Chirikure et al., 2018).
- Most of the assessment organisations worldwide commonly use written questions to assess practical science rather than a direct assessment of students' practical activities, and until

recently, limited information occurred about the validity of a written assessment of practical skills (Mincu, 2015).

- To encourage into valid, reliable and manageable ways of assessing practical work in science, in particular where assessment is indirect and utilising written questions. It is consistent with the assessment in engineering education where the specific evaluation to measure the practical work is needed (Abrahams et al., 2013).

iv. Increase the time allocation for practical work

Time is one of the factors for Mechanical Engineering Studies to become highly effective and this study has indicated that the duration of practical work for Mechanical Engineering Studies is insufficient. During observations, the author has experienced the whole process of practical work from the very beginning and found that it is unrealistic. Much work has to be done by the teacher while preparing for one session of practical work lesson. 90% of the teachers suggested the increase in allocation of time for practical work. This additional time is to give more opportunity for students to utilise the experience of practical work. According to the teachers, there are many elements in practical work that students can learn along the process, but the limitation of time has blocked them from doing that. As well as a need for extra time in the workshop, students also need more time for AutoCAD teaching and learning sessions. It requires time and patience for students to master the practical or drawing skills. It is true that practical works are neither preparing students to become experts in drawing or AutoCAD design, nor to prepare them to become skill workers, but for them to encounter the basic skills as a foundation in mechanical engineering fields are still committed with time. The ministry of education in the curriculum specification has provided the ideal time for practical work 4 to 5 hours per week, but this study has indicated that the majority of students has experienced practical between 2 to 3 hours per week. This lack of time is due to the limitation that mentions earlier and overlap of timing for other subjects that the students have to undergo.

- Allocating time to introducing the concepts of sciences which are required during the practical work, but the study does not suggest how best to structure the practical activities themselves to meet the learning objectives (Abrahams and Saglam, 2010).
- The implementation of practical work in Physics for three different countries (Finland, Germany and Switzerland) has found that the allocation of time for practical work is varied for each country based on the objectives and profoundly influenced by the teacher (Johannes and Peter, 2014).

- Students should experience practical activities in at least half of their science lessons. The half of the total time spent on the subject should be practical work is referred to the half of the lesson should feature practical activities (Hofstein, 2004).

2. A recommendation to the challenges in the school factors

School factor is the second aspect of the Dynamic Model of Education Effectiveness that included only two aspects which are the school policy and the evaluation of the school policy. Different from the education policy, school policy is related to decisions and rules responsible by the management team of school. The policies in school have determined how to spend the allocation of a budget, which area of teaching to prioritise and the focus of preparing the material to maximise outcome from the students. The facilities in technical schools have remained the same since 1994, and from observation, the current condition showed that most of the equipment is not well monitored. 80% of the teachers suggested that besides the curriculum, the facilities and tools also need to be upgraded and aligned with current technology so that it is up to standard. All the equipment for practical work needs to be up to date including the interaction with new inventions and innovations.

i. Upgrade the facilities and equipment in mechanical engineering workshop

The factors at the school level have both direct and indirect effects on students' achievement since they can influence not only the performance of students but also the teaching and learning process. In this case, it is evident that the school factor has a certain influence on the effectiveness of practical work in technical schools (Kyriakides and Creemers, 2008).

- The responsibility of the government is providing supportive ambience for schools to implement the practical task (Holman et al., 2017).
- It is the responsibility of the government to provide sufficient training to all teachers, prepare the teaching and learning tools and manage the equipment for effective teaching and learning environment (Leonidas, 2010).

ii. Improve the technology and internet connection

The internet connection is another problem that needs extra attention in technical schools and the feedback from teachers has suggested to reconsider the current internet provider. Observations have found the limited access to the internet while each teacher provided with a smartphone and tablet for teaching. Current offline application occurred in technical schools did not support the mechanical engineering subjects, especially in practical work elements. The teacher has to use the online service to demonstrate most of the activities example the use of a machine and new technology related to practical work for form 4 and form 5.

- The limitation of the internet connection has led to the delay or incomplete of the demonstration and the teachers and students sometimes has to use their private line to search for the information. The disadvantage of using a private line is the teachers have less control over what students would search on the internet. This factor appears to become a problem in managing the activities, while the school in the school policy should provide all the technology needed in the teaching and learning process.
- Current research on practical work in secondary education has emphasised the utilisation of technology in the implementation of practical work (Dintsios et al., 2018; Jones and Stapleton, 2017).

3. A recommendation to the challenges in the teacher factor

This study concludes that an effective teacher is one of the important aspects of reducing the understanding gap among students in doing practical work. The factors of the Dynamic Model of Education Effectiveness also showed that teacher factor is one of the most critical elements in effective STEM education (Gudrun et al., 2016). It showed in the observations where students' performance in completing the practical task is significant to the how comprehensive the explanation of instructions from the teacher at the beginning of the session. Questioning technique is one of the critical aspects of this research where the author found its significant in influence the teachers teaching styles, student's acceptance and the address of curriculum objectives for each class. Another component which appears relevant is their management of time where the teachers conducted the practical work session with all the limitations.

i. Emphasise the questioning technique

This study indicated the strength of technical teachers emerged from their questioning technique. This factor is closely related to their experience in teaching this subject. This study has indicated the more experienced teachers, the better questioning technique they have compared to the fewer experienced teachers.

- A study on the impact of Singapore teacher experience on questioning techniques indicated that the more experienced a teacher is, the more equipped they are to ask students high-order questions (Wang et al., 2017).

- Research on teachers believed, indicated the teacher’s cognition is also affected by their experience. These factors may explain the relatively good correlation between teachers experience and their expertise in teaching practical work (Pham and Hamid, 2013).
- In similar area linking practical work in sciences with the construct to prepare for the best practical science are the teachers’ expertise, the good lessons plan and the technical support (Holman et al., 2014).
- The teacher can educate students and help them to critically think while partaking in practical work, rather than directly following their teacher’s instructions (Abrahams, 2009).

ii. Continued development through teacher training

Teacher training is part of professional development for teachers in improving their practical skills and is considered a critical aspect that this study found the ministry have neglected. This study indicated that the technical teachers had not been provided with any training for teaching practical work for more than five years. Even though all of the teachers have been trained with the knowledge about the content in mechanical engineering subject during their degree in education training, and the curriculum has not been reviewed since the continuity of instruction is essential to update current teacher knowledge to the technology or work demand that have changed over time. There are several training programmes in the engineering education field that would be convenient for mechanical engineering teachers at technical schools. This study suggested the training includes the elements which help to implement practical work in the domain of idea as suggested in the previous study as follow;

- Most practical lessons were conducted within the domain of observables and thus missed the opportunity to develop a conceptual understanding of the students (Abrahams and Millar, 2008).
- Another reason for the conduction of the domain of observables is the misconception from the teachers. The teachers assumed that by exposing the students to the phenomena in the domain of observables would automatically lead to them developing the explanatory concepts in the domain of ideas which is not proven to work that way (Philip and Taber, 2015).
- Research emphasised the importance not only of recruiting expert teachers but in developing their expertise through Continuing Professional Development (Miller et al., 2017).

iii. Placement of teaching assistants

The issue derives in the teacher factor in this study is the teachers' workload limits them from fully implementing practical work in technical schools. The structures of teaching and learning process are exceptional, but the application does not fulfil these plans. The insufficiency of human resources in conducting practical work in engineering and education sparked contempt in teaching circles for several years. Additionally, this study identified the needs of teaching assistants in practical work for Mechanical Engineering Studies in both workshops and AutoCAD lab. The capacity of work that they receive at the moment requires most of their time, energy and ability compared to the workload that they had 20 years ago when they started to teach this subject. The situation has become more challenging and demanding which causes a limitation of implementing practical work. The author suggested that an increase in resources needs to be enforced to ensure the effectiveness of practical work (which is supposed to be the responsibility of the Ministry) as an immediate action.

- Providing technical support for Practical Science has been agreed to save the teachers' time and improves Science Department morale (Akuma and Callaghan, 2017).
- The position of technicians in schools, and allowing them to work directly with students in the laboratory, they get involved in the STEM Clubs, aid students and help them to get the most out of school projects (Bell, 2015).

This study suggested that the practical work should have support by technician and attention should be given regular opportunity to have professional development similar to the teacher. Mechanical Engineering Studies practical work involve direct engagement with metal, tools, equipment and sharp material, so it is important to have the technician or the workshop as assistant to monitor and prepare the materials so that teachers can focus on carrying out frequent and efficient practical work for an engineering study.

- There is a different way of preparing technical support for the successful implementation of practical work. A study in Finland, Germany and the USA indicated all of these countries have no technician in the lab. The students clean up the place at the end of the lesson, and as a matter of routine it can teach students how to dispose of the materials safely and at the same time give them the available skill to work in the industry in the future (Holman et al., 2017).
- The study in Finland has revealed that teachers have been paid extra to cover the time needed to prepare experiment, order the material and maintain the equipment in a way this is the cost to pay for the technician (Borrego and Bernhard, 2011).

- In the USA where they centralised the teaching area by keeping the tools in a box scheme, and the school prepare a mini prep roll for the teacher to use in teaching practical work without living there class (Schwichow et al., 2016).

4. A recommendation to the challenges in student factor

The findings in this study show that the number of female participants involved in this studies is smaller than the male, which is just 26% (n = 68) female students and 30% (n = 3) female teachers. Even though the ratio between female and male students is 1:3, the female students comply with the practical tasks and provide a high quality of product and design. Additionally, informal interviews with the students during the practical work session observations found that female students face no difficulty in doing practical work and the male students cooperate well with their female friends.

- The study in gender equality showed that between 2010 and 2011, women in the UK remained under-represented in engineering and technology where only 15% of undergraduates were in the in engineering fields and 6.3% of engineering professionals (Powell, 2012).
- Other research in seven countries has stated that the women in engineering represented by a small percentage. It is a maximum of 28% and a minimum of 11% in Germany and Austria (Kadirgan, 2011).
- The current study on gender in STEM showed a substantial difference in the number of young women compared to men in selecting their career as a mechanical engineer (Margaret and Kimberley, 2018).

Another focus regarding gender balance among the participants is to explain the difficulties faced by the female students in conducting the practical task for mechanical engineering subject that dominant by a male. The results of this study do not explain the occurrence of these adverse events where the author, the teachers and students agree that the quality of practical task from a female student is the same as the male students. According to the teachers, there is no obstacle for female students to experience practical work since the curriculum has been customised to counter both male and female equalities. It seems possible that these results influenced by the participants involved in this study which are the secondary education students where the curriculum of engineering is less difficult yet still prepared the students for the transition to tertiary level.

- The gender gap is significantly decreasing as girls consistently outperform boys in many subjects including engineering (Education Performance and Delivery Unit, 2016).

- Female students in speciality areas which are most popular for females had more masculine perceptions of engineers than men did in those specialities and females in other specialities (Perez-Artieda et al., 2014).
- Students engagement-based learning in a practical work environment supported effective and permanent learning, developed science process skills, communication skills and self-learning planning skills, and it promoted motivation and an active learning environment (Tatar and Oktay, 2011).

This study acknowledges the importance of curriculum content to drive students to feel engaged with Mechanical Engineering as a subject by their experience of practical work sessions. In order to develop the engagement, practical work should familiarise students with the latest technology. This study suggested that students engage with the technology while doing practical activities in order to increase their capability in learning engineering subject. This factor has influenced students to enjoy the practical session, and using technology can increase their determination to complete the task within the time given.

- Practical work as it engaged and provided the students with real-life and genuine hands-on experiences while students can also acquire knowledge and experiences actively via individual or collaborative work (Chen, 2014).
- Despite the limitation of a slow internet connection in technical schools, this study suggested a mechanism for teachers to monitor the use of gadget in the classroom, especially to search for information regarding practical work. This approach needs teachers to be a good moderator to direct students to use technology effectively in the teaching and learning process (Jones and Stapleton, 2017).
- Students should be encouraged to search for information about the materials that they have used during preparing for the project work and design (Li, 2012).
- Multiple approaches for connecting early interest in and the pursuit of STEM careers included project-based and hands-on learning that involved personal and real world relevance that offered in engineering education (Knezek, 2015).

This study also indicated that most of the students are highly interested and motivated in experience practical work. The findings from this study showed the students' motivation and interest in practical work in engineering education highly influenced by their time spent doing practical work inside or outside the formal education in technical schools.

- The students' motivation is correlated with their interest where the specific practical task could generate student interest and engagement in particular lesson. It was a mirror to the students' motivation toward particular subject which could sustain by experience the practical work (Sellami et al., 2017).

- Factor initiated to influence students' interest toward STEM subject is the time they spent on the subjects (Krapp, 2005).
- The more students spend to experience and practice, the more interest they get from their field (Martindill and Wilson, 2015).

All of these factors concluded that the level of effectiveness in certain technical schools in which student factor closely related to the other three effective factors (teacher, school and education system). It showed that time allocation for practical work strongly linked to the facilities provided in the mechanical engineering workshop which is therefore associated with the teacher monitoring skills regards to complement each other.

6.4 Contributions to the body of knowledge

This study provides five original contributions to the body of knowledge in engineering education which are;

i. The development of the table of degree of adverb in this study as a medium to convert the statement from interview and observation into the score which can be analysed quantitatively. This table also allowed the formulation of the level of effectiveness that can be used consistently to evaluate the effectiveness of curriculum objectives. The system includes the combination of all qualitative and quantitative approaches and statistically generate the mean that explains the level of effectiveness for each of the curriculum objectives. This system can accommodate a complicated (qualitative and quantitative) data transmitted from the SPSS and NVivo as it is designed to support these two software concurrently. The system might benefit the government in addressing the quality of the curriculum with the involvement of limited time and resources. This is the main contribution in this study which introduced the thematic codes analysis for assessing the curriculum objectives and successfully generated the level of effectiveness.

ii. This study adds to the understanding of the effectiveness of practical work in achieving the curriculum objectives for secondary mechanical engineering studies at technical schools in Malaysia. This study has developed the initial approach to evaluate the effectiveness of the practical work which addressed all elements and sub-elements in the curriculum objectives. The approach is useful to the Ministry of Education, especially for the curriculum developer and the policy maker in assessing the outcome of the written curriculum objectives. It provides a comprehensive report to the Ministry of Education

Malaysia about the implementation of practical work in the technical schools and the challenges faced by the teacher (since the ministry conducted no observations in technical schools in the past five years). This intensive evidence-based report also addressed the limitations in conducting practical tasks in all technical schools where the outcome suggested the improvement of current technical school and to upgrade the engineering education at the secondary level.

iii. This study contributes to the complement of the curriculum development cycle (evaluate the curriculum objectives) where in a certain period, the curriculum should be evaluated before it could be reviewed. This approach helps the ministry to categorise the curriculum objective into five levels of effectiveness and plan for the upcoming action accordingly. This new understanding should help the curriculum developer to improve predictions of the impact of practical work in engineering education and at the same time assists the Ministry of Education to evaluate the outcome of the curriculum objectives more holistically by using this systematic approach of curriculum evaluation. The main focus is to determine the effectiveness of all the elements in the curriculum objectives which not measured through terminal examinations (the combination of the cognitive and affective domain).

iv. This study provides the first comprehensive calculation of the students and teachers perspectives of practical work in engineering secondary education. This study is the first on Mechanical Engineering subject which evaluate the effectiveness of practical work in achieving the curriculum objectives that apply the triangulation of methods for data collection and mixed methods of data analysis in generating the results. The findings indicated useful in expanding our understanding of how the effectiveness can be classified using triangulation methods of data collection. The mixed method analysis undertaken here has extended our knowledge of evaluating the domain of affective in the curriculum objectives that not significant to be evaluated in written examinations, for example, the element of interest, values and motivation. The development of the statistical system can calculate the mean of a score for the specific curriculum objectives.

v. This study contributes to the new knowledge in practical work at the secondary level as this study is the first worldwide that focused on engineering education. Even though the research on STEM education is well established, this research is the first to investigate the effectiveness of practical work in achieving the curriculum objectives and the first to use the method of triangulation to calculate the effectiveness. This study has also acknowledged the international perspectives on practical work in secondary education that might be useful to help the ministry in adapting the information to improve the current curriculum. This study has highlighted the importance of practical work in engineering studies which would reflect the performance of engineering curriculum in the Malaysia Education Blueprint 2013-2025, where the focus is to enhance the quality of STEM education including the practical work as a major element in most STEM curricula.

6.5 The implication of the study

The findings from this study would make several implications to the current education principles in the development of the engineering curriculum, teaching practice, engineering knowledge and method of evaluating the effectiveness.

6.5.1 The implication to the curriculum development

i. Upgrade version of curriculum

- It is believed that technical schools may find it helpful to have a review of Mechanical Engineering curriculum since the current curriculum in secondary engineering education has been practised for the past 24 years and has not been reviewed since.
- From this study, 80% of teachers suggested that it is about time the curriculum should change to become more aligned with the technology and industry.
- The demand for mechanical engineering fields has improved, and the preference is mostly different from 24 years ago when this curriculum was first developed.
- The design of the curriculum specification for Mechanical Engineering Studies showed that practical work elements consist of 60% of the total curriculum content.

ii. Evaluation methods

- This study found the importance to give a specific allocation of marks to the practical work project work since too much effort has been nailed on the task by the students. The results of this study have statistically demonstrated the effectiveness of practical work in achieving all curriculum objectives which indicated the importance of practical work in engineering education.
- The assessment system in Malaysia has influenced the way of teaching to become exam oriented rather than outcome-based education. Through the findings of this research, the author would suggest the government needs to introduce the new arrangement for practical engineering education assessment at the secondary school level.
- The assessment should put into consideration the performance of students in their practical task, the projects that they have created, the creativity and the problem-solving skills that they have acquired while participating in practical work.

- This study has provided the evidence for evaluation of the affective domain which is highly important to assess the effectiveness of the curriculum. It indicated an alternative solution to evaluate the affective domain in the curriculum objective beyond examination alone. The assessment of this domain was rarely discussed in previous research which made this method a genuine contribution to the evaluation of the affective domain.

6.5.2 The implication to the teaching practice in Mechanical Engineering Studies

i. Class control and workshop safety

- This study suggested the allocation of teaching assistant for engineering subjects to overcome the limitation in achieving the quality of teaching in technical schools.
- The teaching assistant works to help students with AutoCAD and to handle engineering material or utilised engineering tools in the workshop which requires extra monitoring, especially toward safety. It is also mentioned by the teachers who assert that there need to be at least two members of staff for every practical class in order to have effective classroom control.
- During observations, the author found that class control in the practical work session is the primary element that can be improved upon because it is related to the safety not only of the students but also the teachers and the working area more generally. One teacher cannot monitor the progress of an individual while they are continually moving around the workshop trying to facilitate and encourage student' activities.
- This study suggested that engineering teachers and technicians should adopt a balanced and proportionate approach to managing risks and be supported by school management in doing so (especially when it related to practical work).
- The precautions of action that teachers applied during the teaching process of practical work is to ensure that the session is successful in achieving its objectives. These actions mean that the workload of the teacher is extended greatly over their teaching time. It also contributed to the reason for insufficient students time spent on practical work (see 5.2.3). The amount of time that is taken to enforce health and safety regulations, as well as the preparation of the workshop, makes it very time-consuming.
- In comparison to laboratory work in the Sciences, every lab has an assistant. So the role of teachers in the practical work session for science subjects is to deliver the knowledge and focus on the successfulness of teaching and learning process, not to prepare the tools and materials, or to monitor the surrounding safety issues in the workshop.

- This issue is crucial since this study came across a few minor accidents happened to the students during a practical work observation, (example in form 4 practical work, there are few times students unintentionally cut their finger by a metal plate). It is the outcomes of a lack in monitoring the safety attire that students should be wearing while doing the tasks, and since the teacher has no assistance in the workshop, he/she has to move around almost all the time to correct the student's mistakes, resulting in overlooked on some action.

ii. Time management

- This study has indicated that the actual implementation of the mechanical engineering curriculum practical work is between 20% and 30%. This percentage included, the practical activities in the AutoCAD lab, outside the classroom and in the workshop. The duration of practical work included the preparation process, the conduction of teaching and learning practical work and the follow up of the practical work activities after each lesson.
- The other aspect that this study indicated is the condition of most mechanical engineering workshop is unmanaged because the teacher has insufficient time to take care of the workshop alone. Teachers at technical schools have to teach the minimum of 29 hours formal session per week, and they also have to perform with other curriculum and co-curricular activities related to students at the informal education time.
- Teachers are expected to deliver knowledge to help students to complete their tasks. It puts much pressure on the teacher and at the same time intimidated students from the support that they need. For the 40 minutes of a practical task, teachers took approximately 30 minutes to prepare the materials before the lesson and another 20 to 30 minutes after the practical work sessions to replace the tools in the workshop.

iii. Equipment and teaching materials

- Based on observations, the main constraints in technical school is to implement practical work is insufficient equipment in the workshop. In this case, this study suggested the technical schools for upgrading the facilities and technology.
- Every topic should have its practical work, and the government should prepare equipment for this task, especially the AutoCAD design. They also suggested the change from the dependency to a traditional textbook to the user online note.
- Most of the teachers suggested on an upgrade of the facilities and technology in mechanical engineering workshop because of the time change, the industry move and the education should remain relevant over time to accommodate the transition. Secondary engineering

education is the best time to start introducing the current technology in the mechanical engineering field to students.

- A majority of teachers requested that they want to add more tools, equipment and machines in the workshop so that students do not have to share and wait for their friends to use the tools. The more implementation of the practical task allowed within the time given if the tools in the workshop are sufficient for every student.
- They also requested the upgrade of the AutoCAD and installation of the latest versions of the software. The used of social media platform in teaching and learning like sharing teaching note via telegram, show a demonstration from YouTube and preparing portal for easy access of mechanical engineering sources for all members can be fully utilised if the internet connection is stable in the technical schools.

iv. Professional development

- The findings in this study have acknowledged the suggestion to develop the Continuing Professional Development for practical work because the feedback from teachers during interviews showed that even after initial training, teachers need to have their subject knowledge updated.
- The training is vital to find new ideas for practical activities in order to sustain their confidence as well as their skills and knowledge. Continued short courses for teachers specialising in practical work might help teachers to ascertain and enhance their skills.
- The specific trainings require for pedagogical development are the teacher teaching orientation, how they structure the session, the modelling technique they adopt, the application they use, their questioning technique, their assessment toward their practice, their management of time and how they sustain the classroom as a learning environment.
- A lengthy, intensive course is unnecessary as this would mean that teachers would have to leave the school for quite some time but the effectiveness of training is important to generate the quality of teaching as inspired by the Ministry in the blueprint and to prepare teachers with significant skills in order for them to deliver the knowledge to students.

6.5.3 The implication to the knowledge in engineering education

- The current situation in technical schools requires the ministry and schools to collaborate to determine the priority of learning that they want students to experience.
- The universities should get involved in providing a place for technical schools students to get the training they require and to practice using equipment in the workshop for practical

work. This effort is achievable by agreement between the ministry of education, the industries and the local universities.

- This type of collaboration is bridging of the gap between schools and work, demanding to prepare students from technical schools for a further career in engineering industries.
- In interview sessions, 80% of teachers have suggested that the continuity of the learning among mechanical engineering students needs to improve by giving them extra training to enhance the practical work skills even after they finish their studies in technical schools. This duration is where the transition from the secondary to tertiary education and the opportunity for students to establish mechanical engineering practical skills.
- The collaboration should provide a supporting programme that can improve the limitation from the previous practice to prepare them for their future in engineering fields.

6.5.4 The implication to the method of evaluating the effectiveness

- The approaches suggested in this study would provide holistic action for government to evaluate the effectiveness of the curriculum.
- It would help the curriculum developer to change the way of evaluating the effectiveness of curriculum objectives by providing a systematic indicator to calculate the level of effectiveness.
- Continues monitoring for the implementation of practical work has to be done to ensure that it meets the expectations and produce the outcomes that have been outlined in the curriculum objectives.
- This study suggested that the ministry needs to review and monitor the allocation of time for practical work in technical schools, so that is consistent with a written curriculum, and provides enough time for teachers to deliver the practical work in a more effective timeframe.

6.6 Reflection on limitation in this research

The outcomes from this research are the development of the approach to determine the degree of effectiveness for practical work as one of the elements in the teaching and learning to engineer for secondary education. Even though this research has achieved the purposes and has answered all the research questions, the author acknowledges there are four limitations and difficulties while conducting the research. These barriers, to a certain extent, have impacted this research and provided a different experience for the author in completing the whole process, especially with regards to data collection and the data analysis. Despite its limitations, this study certainly adds to the author’s understanding of the implementation of research in schools that involve the schools' policies towards students and teachers. Thus, the challenges faced by the author are as follows;

i. Cooperation from teachers and school management to observe the practical work lesson should be improved in the future by the direction from the ministry and more open acceptance by the schools. The process for data collection brought the author to attend all the technical schools in Malaysia, somehow, the process of bureaucracy in the education system has delayed out the data collection process for certain reasons. One of the challenges was to meet the mechanical engineering teachers for the first time and for them to allow the recorded conversation about their teaching practice. This difficulty led to the modification of interview questions several times. The practical work session observations also have undergone few times reschedules according to teachers' availability. This action is due to the order from the ministry and schools that the researcher is allowed to approach the participants only during their free time. Due to that, this data collection process took much more time than the author anticipated. It would have been much more beneficial for the author's research if schools allowed more access to classrooms and were able to refer to the educational documents and communicate with participants frequently. This limitation has led to adjustments of research design, and the author had to accommodate to this situation with the philosophy of this research. The stance on the axiological consideration that this research has outlined since the beginning which is the flexibility and fairness has allowed the success on most of the data collection process.

ii. The more participants to inform the practical work in technical schools would help the author to establish a higher degree of accuracy in determine the level of effectiveness. The limitation of participants in this study regarding the setting of the research within three years still represents the total population of the mechanical engineering committee at technical schools. However, interviewing and observing students from different backgrounds is preferable and might contribute to the normal distribution of data in the future. By increasing the number of participants in the study, it allowed the opportunity to perform a more accurate statistical test, and therefore, the information about the implementation of practical work in schools would be more fruitful. Similarly, further research to apply and assess the use of the table of degree of adverb in generating the mean for mixed method studies for a different and bigger number of participants should be carried out in the future. It is important to test the efficiency of the table of converting a qualitative statement into numerical code in mixed method data analysis using a wide range of participants.

iii. This study is neither explicitly designed to investigate the students' understanding (effectiveness Level 2) toward mechanical engineering by experience the practical work, nor to test their competency in this subject before and after their experience with practical work. The main idea is to get the students' and the teachers' perspectives on practical work, then triangulate these with the observations for each element in achieving the curriculum objectives. It is undeniable that a greater focus on the student assessment process of practical work could produce interesting findings and might encounter more important aspects of practical work in engineering education. It is difficult in Malaysia context at the moment because no specific assessment has been conducted to evaluate the practical work. In the future, the author is interested in investigating the effectiveness of practical work based on the students' performance in the specific assessment. It is going to bond with certain criteria, require specific instruments and a different set of research which is more time-consuming.

iv. The translation process for interview sessions has been highly challenging because the word choice in the Malay language is sometimes difficult to translate to English. Plus, some words have more than one meanings, and therefore, the interpretation is important to provide the correct score by referring to the table. Despite its weaknesses, this table of degree of adverb also has a strength - this table is considered the first indicator to convert the statement into a score and calculate using the formula. On the other hand, it also takes a considerable amount of time for the author to translate and transcribe all the interview and observation notes. This process is very time consuming, but the author feels that the extensive time spend translating has provided extra and accuracy and depth to their project. The development of the table of degree of adverb helps the author to determine the most suitable words to be used in the translation, while then the words have been validated by the second and the third reader. The author would suggest the development of the table of degree of adverb in the same language that has been used for participant interviews since it will be even more reliable.

6.7 Further research recommendations

Based on the results of this study, there is five area of further research that could be undertaken. The suggestions for further research include the continuity of study in other related fields of science and engineering which can integrate a similar method of investigation. The recommendations are as follows:

i. To study the effectiveness of practical work in achieving the curriculum objectives for Science subjects such as Physic, Chemistry and Biology as well as Technology based subjects such as Information Technology, and Engineering subjects. A greater focus on these STEM subjects could produce interesting findings that consider the investigation into the effectiveness of practical work in achieving the curriculum objectives including the other two main engineering fields which are Civil Engineering and Electrical Engineering. The study would investigate the level of effectiveness using a similar approach with different subjects to evaluate the curriculum objective and help the curriculum developer to improve the practical work for that particular subject.
ii. Further research could also be conducted to investigate the level of effectiveness of other elements in teaching this subject which is the theoretical and mathematical elements (rather than practical work) in achieving the curriculum objectives for engineering education. It should be conducted using the same triangulation methods with a different focus. The combination of these elements allowed more efficient evaluation of the overall implementation of Mechanical Engineering Studies in the classroom in comparison to what is currently written in the curriculum specification. This approach also would open a broader discussion on the comparative level of effectiveness among these three elements (practical, theoretical and mathematical) in the achieving the curriculum objectives.
iii. What is emerged from this study is there is a lack of clarity about the relationship between the implementation of practical work and students' performance. This study suggested that further research is undertaken to ascertain whether there is a direct correlation between the effectiveness of practical work and the student's measurable output regarding mean or frequency. More broadly, research is also needed to determine the relationship between the implementation of practical work and the students' performance in STEM education in extending the findings from this research toward the effectiveness of the practical work into students' performance. The idea is to measure the domain of idea instead of the domain of observable in the related practical based subject in secondary education.
iv. Further research should be carried out to establish the evaluation and testing of the use of the table of degree of effectiveness. A mixed methods studies that implement the data transformation process from a qualitative statement to numerical score that can be analysed quantitatively. In addition, the re-testing and revision of the table of degree of adverbs in necessary to increase the reliability. It is also suggested that this table is adopted in other mixed method studies to statistically evaluate and classify the level of effectiveness of any aspects or component in the curriculum development process. These tables can also be

translated according to the research participants' language and would use as an indicator in given any 5 Likert scores to a statement.

v. Considerably more work will need to be pursued to determine the effectiveness of practical work regarding different levels of education to investigate the difference between practical work in primary, secondary and tertiary education. It is a bigger scale of research that will include a much broader range of participants in the broader contact than the Malaysia education system as it also applicable in other countries which share similar education context. This study is where the continuity level of effectiveness can be determined, by a comparative study that allowed the Ministry to view the effectiveness of practical work on a bigger scale. This type of study would provide a significant impact on planning engineering education in the early stages of education. It would require a group of researchers with substantial funding as it would involve a collaboration of participants from different levels of education and would, therefore, require much more time for data collection as a considerable amount of data analysis.

6.8 Chapter summary

This chapter has discussed the suggestions of each factor to improve the practical work in achieving the curriculum objectives and link the findings to the research questions. In Malaysia, this is the situation that currently happens, and the author acknowledges the previous research on practical work in achieving curriculum objectives for STEM education worldwide. The main contribution of this study is the evidence for the effectiveness of element in the curriculum which can be determined and categorised by calculation for the curriculum improvement. This study also provided the first comprehensive assessment of the practical work in achieving curriculum objectives based on one of the major elements in the curriculum which is the practical work. From the findings, this study suggested that the triangulation of methods used for this study to determine the level of effectiveness of practical work for engineering education in Malaysia applies to other subjects elsewhere in the world. Consistent with the literature, this research found that the practical work was highly effective in achieving curriculum objective 1 (assisting students to understand the terminologies, process, and procedure) and was highly effective in achieving curriculum objective 3 (creating interest in the field of mechanical engineering). It was highly effective in achieving curriculum objective 6 (encouraging students to apply safety). Despite all the limitations during the data collection and the data analysis process of mixed methods, this study has successfully achieved its fundamental objectives and answered all the research questions. The author is pleased to present the findings of this study to the Ministry of Education Malaysia with regards to their perusal and forthcoming action for the improvement of all the technical schools and the engineering curriculum.

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APPENDIX

Appendix 1: Questionnaire

UNIVERSITY OF
LINCOLN

Confidentiality

The information you provide will be kept strictly confidential. To protect your privacy, your responses to this questionnaire will only be identified with a code number and will be kept in the Faculty of Education, University of Lincoln. All project materials will be kept for three years after the study has ended, and will be accessible only to members of the research team. You do not have to write your name. The information obtained in this study may be published in scientific journals and presented at professional meetings, but only group patterns will be described, and your identity will not be revealed.

Your Right to Refuse or Withdraw

The decision to participate in this research project is entirely up to you. You may refuse to take part in the study. You may also choose not to answer any question in this document.

Your Right to Ask Questions

You have the right to ask questions about this study and to have those questions answered by any of the study investigators before, during or after the research. If you have any other concerns about your rights as a research participant that has not been answered by the researcher, you may contact the Faculty of Education, University of Lincoln United Kingdom.

What to expect from this study

With this questionnaire, I would like to get information about the effectiveness of practical work in achieving curriculum objective for Mechanical Engineering subject. It consists of 6 items in Section I and 30 items in Section II. It is important that you answer these questions on your own because I am interested in *your* preference in practical work for Mechanical Engineering Studies as you experienced. Please do be honest on what you are answering because it will end up as a result of improving the Mechanical Engineering Studies in the future. If you do not understand a certain question, please do not hesitate to ask me.

Thank you in advance for your cooperation.

Researcher: Suhaiza binti Zainuddin (PhD Student)
Phone: 017-6909405, Email: szainuddin@lincoln.ac.uk

Section I : Personal Information (*Please tick one*)

1. What age are you?

   16 ☐
   17 ☐

2. Gender:

   Male ☐
   Female ☐

3. How interested are you in Mechanical Engineering?

   High Interest ☐
   Moderate Interest ☐
   Low Interest ☐

4. How many hours do you normally spend on Practical Work in Mechanical Engineering Studies per week (inside and outside schedule)?

   1 hour or less ☐
   2-3 hours ☐
   4-5 hours ☐
   6-7 hours ☐
   More than 7 hours ☐

5. Do you feel motivated doing practical work in Mechanical Engineering Studies?

   Yes ☐
   No ☐

6. Do you enjoy doing the Practical Work element in Mechanical Engineering Studies?

   Yes ☐
   No ☐

Section II :

- Read each question carefully, and pick the answer you think is best.
- Fill in the circle next to question.
- If you decide to change your answer, draw χ through your first answer, like this ⊗. Then, fill in the circle on your new answer.
- Ask for help if you do not understand something or are not sure how to answer
- *Fill **one** circle for each line*

	By doing practical work, I am **able** to:	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
1.	identify the terminologies in Mechanical Engineering	1	2	3	4	5
2.	interpret the terminologies in Mechanical Engineering	1	2	3	4	5
3.	define the concept/principle in Mechanical Engineering	1	2	3	4	5
4.	explain the concept/principle in Mechanical Engineering	1	2	3	4	5
5.	distinguish the fact in Mechanical Engineering	1	2	3	4	5
6.	relate the fact in Mechanical Engineering	1	2	3	4	5
7.	list the process in Mechanical Engineering	1	2	3	4	5
8.	explain the process in Mechanical Engineering	1	2	3	4	5
9.	recall the procedure in Mechanical Engineering	1	2	3	4	5
10.	discuss the procedure in Mechanical Engineering	1	2	3	4	5
11.	apply knowledge of mechanical engineering	1	2	3	4	5
12.	form rational opinions pertaining to problems related to mechanical engineering	1	2	3	4	5
13.	use the computer effectively	1	2	3	4	5
14.	use engineering tools effectively	1	2	3	4	5
15.	utilise machines in engineering effectively	1	2	3	4	5
16.	utilise workshop equipment effectively	1	2	3	4	5

		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
17.	develop creative thinking through intellectual activities	1	2	3	4	5
18.	demonstrate creative thinking through practice	1	2	3	4	5
19.	develop creative thinking through hands-on work	1	2	3	4	5
20.	solve problems related to mechanical engineering field	1	2	3	4	5

By experience practical work, I **believe** I am:

21.	interest in the field of mechanical engineering	1	2	3	4	5
22.	manage to meet the demands of a career in the mechanical engineering field	1	2	3	4	5
23.	preparing myself to become an engineer in the future	1	2	3	4	5
24.	cooperate well in a team	1	2	3	4	5
25.	aware of my own safety	1	2	3	4	5
26.	responsible for my own safety	1	2	3	4	5
27.	aware of my friends' safety	1	2	3	4	5
28.	responsible for my friends' safety	1	2	3	4	5
29.	aware of the workplace's safety	1	2	3	4	5
30.	responsible for the workplace's safety	1	2	3	4	5

- **End of the questionnaire and thank you for your time** -

Appendix 2: Interview Questions

(*Duration: 35-45 minute after practical work session*)

Teacher background information

1 What is your education background?

2 How long have you been teaching this subject?

3 How do you feel about teaching this subject?

4 What are the challenges you have faced in teaching this subject?

The interpretation of curriculum objectives

5 What is your opinion of the curriculum as a whole?

6 What is your interpretation of the curriculum objectives?

7 What is the knowledge that you expect the student to learn from practical work?

8 In general, what are your goals for your students when looking at the curriculum?

Teaching Techniques and Pedagogy

9 What technique do you think is the most suitable for teaching practical work?

10 How do you choose the approach to apply in teaching practical work?

11 How do the students respond to this teaching approach?

12 To what extend the approach is effecting students learning?

Teaching and Learning Outcomes (Cognitive Domain) I

13 What is your learning expectation from students after practical work?

14 Do you expect students to understand the terminologies concept/principle/fact/process after doing practical work? Why?

15 Do you expect students to remember the procedure? Why?

16 Do you think students can apply knowledge from doing practical work?

17 How do you think students will apply the knowledge they learn by doing practical work?

18 What kind of problems solving skills do you expect from students during practical work?

19 Which part of practical work can promote creative thinking among students?

Teaching and Learning Outcomes (Effective Domain) I

20 Do you think that practical work is effective in promoting students interest in the field of mechanical engineering?

21 Do you agree that by doing practical work students manage to meet the demands of a career in the mechanical engineering field?

22 Why yes/ why not?

23 Do you agree that practical work prepares students to become a better engineer in the future?

Other supporting factors

24 What would the staff, students, and parents say to be the strengths of the subject?

25 How does the school support professional development?

26 Do you have any support group program among peers?

27 How do you integrate technology into the classroom/ workshop?

Lesson Reflections

28 How do you feel after the practical work sessions?

29 Did the curriculum objectives achieve? If not why?

Teaching and Learning Outcomes (Cognitive Domain) II

30 Do you see that students generate rational opinions after experience practical work?

31 Do the students use the computer effectively after practical work session? How?

32 Can the students handle engineering tools correctly after doing practical work?

33 Can the students utilise the used of machines/workshop equipment after doing practical work?

34 Does practical work promote creative thinking among students? How?

35 Do practical work train students for problems solving skills? How?

Teaching and Learning Outcomes (Effective Domain) II

36 Do you realise that students cooperate well in a team by doing practical work?

37 Do you realise that students aware and responsible for their own safety by doing practical work? How?

38 Do you realise that students aware and responsible for their friends' safety by doing practical work? How?

39 Do you realise that students aware and responsible for the workplace's safety by doing practical work? How?

General Reflections

40 What is the thing that you really want to improve in the future on curriculum related to practical work?

41 Why do you want to improve that particular thing?

42 How are you going to improve it?

Appendix 3: Observation Outline

	What to focus during observations	How to observe	Notes
1	Teacher teaching style	Introduction to topic explanation to students Teaching approach use	
2	Workshop management	Workshop environment (clean/organise) Preparation and planning	
3	Teacher present correct terminology/concept	Teacher's explanations	
4	Student use correct terminology/concept	Students' respond Workshop report	
5	Teacher show the correct procedure	Teacher's command Refer to textbooks/other sources	
6	Student apply the correct procedure	Students' works	
7	Student give an opinion and rational	Students' opinion/ While answering questions	
8	Teacher promote the real demand in the engineering field	Give some idea about the real application in engineering fields	
9	Student show interest in doing practical work	Students' body language / facial expression/	
10	Teacher promote creative thinking among students	The way the teacher asking questions Higher order level of questions	
11	Student produce idea or product in a creative way	Project work/ product	
12	Student show creativity in activity	The way student create something/ think out of the box	
13	Teacher guide student to use computer/workshop equipment	Teacher shows the correct guidance/ demonstrate the use of computer/ workshop equipment effectively	
14	Student can use computer effectively	Students' work by using computer/ design/ information search	
15	A student can use workshop equipment effectively	Students' performance in using workshop equipment	
16	Teacher prepare the cooperative environment	Task divide/ encourage for discussion/ Teacher give praise/	
17	Student show cooperation/ teamwork	Classroom interactions / discussion / working in group	
18	Student aware and apply safety procedure	Student wear safety shoes/ suitable outfit/goggles/glove ask the student about the safety procedure that they aware	
19	Teacher promotes problem-solving skill environment to student	Ask students to solve problem / provoke some tricky questions	
20	The student can solve the problem during activity	How students solve the problem/ how students react to the problem/	