EXPLORING THE EFFECT OF AN INTEGRATED STEM-BASED WATER ROCKET MODULE ON STEM ELEMENTS APPLICATION IN A SELECTED SCIENCE SCHOOL: A CASE STUDY

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SULTAN IDRIS EDUCATION UNIVERSITY

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This declaration is made on the 6th day of July 2021

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I, NUR ROSLIANA BINTI MOHD HAFIZ, M20181001134, FACULTY OF SCIENCE AND MATHEMATICS hereby declare that the work entitled EXPLORING THE EFFECT OF AN INTEGRATED STEM-BASED WATER ROCKET MODULE ON STEM ELEMENTS APPLICATION IN A SELECTED SCIENCE SCHOOL: A CASE STUDY is my original work. I have not copied from any other students' work or from any other sources except where due reference or acknowledgement is made explicitly in the text, nor has any part been written for me by another person.

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I ASSOC. PROF. TS. DR. SHAHRUL KADRI BIN AYOP hereby certifies that the work entitled EXPLORING THE EFFECT OF AN INTEGRATED STEM-BASED WATER ROCKET MODULE ON STEM ELEMENTS APPLICATION IN A SELECTED SCIENCE SCHOOL: A CASE STUDY was prepared by the above named student, and was submitted d to the Institute of Graduate Studies as a full fulfillment for the conferment of DEGREE OF MASTER OF EDUCATION (PHYSICS) and the aforementioned work, to the best of my knowledge, is the said student's work.

August 16th, 2021

Date

Signature of the Supervisor

ACKNOWLEDGEMENT

What started this journey in the first place was my thirst for knowledge. Little did I know that the journey would not be as easy as it looked. Embarking on this journey has made me realize that each knowledge contained within a book is the product of someone's hard work. Now, I finally understand the true value of knowledge and hard work. The body of knowledge that existed in the world today is the result of the dedication of many, not from a single entity. In the end, I have gained knowledge through a similar fashion, from the dedication of countless individuals around me.

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I am indebted to the Educational Planning and Research Division, Education State Department, Wilayah Persekutuan Kuala Lumpur Department of Education, and Science School Management Division and the School of Excellence, for granting the permission to conduct both my pilot and field studies in the selected school in my studies. My gratitude also goes to all the principals from the two science schools in Kuala Lumpur, the teachers in charge, and the pupils' participants from three secondary schools that had given a total commitment during the study. To all the pupils especially, thank you for willing to participate in the research. Without your commitment, such endeavour would never be possible.

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ABSTRACT

The aim of the study is to develop an integrated STEM-based water rocket module, known as SEMARAK (SElangkah Menuju Angkasa RAya Kita) and explore its effect on STEM elements application in a selected science school. The study was divided into two stages, namely the module development stage and the module effect study. Sidek Module Development Model (SMDM) was used in the first stage. The module development stage involved validity evaluation by seven STEM subjects' experts. A pilot test was conducted for reliability evaluation on a group of Form Three pupils (the first batch undergoing the Kurikulum Standard Sekolah Menengah (KSSM)). In the second stage, a single-case embedded case study was conducted to explore SEMARAK's effect on STEM elements application. Representatives from eight subgroups among 32 Form Four participants from a science school in Kuala Lumpur were selected as respondents. Data were collected using document analysis and observation based on criterion rubric. These data were triangulated with pupils' activity record and semi-structured interviews. Findings showed that SEMARAK had excellent validity value for face (S-CVI/Ave=1.00), content (S-CVI/Ave=0.95), and activity (S-CVI/Ave=1.00). SEMARAK also had excellent reliability (α=0.94). In terms of STEM knowledge, SEMARAK encourages the application of STEM concepts such as force, pressure, trigonometry, and others. Most of the representatives managed to obtain at least 80% for STEM skill (62.5%) and STEM value (75.0%) based on the provided rubric. However, accepted positive responses on STEM skill and value from the journal and interview were low, indicating low STEM skill and value awareness among the subgroup representatives. In conclusion, a validated and reliable module was successfully developed to encourage STEM elements application. SEMARAK has positive effects on STEM elements application among its targeted pupils. This study implies that a systematically developed module can encourage STEM elements application among pupils via water rocket activities.

MENEROKA KESAN MODUL ROKET AIR BERASASKAN STEM BERSEPADU KE ATAS PENGAPLIKASIAN ELEMEN STEM DI SEBUAH SEKOLAH SAINS TERPILIH: SATU KAJIAN KES

ABSTRAK

Kajian ini bertujuan untuk membangunkan modul roket air berasaskan STEM bersepadu yang dikenali sebagai SEMARAK (SElangkah Menuju Angkasa RAya Kita) dan meneroka kesannya ke atas pengaplikasian elemen STEM di sebuah sekolah sains terpilih. Kajian ini dibahagikan kepada dua peringkat iaitu peringkat pembangunan modul dan kajian kesan modul. Model Pembangunan Modul Sidek (SMDM) telah digunakan pada peringkat pertama. Peringkat pembangunan modul melibatkan penilaian kesahan oleh tujuh pakar mata pelajaran STEM. Kajian rintis telah dijalankan untuk penilaian kebolehpercayaan ke atas sekumpulan murid Tingkatan Tiga (ambilan pertama Kurikulum Standard Sekolah Menengah (KSSM)). Dalam peringkat kedua, kajian kes jenis kes tunggal terbenam dilaksanakan untuk meneroka kesan SEMARAK ke atas pengaplikasian elemen STEM. Wakil daripada lapan kumpulan dalam kalangan 32 murid Tingkatan Empat dari sebuah sekolah sains di Kuala Lumpur telah dipilih sebagai responden. Data telah dikumpul melalui analisis dokumen dan pemerhatian berpandukan rubrik kriteria. Data ini diselaraskan (triangulasi) dengan menggunakan rekod aktiviti murid dan temubual separa berstruktur. Hasil dapatan menunjukkan bahawa SEMARAK mempunyai kesahan muka (S-CVI/Min=1.00), kesahan kandungan (S-CVI/Min=0.95), dan kesahan aktiviti (S-CVI/Min=1.00) yang cemerlang. SEMARAK juga mempunyai kebolehpercayaan yang sangat tinggi (α=0.94). Dari segi pengetahuan STEM, SEMARAK menggalakkan aplikasi konsep STEM seperti daya, tekanan, trigonometri, dan lain-lain. Kebanyakan wakil kumpulan berupaya memperolehi sekurang-kurangnya 80% untuk kemahiran STEM (62.5%) dan nilai STEM (75.0%) berdasarkan rubrik yang diberikan. Walau bagaimanapun, penerimaan maklumbalas positif terhadap kemahiran dan nilai STEM daripada jurnal dan temu bual adalah rendah, menunjukkan kesedaran kemahiran dan nilai STEM adalah pada tahap rendah dalam kalangan wakil kumpulan. Kesimpulannya, modul yang mempunyai kesahan dan kebolehpercayaan telah berjaya dibangunkan untuk menggalakkan pengaplikasian elemen STEM. SEMARAK memberikan kesan positif terhadap pengaplikasian elemen STEM dalam kalangan murid yang disasarkan. Kajian ini menunjukkan bahawa modul yang dibangunkan secara sistematik dapat menggalakkan pengaplikasian elemen STEM dalam kalangan murid melalui aktiviti roket air.

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LIST OF ABBREVATIONS

STEM	Science, Technology, Engineering, and Mathematics
T & L	Teaching and Learning
MOE	Malaysian Ministry of Education
KSSM	*Kurikulum Standard Sekolah Menengah* (Standard Secondary School Curriculum)
KSSR	*Kurikulum Standard Sekolah Rendah* (Standard Primary School Curriculum)
KBSM	*Kurikulum Bersepadu Sekolah Menengah* (Secondary School Integrated Curriculum)
OECD	The Organization for Economic Co-operation and Development
PISA	Programme for International Student Assessment
PjBL	Project-Based Learning
PBL	Problem Based Learning
EDP	Engineering Design Process
CLT	Constructivist Learning Theory
ELT	Experiential Learning Theory
SLT	Situated Learning Theory
CVI	Content Validity Index
I-CVI	Item Level Content Validity Index
S-CVI	Scale Level Content Validity Index
SPSS	Statistical Package for the Social Sciences

ICC	Intraclass Correlation Coefficient
SMDM	Sidek Module Development Model
SEMARAK	*Selangkah Menuju Angkasa Raya Kita*

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter describes the background of the study, which aims to develop an integrated STEM-based water rocket module that can encourage Science, Technology, Engineering and Mathematics (STEM) elements application among Form Four pupils.

The Malaysian Ministry of Education (MOE) has outlined an ideal STEM teaching and learning (T&L) that involves pupils applying STEM elements. The STEM elements are knowledge, skill and value. However, there seems to be a disconnection between this ideal STEM practice and implementing water rocket activities in schools.

Water rocket activities are among the most popular activities to be organized as a part of the STEM education programme. The pupils' achievement will usually be determined by the rocket's performance. The terminal assessment creates a disconnection between the ideal instructional practice for STEM outlined by MOE and water rocket activities.

Hence, this chapter features the overall outlook of the study carried out by the researcher to address this problem. The research background, problem statement, aim, objectives, research questions, hypothesis, significance, limitations, framework, and the operational definition for various research variables are described in detail in this chapter.

1.2 Research Background

STEM education is among the main highlights in the Malaysian Education Blueprint (MEB) 2013-2025. STEM education reform in Malaysia aims to be among the top 20 countries globally in terms of economy, citizen well-being, and creativity and innovation under the 2050 National Transformation (TN50) initiative. It is estimated that 493,830 scientist and engineers are needed to fulfil this vision (Ministry of Education Malaysia, 2013b). Incorporating STEM education in the current education system will ensure that there will be an adequate number of certified and skilled STEM workforces in the future. However, a certified and skilled STEM workforce must be endowed with STEM literacy of knowledge, skill and value, apart from possessing academics qualifications.

In Malaysia, the current curriculum and teaching and learning (T&L) approach is developed while considering integrating STEM in education. In the current curriculum, STEM-based subjects are offered to all levels in schools. The STEM stream in several packages is offered as a pathway for upper secondary pupils. The STEM stream allows the upper secondary pupils to enrol themselves in learning more focused STEM subjects. To achieve that, MOE has outlined a STEM T&L approach that aims to enculture STEM practice among Malaysian citizens. The model for the STEM T&L approach in Malaysia is as illustrated in *Figure 1.1*.

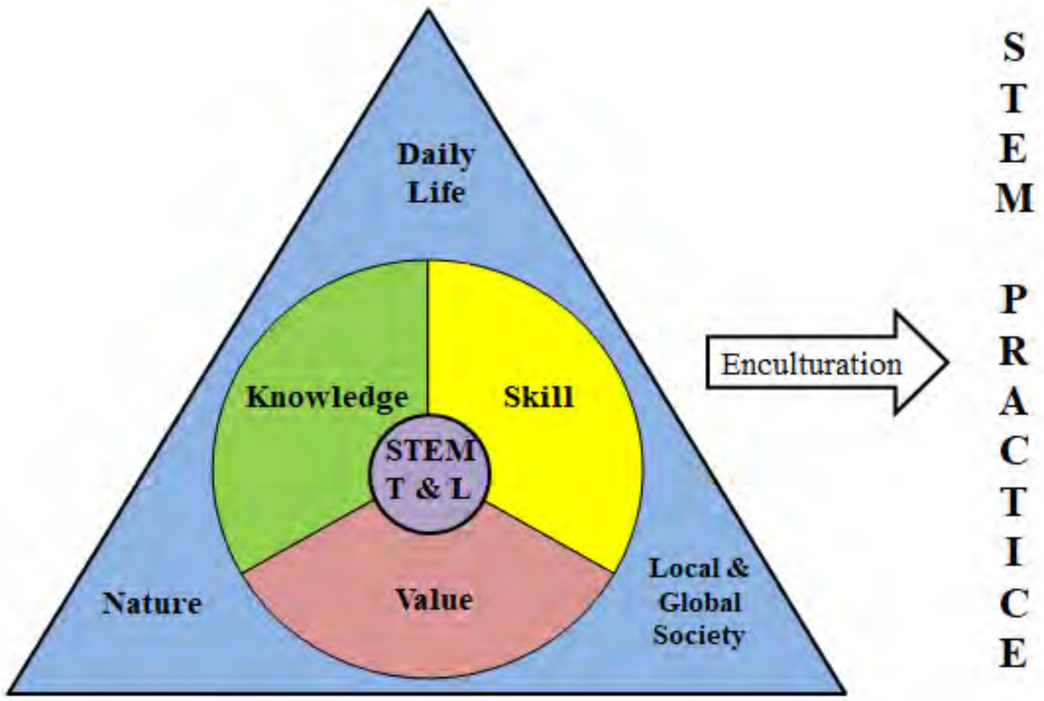

Figure 1.1. STEM T&L Approach. Source: Curriculum Development Division Ministry of Education Malaysia (2016a)

According to this approach, the instructional strategy used to teach STEM subjects should prompt pupils to apply three STEM elements of knowledge, skill, and value to solve daily life problems, local & global society and nature (Curriculum Development Division Ministry of Education Malaysia, 2016a).

Additionally, the MOE has outlined the seven characteristics of STEM T&L to guide STEM teachers in achieving the aim of STEM education. The T&L characteristics are as shown in *Figure 1.2*.

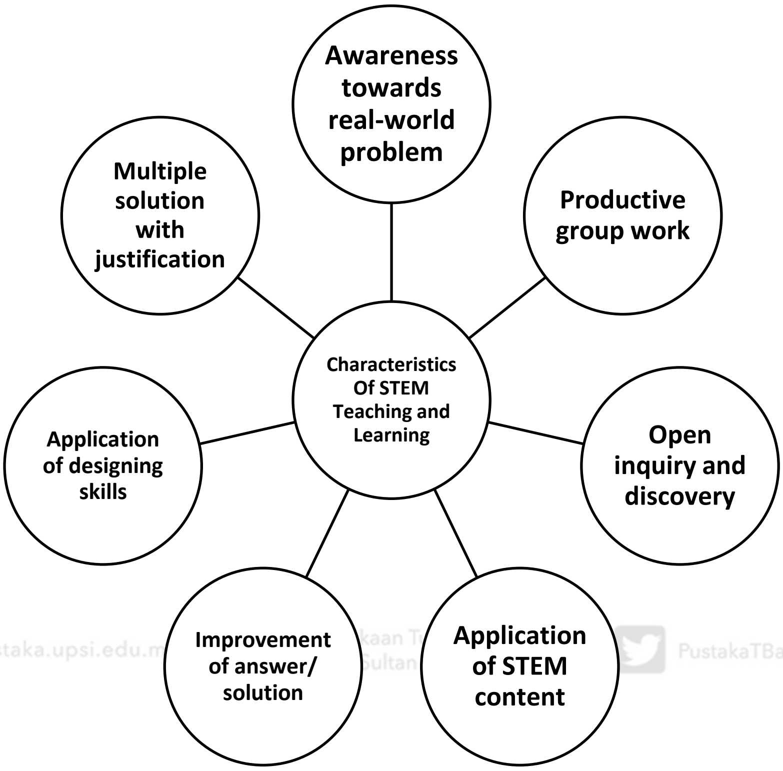

Figure 1.2. Seven Characteristics of STEM T&L. Source: Curriculum Development Division Ministry of Education Malaysia (2016)

Recent researches on STEM education has referred to STEM as integrated STEM (Estapa & Tank, 2017; Jayarajah, Saat, & Rauf, 2014; Kelley & Knowles, 2016; Mustafa, Ismail, Tasir, & Mohamad Said, 2016; Rasul, Zahriman, Halim, & Rauf, 2018; Shernoff, Sinha, Bressler, & Ginsburg, 2017). The term was used to highlight the act of combining several STEM disciplines in the research.

As an additional effort to enculture life-long learning towards STEM literacy, MOE also introduced a conceptual framework, as illustrated in *Figure 1.3*, showcasing the ministry's different efforts in promoting STEM based on educational level. For upper secondary level pupils, MOE's effort focuses on STEM implementation effort that enhances STEM skill. Hence, the STEM-based activity that targets Form Four pupils should focus on the efforts that will enhance the pupil's STEM skill. At this level, Form Four pupils should be given the opportunity to demonstrate STEM concepts at an advanced level (Ministry of Education Malaysia, 2015).

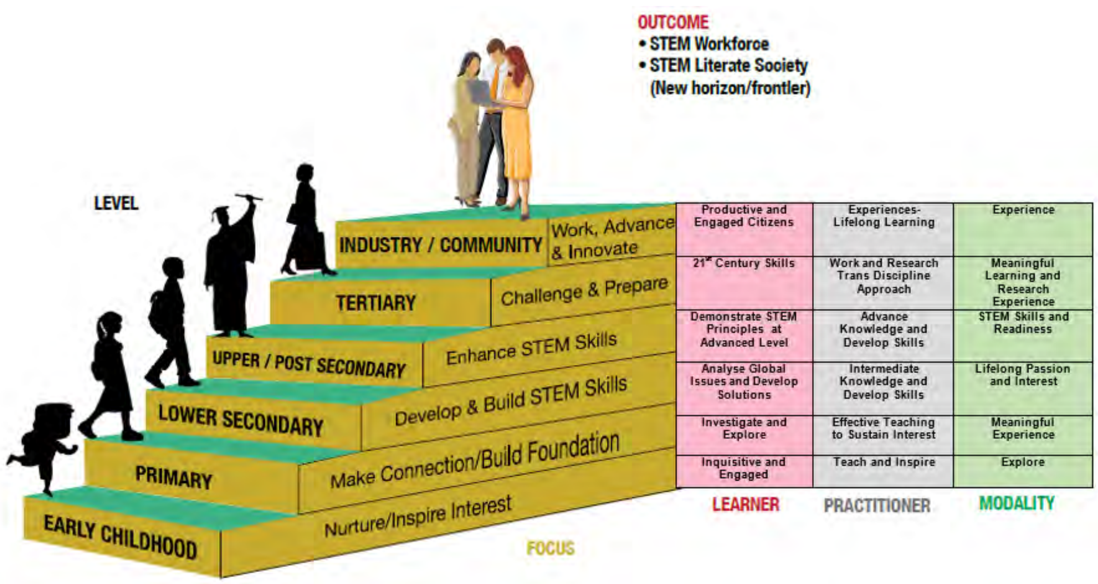

Figure 1.3. Malaysian STEM Education Conceptual Framework.Source:Educational Planning and Research Division in the Ministry of Education Malaysia (2015)

Additionally, as a part of the STEM education initiative, MOE also stresses the importance of pupils' involvement in non-formal and informal STEM education (Ministry of Education Malaysia, 2013b, 2018a). Water rocket activities are among the popular activities to be organized as part of this initiative, besides robotic and F1 car in Malaysia. Water rocket activities are popular in STEM-based competitions due to their potentials, especially in engaging and encouraging the pupils to learn science concepts

(Yang & Houston, 2016). Through water rocket activities, pupils can obtain first-hand experience on the science concept in action, thus enhancing their understanding. Moreover, water rocket can increase pupils' interest in science and engineering (Takemae, 2009) and enhance learning motivation (Pitriana, Agustina, Zakwandi, Ijharudin, & Kurniawan, 2018; Saunders-smits & Kat, 2009).

Additionally, water rocket activities are ideal to be a platform for STEM disciplines integration. Constructing a water rocket model requires the pupils to plan, design, test, analyse, and redesign, which allows for the possibility of STEM disciplines integration (M. L. Hortman, 2017). The STEM knowledge in water rocket is not restricted only to science concept but mathematical concepts as well (Yang & Houston, 2016). Momentum, Newton's law of motion, pressure, trigonometry, ratio and proportion, and mathematical reasoning are among the science and mathematics concepts that can be cross-connected in water rocket activities.

Among the advantages of organising water rocket activities are its low operational cost, low safety risk, and ease of making and testing (Tomita et al., 2007). The usage of polyethylene terephthalate (PET) bottles for soft drinks, cardboard and other reusable materials to construct a functional water rocket can also promote the idea of reusing unwanted materials to save the environment. In terms of the pupils' professional development, the water rocket allows the pupils to experience real rocket engineers working environment since the working principle is similar to real rockets (Ishii, 2006).

Pupils' achievement in water rocket activities is highly dependent on the final performance of the water rocket constructed. Among the most common indicator of success for water rocket activities is the ability of the rocket to reach the targeted distance, to land in the designated landing zone, to spend the longest time on-air, and to keep the payload safe (Omri et al., 2018; Planetarium Negara Malaysia, 2018). Although new categories of performance are added to water rocket activities, such as oral presentation and water rocket innovation (Omri et al., 2018; Planetarium Negara Malaysia, 2018), pupils' achievement in water rocket activities is not based on the pupils' STEM knowledge, skill and value application.

Implementing the ideal instructional strategy for STEM that uses the right approach can be difficult, especially in non-formal learning activity such as water rocket. Existing teacher incompetence (Abd et al., 2020; N. F. Ramli & Talib, 2017) and shortages of resources for STEM (Curriculum Development Division Ministry of Education Malaysia, 2016b; Khalid et al., 2019; Siew et al., 2015) are among the hindrances for the practice of an ideal instructional strategy in teaching STEM subjects, as well as in water rocket activities.

There is a lack of systematically developed resource that STEM teachers can use for water rocket activities. Furthermore, the available guides do not explicitly include the current KSSM curriculum's learning standards or are not developed based on the Malaysian curriculum. The resource also utilizes STEM T&L that is different from the ideal STEM T&L outlined by MOE, whereby the resource practices: (1) the T&L approach that minimally prompts the application of STEM knowledge, skill and value; (2) a minimum number of STEM T&L characteristics and; (3) unclear integrated STEM disciplines; and (4) unsuitable activities to promote STEM among Form Four pupils. In essence, there is a lack of available resources to guide an ideal water rocket activity for Malaysian pupils.

Similarly, the same issue related to the implementation of water rocket activities is also experienced by pupils in science schools. Science school is a school that is categorized under a fully residential school system. Other types of schools that are placed under this system are premier schools, integration schools, and federated Islamic schools. There are 69 fully residential schools in Malaysia, with 44 schools being categorized under science schools (Ministry of Education Malaysia, 2021c). Science schools were first established under the New Economic Policy (NEP) to cater to the Malaysian science and technology workforce needs (Ministry of Education Malaysia, 2021b; Phang et al., 2014). All the residential schools are under the purview of the Residential School and Excellent Schools Management Division Ministry of Education Malaysia. Among the objectives of this division is to offer STEM field elective subjects for school pupils that produce high-quality future scientists and professional technocrats (Ministry of Education Malaysia, 2021a).

In terms of the water rocket competition at the national level, residential schools' performance, particularly science school, does not stand out. In the past five years, only one integration school from Johor had managed to win any top spots in any national-level water rocket competitions. Most of the top spots were occupied by pupils from regular daily schools. In the first-ever STEM carnival organized by the Ministry of Education in 2018 that featured prominent non-formal STEM activities, most of the competitions were also dominated by pupils from regular daily schools (Ministry of Education Malaysia, 2018b). Overall, science schools exhibited unremarkable performance in competitions related to water rocket activities at the national level.

However, in terms of STEM subjects' performance, science schools are well-known for their excellence.

1.3 Problem Statement

STEM education aims to enculture STEM among pupils (Curriculum Development Division Ministry of Education Malaysia, 2016a). STEM enculturation can be achieved by STEM practice in which STEM knowledge, skill and value application become a part of the pupils' lives. Hence, among the effort carried out by MOE is introducing a STEM T&L approach that provides the opportunity for pupils to apply STEM elements during STEM subjects' lessons. It is not surprising that teachers highly anticipate the availability of resources that can aid STEM T&L.

However, in reality, these ideals are far from being achieved for STEM resource and STEM element applications among pupils, especially in Malaysia. In terms of resource, Malaysia experiences a lack of valid and reliable STEM T&L resources such as guidelines, models, modules and reference materials for primary and secondary schools (Curriculum Development Division Ministry of Education Malaysia, 2016b; Ismail & Mohamad, 2017; A. A. Ramli et al., 2017; Siew et al., 2015). This shortage is most evident in the availability of standardized instruments to evaluate pupils' performance and attributes for STEM (Margot & Kettler, 2019). STEM learning outcomes are typically evaluated using standardized achievement tests on a single discipline that does not include the full range of integrated STEM experiences (National Academy of Engineering and National Research Council, 2014). This practice is demonstrated in a study done by Meng & Idris (2016), whereby Malaysian pupils felt that their understanding and skill regarding engineering design were given the least attention in STEM subjects' assessment. Furthermore, the shift of curriculum from KBSM to KSSM caused the currently available resource to become obsolete.

In addition, Malaysian pupils' STEM elements application ability is still low, which is supported by various facts. In terms of STEM knowledge application, only 2% of Malaysian pupils could use mathematics in problem-solving strategies, and only 1% could creatively apply science knowledge in various situations (OECD, 2019a). At the national level, the inability of Malaysian pupils to apply STEM knowledge was also reported by a study by Hung et al. (2013). In the study, it was reported that the school pupils ability to apply physics concepts were low. Similar findings were found in a study carried out by Theng & Kassim (2009) in which pupils ability to apply the acid-

base concept in daily life were also found to be at a low level.

In terms of STEM skill application, several studies reported unsatisfactory level of various skills such as computational thinking skill, science process skill, mathematical process skill and designing skill among school pupils. In Malaysia, the pupils' computational skill was observed to be at a low level (Ling et al., 2017; Wei, 2020). This problem directly results from the lack of exposure given to Malaysian pupils either by teachers or reading resources (Wei, 2020). Furthermore, the exposure to computational thinking skill is also limited to specific subjects (Mohd Kusnan et al., 2020). Pupils level of science process skill is only at a satisfactory level, with several skills that the pupils have not mastered (Kiang & Sangguro, 2015).

In terms of STEM value, Bajuri et al. (2017) reported that creativity among Malaysian boarding school pupils in physics is still low. In the study, the researchers suggested that more effort should be introduced to achieve 100% excellence with creativity among school pupils. Creativity will help improve STEM subject learning achievement among pupils, as there is a significant relationship between creativity and learning (Bajuri et al., 2017; Shukri et al., 2020). The low level of creativity among pupils was caused by the lack of value given to pupils' creative ideas while given limited opportunity to experience activities that require creative application in classrooms (Bozkurt Altan & Tan, 2020).

As an implication, these problems have contributed to several issues that are highly interconnected with one another. For instance, pupils' application of STEM elements is highly dependent on the teacher's STEM T&L approach. The lack of resource causes teachers to teach using teacher-centred approaches. They are not confident to carry out more holistic learning such as project-based learning (N. F. Ramli & Talib, 2017; Siew et al., 2015), engineering and technology-infused STEM learning (Bunyamin, 2017; A. A. Ramli et al., 2017) and integrated STEM learning (Estapa & Tank, 2017; Kelley & Knowles, 2016; Ling Chia & Maat, 2018) . Hence, the pupils were not given ample opportunities to apply STEM elements. As a result, STEM subjects learning become less attractive, and pupils become disinterested in the subjects. Maintaining pupils' interest is imperative, as interest in STEM subjects is closely related to the quality of subjects teaching and learning that the pupils have experienced (Shahali, Halim, Rasul, Osman, & Arsad, 2019). Consequently, traditional learning causes pupils to lose interest and confidence; thus, discouraging the pupils from choosing STEM as their future career choice. Ultimately, pupils' difficulty in applying STEM elements will cause the pupils to refrain from enculturing STEM in their daily lives.

Providing a valid and reliable resource for implementing a STEM T&L approach that leads to STEM enculturation among pupils is imperative. Such resources can aid teachers in practising the STEM T&L approach that provides the opportunity for pupils to apply STEM elements. Subsequently, STEM elements application among Malaysian pupils can be improved. However, attention should also be given to non-formal activity such as water rocket activities in developing such resource, as the activity is highly beneficial towards STEM learning (Bunyamin, 2017; M. L. Hortman, 2017; Pitriana et al., 2018; Saunders-smits & Kat, 2009).

As part of the STEM education initiative, water rocket activities are among the popular activities organized in Malaysian schools. All the problems discussed earlier are also prevalent in water rocket activities. There is indeed a lack of resource for this activity (refer to subsection 2.6.3, Water Rocket Module). In terms of STEM elements application, pupils tend to leave out STEM knowledge application in water rocket activities (Chue & Lee, 2013). The problem occurs as pupils participating in water rocket activities tend to focus on achieving the water rocket flight objective; set in the activity. This phenomenon is corroborated by the need assessment conducted in this research (see subsection 3.2.3, Conduct Need Assessment). Only four out of 50 STEM teachers with water rocket activities experience measured pupils achievement based on STEM knowledge application. Although 37 of these 50 teachers believe that STEM knowledge application should be the success indicator, only four teachers could organize water rocket activities with such an objective. This finding shows that STEM teachers are aware of the ideal practice for STEM. However, given the complexity of the STEM T&L approach, the teachers opted to stick to the conventional method.

The discussion above justified the need to develop a resource that can encourage STEM elements application for water rocket activities. Hence, this study aims to develop and explore the effect of an integrated STEM-based water rocket module. This module aims to encourage STEM knowledge, skill and value application among pupils. Most importantly, the module incorporates the current KSSM learning standards to create relevance between formal and non-formal learning. The module, *SEMARAK,* is also designed to adhere to the STEM T&L approach, characteristics of STEM T&L, and the type of STEM promoting effort for Form Four pupils outlined by MOE. The adherence is achieved by incorporating a systematic procedure of module development, ideal instructional strategies and learning theories. The module development will eventually help minimize the disconnection between water rocket activities and STEM elements application.

1.4 Rationale of Research

This research is carried out to develop and explore the effect of an integrated STEM-based water rocket module on STEM elements application. The developed module called *SEMARAK (SElangkah Menuju Angkasa Raya Kita* = A step toward our outer space) is an integrated STEM-based water rocket module. *SEMARAK* has been developed not for water rocket competition but for non-formal STEM learning that aligns with the current KSSM syllabus and the STEM T&L approach. The module aims to encourage STEM elements application by its users via water rocket activities. A case study was conducted to explore the effect of SEMARAK on STEM elements application in a selected science school.

1.5 Research Objectives

The objectives of this research are as follows:

1. to develop a valid integrated STEM-based water rocket module (*SEMARAK*) through systematic module development procedures.

2. to develop a reliable integrated STEM-based water rocket module (*SEMARAK*) through systematic module development procedures

3. to explore the effect of *SEMARAK* on the subgroup representatives in terms of STEM knowledge application

4. to explore the effect of *SEMARAK* on the subgroup representatives in terms of STEM skill application

and;

5. to explore the effect of *SEMARAK* on the subgroup representatives in terms of STEM value application.

1.6 Research Questions

Research questions are developed to acquire information related to the study and guide the direction of this study. The research questions for this study are:

1. What is the validity of the systematically developed *SEMARAK* module?

2. What is the reliability of the systematically developed *SEMARAK* module?

3. What is the effect of *SEMARAK* on the subgroup representatives in terms of STEM knowledge application?

4. What is the effect of *SEMARAK* on the subgroup representatives in terms of STEM skill application?

5. What is the effect of *SEMARAK* on the subgroup representatives in terms of STEM value application?

1.7 Research Framework

A research framework is a structure that depicts the support system used in the research in achieving the objectives.

1.7.1 Conceptual Framework

In an ideal STEM instructional practice, pupils are required to apply STEM elements of knowledge, skill and value (Curriculum Development Division Ministry of Education Malaysia, 2016a). Thus, a module for STEM should be based on this practice. However, to ensure that the module is of high quality and can fulfil the objectives set, the module must undergo a validity and reliability evaluation process (Noah & Ahmad, 2005). Considering both aspects, a conceptual framework for this study is developed, shown in *Figure 1.4*.

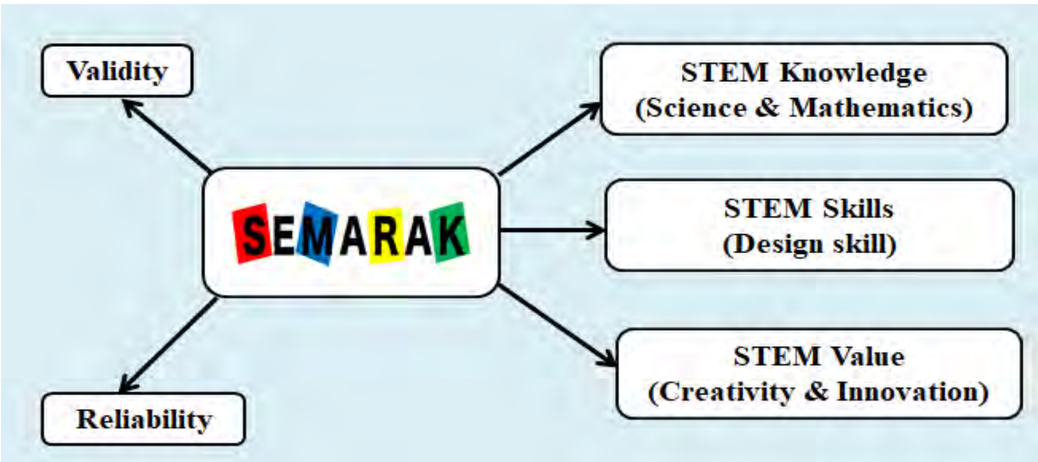

Figure 1.4. Conceptual Framework

The conceptual framework involves evaluating the validity, reliability and exploring SEMARAK's effect on pupils' STEM knowledge, skill, and value application. Nevertheless, in this research, a specific STEM knowledge, skill and value were chosen. Various concepts from the KSSM science and mathematics syllabus were chosen for STEM knowledge, design skill for STEM skill, and creativity & innovation for STEM value. The selection of STEM elements and concepts is based on the need analysis.

1.7.2 Theoretical Framework

Figure 1.5 shows the theoretical framework that was employed in the development of *SEMARAK*. The constructivist learning theory (CLT) was chosen due to its ability to provide an active student-centred learning environment. In this environment, pupils build new knowledge by actively constructing meaning from their experience and connecting it to their prior knowledge (Atasoy et al., 2011; Padirayon et al., 2019). Moreover, the CLT also helps to bring relevance to collaborative learning, where the theory stresses the importance of social interaction in pupils' learning (Hein, 1991; Wallace & Brooks, 2015). The prominence of this theory is evident, as this theory has guided many STEM education modules development, as will be discussed in subsection 2.3.1.

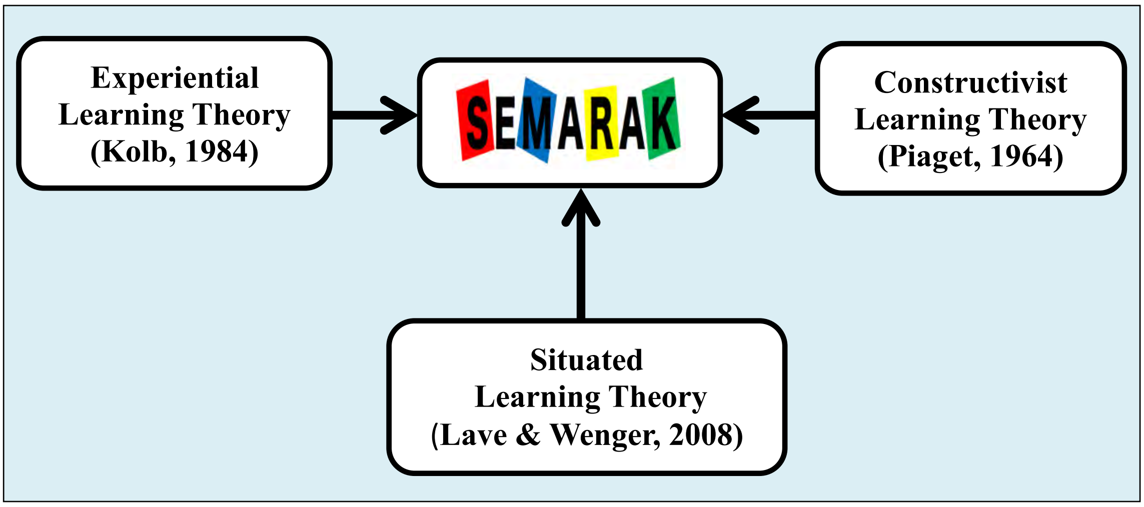

Figure 1.5. Theoretical Framework

On the other hand, situated learning theory (SLT) is introduced as an effort to understand and adopt features such as knowledge and socio-culturally strong foundations, including the linking of society and social capital to education, as recommended by (Thomas & Watters, 2015). The SLT helps ensure engagement in more complex tasks within social communities and authentic contexts of practice (Besar, 2018).

The idea proposed by Experiential Learning Theory (ELT) is also incorporated in the development of *SEMARAK* to ensure that the pupils will experience a complete cycle of learning that leads to skill and value enhancement. This theory stresses the importance of integrating total human traits such as thinking and behaving that can adapt the scientific method to everyday problem-solving, decision-making, and creativity (A. Y. Kolb & Kolb, 2009).

1.8 Significance of Research

This research involves exploring the effects of *SEMARAK* towards STEM elements application. The significance is discussed in the following subsections.

1.8.1 Knowledge

The outcome of this research is essential in providing the knowledge of how an integrated STEM-based module can be systematically developed. The knowledge procured in this research should be useful to other researchers and module developers. As many ambiguities surround integrated STEM, this research will shed some light on how the integrated STEM concept can be manifested in real situations. Furthermore, the researchers and the module developers can emulate the research framework, procedures, and models that have been applied in this research. Finally, the findings procured from this research would provide insight for researchers who wish to replicate this study in the future.

1.8.2 Activity

This research highlights the potential of non-formal STEM learning, specifically water rocket activities, in encouraging STEM elements application. Furthermore, the *SEMARAK* module provides a comprehensive guide on how water rocket activities can be carried out. This research's findings are significant for the Malaysian Ministry of

Education as it justified the need to continue organising water rocket activities as non-formal STEM intervention.

In terms of water rocket activities implementation, teachers, water rocket instructors, and pupils will significantly benefit from the product of this research. As water rocket activities are commonly organized as a competition, not all teachers and pupils are given the opportunity to experience it. As a result, some teachers might not have the proficiency to organize such an activity independently. The availability of activity guidelines in the module will provide the teachers with the knowledge and confidence to organize water rocket activities. In turn, more pupils will be allowed to experience water rocket activities and learn STEM concepts in a more engaging and fun way.

Lastly, the module can be utilized by water rocket activities instructors to encourage systematic documentation of water rocket flight data among participants. This practice would provide a valuable future reference for the best designs and conditions for a water rocket launch.

1.8.3 Instructional Strategy

This research will provide insights into the feasibility and benefits of utilising the engineering design process (EDP) as an instructional strategy. EDP as a learning strategy is not as popular as other instructional strategies such as inquiry-based learning, problem-based learning and project-based learning. By providing insight into how EDP can be utilized and its benefits, more information on EDP can be brought to light. This information will be significant for the Malaysian Ministry of Education to introduce EDP as an instructional strategy to teach STEM.

1.8.4 Assessment

Apart from the guides and reference, the module also includes instruments to assess all three STEM elements. The inclusion of the instruments should be significant to the pupils and teachers. The availability of these instruments would provide an opportunity for teachers to assess pupils fairly. Assessment on what matters in STEM can be carried out instead of taking water rocket flight performance as the indicator of success. The findings will provide an insight into the feasibility of STEM literacy to be assessed fairly in schools.

1.8.5 Curriculum

The main feature of the product from this is research is the alignment with the current KSSM syllabus. The syllabus covered in the module is mainly taken from the Form Four Science and Mathematics subject syllabus, as the module is dedicated to Form Four pupils. Form Four level is chosen as there is a limited number of Form Four resources (see 2.4.1, Module Development), as the KSSM syllabus has just been introduced in the year 2020. Hence, the inclusion of more of the Form Four STEM subject syllabus is a welcomed addition for Form Four Science and Mathematics subjects' teachers and pupils. Most importantly, the teacher can utilize non-formal learning to teach important science and mathematics concepts in the syllabus. The alignment of the product of this research with the curriculum would also benefit water rocket instructors. The instructors can use the module to ensure water rocket participants can master both the technical and academics aspects of water rocketry.

1.8.6 The Case

This research documented a case study of the effect of a module intervention on eight subgroup representatives in a science selected science school. The data collected from the subgroup representatives that function as embedded subunits provided various insights for the case (school). Among the insights that can be provided by the data collected are ; (1) the feasibility and benefits of water rocket activity towards pupils, (2) feasibility of STEM T&L approach, and (3) pupils' awareness of STEM.

The insights procured on the feasibility and benefits of water rocket activity will aid the school in determining whether to carry out water rocket activities using the conventional way or vice versa. Previously, a pupil's performance in water rocket activities was determined by water rocket flight. Similarly, as SEMARAK incorporates the STEM T&L approach, the research outcome can aid the school in deciding the best approach for STEM subjects to be taught in the school. Finally, the findings of this research will help the school tracks pupils' awareness of STEM. The school can discover whether the pupils are aware of STEM knowledge, skill and value that the pupils should be mastering.

In conclusion, the insight procured by the school selected as the case to be studied in this research are abundant, which will aid the school in making decision-related on STEM education policies in school. Most importantly, the research findings will determine how water rocket activities will be coordinated in the school onwards.

1.9 Scope of Research

This research involves collecting information on the effects of a systematically developed STEM-based module towards STEM elements application. The module, an integrated STEM-based water rocket module known as *SEMARAK*, was tested among Form Four pupils in a science school in Kuala Lumpur.

1.10 Limitation of Research

In this research, the developed module studied effect was limited only to Form Four pupils in a selected Science school in Kuala Lumpur. Form Four pupils were selected as the sample for this research because; (1) Form Four pupils in the year 2020 present a unique case to be studied, as the pupils were the first cohort to experience the newly introduced KSSM curriculum (SPI Bil 6 Tahun 2019 Pelaksanaan KSSM Menengah Atas Dan Pakej Mata Pelajaran Tahun 2020, 2019), and; (2) the lack of resources available to date for Form Four level (Refer to subsection 2.4.1 Module Development).

In terms of the type of school selected, science school is selected because it focuses on enhancing STEM enrolment among school pupils in Malaysia (Phang et al., 2014). Thus, it can be assumed that the pupils would already have the awareness and interest towards STEM, as they have chosen to be enrolled in STEM education-based schools. Naturally, science school pupils will exhibit excellent performance in STEM subjects (Bahagian Pengurusan Sekolah Berasrama Penuh dan Sekolah Kecemerlangan Kementerian Pendidikan Malaysia, 2017).

However, based on a study carried out by Bajuri et al. (2017), science school student's creativity in Physics concept application is at a low level. Most science school pupils have low ability in terms of idea originality (Bajuri et al., 2017). This phenomenon is evident in water rocket activities, whereby most of the national level winners of the activity came from regular daily school (Ministry of Education Malaysia, 2018b). This phenomenon shows that science school pupils also exhibited a typical disconnection between STEM element application and water rocket activities. Hence, science school was selected to be the focus of this research. More effort should be given to science school pupils to achieve 100% excellence in creativity (Bajuri et al., 2017).

Most importantly, the science school was selected for the research based on the objective, function and commitment of the Residential School and Excellent Schools Management Division Ministry of Education Malaysia (BPSBPSK) towards STEM education. As discussed in subsection 1.2, BPSBPSK is an organization that manages all the residential school, including science schools in Malaysia. Among the notable effort done by the organization was to coordinate the development of *Modul Multimedia dalam PdPC STEM Abad 21* (Ahmad et al., 2017) and organising annual STEM teaching and learning workshop for teachers (Bahagian Pengurusan Sekolah

Berasrama Penuh dan Sekolah Kecemerlangan Kementerian Pendidikan Malaysia, 2017).

Hence, two science schools in Kuala Lumpur were selected. One school was chosen for the module's pilot test, and the other for the module's case study. The two schools were chosen as the schools exhibited the typical disconnection in water rocket activities. Both schools have excellent performance in STEM subjects but unremarkable performance in the state or national level water rocket competition in the recent five years. Excellent performance in STEM subjects suggests that the pupils have a good command of STEM knowledge. Selecting both schools has helped the researcher explore the effect of the developed module on STEM elements application during water rocket activities. This aspect is crucial to the research, as the module aims to encourage the application of STEM elements.

Apart from that, the two schools were selected due to the commitment of the administrators towards STEM. The two schools were the joint host for the 2017 Residential School STEM Teaching and Learning workshop. The administrators' consistent commitments from both schools were further shown by the willingness to allow the research to occur. The administrators were willing to participate in the research, as the research includes the implementation of a STEM-based intervention. The school administrators were hoping the intervention would allow the pupils to apply the STEM elements that the pupils have acquired through school.

In terms of the number of samples, the module's effect on STEM elements applications was limited to eight. As the research involves developing and testing a new module, more in-depth data collection and analysis are required. The case study research design was utilized as the design allows more in-depth information to be collected (Gerring, 2004; Piaw, 2016; Vu & Feinstein, 2017). As case study research involves comprehensive data collection and analysis, employing a limited number of individuals as samples are is a more feasible option (United States General Accounting Office, 1990; Z. Zainal, 2007). Thus, only eight pupils who are the representatives from each group involved in the research were selected to be studied. The limited number of samples would allow for a more comprehensive data collection to take place.

As this research employed a single-case embedded designs (Type 2) case study (Yin, 2018), the eight subgroup representatives were the embedded units within the selected science school that act as the case for this research. Hence, the findings procured on the module's effect are only limited to the subgroup representatives upon which the case study was conducted.

1.11 Operational Definition

1.11.1 Validity

In this study, validity refers to the module's face, content and activity validity. Face validity is defined following the items featured in the adapted face validity questionnaires developed by Noah & Ahmad (2005) and the definition provided by Taherdoost (2016). In other words, face validity refers to the appearance of the module or instruments in terms of feasibility, readability, consistency, formatting, and the clarity of the language used.

On the other hand, content validity is defined based on the items featured in the adapted content validity questionnaires developed by Arip (2018) and the definition provided by Straub & Gefen (2004) and Saper, Ain, Daud, & Ahmad (2016). Hence, content validity refers to the accuracy of the module's content to the module's concept and the accuracy of instruments to represent the construct that it is supposed to measure.

Finally, activity validity is defined based on the items featured in the adapted activity validity questionnaires developed by Arip (2018). In this study, activity validity refers to how well the activities featured in the module can lead to the achievement of the module's objectives. The validity of a module refers to how accurate the content is to the concept of the module.

In this research, the module's validity was measured using evaluation questionnaires. Three different questionnaires, known as *Kesahan Muka Modul SEMARAK*, *Kesahan Kandungan Modul SEMARAK* and *Kesahan Aktiviti Modul SEMARAK,* were distributed among seven STEM education experts to evaluate the module in terms of the module's face, content and activity validity. The experts were given several 7-point items in each questionnaire to rate the module. The ratings given by each of the experts were used to calculate the content validity index (CVI). The value of Item Content Validity Index (I-CVI) and Scale Content Validity Index (S-CVI) were compared to the evaluation of I- CVI values provided by Polit, Beck, & Owen (2007). These evaluations were used to determine the developed module's validity.

1.11.2 Reliability

Reliability can be defined as the extent to which an instrument is giving consistent measure (Heale & Twycross, 2015). In this study, the module's reliability is determined based on its ability to fulfil its objectives across users consistently. Hence, to measure the reliability of the module, a questionnaire was administered to 34 pupils that were involved in the pilot test of the module. The questionnaire, known as *Soal Selidik Kajian Kebolehgunaan Modul SEMARAK* consists of several 5- point items. The ratings given by all the pupils were analysed to determine the internal consistency of the feedback by calculating its Cronbach's alpha value. Subsequently, the Cronbach's alpha value was compared to the evaluations of alpha value provided by George & Mallery (2003). The evaluation of the alpha value was used to determine the developed module's reliability.

1.11.3 STEM Knowledge Application

STEM knowledge is an idea, concept, principle, theory, and understanding in the STEM field that has been drafted in all STEM-related subjects' curriculum (Curriculum Development Division Ministry of Education Malaysia, 2016). In this research, STEM knowledge refers to any concept of science/physics and mathematics featured in the KSSM curriculum of any level.

STEM knowledge application in this research is determined using documents analysis. The subgroup representatives' written work in the Missions and Challenges in the module booklet were analysed for any mention or indication of any science/physics or mathematics concept applications. Any mention of concepts by the representatives is considered to indicate their ability in STEM knowledge application.

The feedback from semi-structured interview and the journal entry inside the module of the subgroup representatives were analysed to triangulate the findings procured from the document analysis. Similarly, the interview transcripts and the journal entry were analysed for any mention of any science/physics or mathematics concepts.

1.11.4 STEM Skill Application

STEM skill is the effectiveness or competency to discover, solve problems, design, and develop a product (Curriculum Development Division Ministry of Education Malaysia, 2016). In this study, STEM skill refers specifically to the design skill that pupils exhibit based on the Design Skill Rubric criteria either through displayed behaviour, writing, oral communication or water rocket construction. Design Skill was the skill selected by most STEM teacher respondents in Need Assessment (see subsection 3.2.3, Conduct Need Assessment).

STEM skill application in this research is determined by guided observations. A criterion rubric was used to guide the observations. The subgroup representatives' written work in the module booklet, work processes, and water rocket model crafted were observed and scored by the STEM teacher on duty based on the Design Skill Rubric criteria. The percentage of the total score attained is indicative of the subgroup representative's STEM skill application.

Furthermore, to triangulate the findings procured from the observations, the feedback from semi-structured interviews and the journal entry inside the subgroup representatives' module were analysed. The interview transcripts and the journal entry were analysed for any explicit mention of any skill and the criteria listed in the rubric.

1.11.5 STEM Value Application

STEM value is any positive attitudes or guidelines abided by any STEM pupil (Curriculum Development Division Ministry of Education Malaysia, 2016). In this study, STEM value refers specifically to creativity and innovation that pupils exhibit based on the criteria listed in the Creativity & Innovation Rubric either through displayed behaviour, writing, oral communication, presentation video/ E-Brochure crafted, or water rocket construction. Creativity & Innovation is the most selected value in the Need Assessment conducted (see subsection 3.2.3, Conduct Need Assessment).

STEM value application in this research is determined using guided observations. The observations were guided by a criterion rubric known as Creativity & Innovation Rubric. The subgroup representatives' written work in the module booklet, attitude displays, water rocket model created were observed and scored by the STEM teacher on duty based on the rubric. The percentage of the total score attained is indicative of the subgroup representative's STEM value application.

Similarly, to triangulate the findings procured from the observations, the feedback from semi-structured interviews and the journal entry inside the subgroup representatives' module were analysed. The interview transcripts and the journal entry were analysed for any explicit mention of any thinking or action that might indicate the application of creativity or innovation and the rubric criteria.

1.12 Summary

This research aims to explore the effect of a systematically developed integrated STEM-based water rocket module towards STEM elements application. The problems related to Malaysian STEM education extend not only to formal learning but also to non-formal STEM learning. The alignment of water rocket activities with the current KSSM syllabus should be considered to ensure that non-formal STEM activity goes hand in hand with formal STEM learning. Furthermore, water rocket activities outcomes should reflect the desired outcome of Malaysian STEM education. Hence, *SEMARAK* was developed with the highest commitment to adhere to the current KSSM curriculum, STEM T&L practice outlined by the Malaysian Ministry of Education, as well as providing the ideal assessment system. The research also strived to develop a high-quality module with the Sidek Module Development Model employment and several learning theories that complement STEM. This research will open more doors for more opportunity to explore the potential of *SEMARAK* towards encouraging STEM elements application among school pupils via water rocket activities. The following chapter discusses the previous research on integrated STEM modules development, theories, water rocket activities potentials and the variables involved in this research.