STEM Education in Malaysia: A Review

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Received first draft 30 November 2021. Received reports from first reviewer (14 February 2022); second reviewer (20 September 2022). Received revised draft 10 December 2022. **Accepted** to publish 19 December 2022.

Abstract

Purpose and Research Question – STEM's education is an education that is based on four disciplines namely Science, Technology, Engineering, and Mathematics. STEM education is one of the agenda emphasized the implementation of the Malaysian Education Development Plan (PPPM) 2013-2025. This study aims to examine the development of STEM education and challenges of the implementation of STEM education in Malaysia.

Methodology – Systematic Review is the research methodology that is employed in this study. The review focused on several articles, papers and dissertations on STEM education and are selected according to criteria that fit into our research framework. The selected studies are then brought to analysis and synthesis processes to specify and present findings based on these two themes: (1) developments on STEM education, and (2) challenges of the implementation of STEM education in Malaysia.

Findings – The analysis of findings revealed the strong alignment between the STEM education approach and implementation in Malaysia. STEM learning can be applied using some integration patterns including silo, embedded and integrated approach. In addition, integrated approaches are capable in producing students with high interest and motivation to learn Science and enhancing the academic achievement of students on this subject

Significance and Contribution in Line with Philosophy of LSM Journal -

This article contributes by showcasing the importance of achievement in Science learning based on STEM education that is necessary to further scientific research learning models based on effective STEM education in schools, especially in Malaysia. For that, various initiatives have been made comprehensively in ensuring STEM education can be implemented in the teaching process and learning.

Keywords: STEM curriculum; 21st Century education; STEM-based learning; Science and Technology

Introduction

In the 21st century, Malaysia faces many challenges, such as challenges brought about by globalization and the development of communication technology. Malaysia places great value on STEM education as a method of developing the country, achieving the desired number of STEM workers, and ultimately fulfilling the challenges and demands of a STEM-driven economy. Therefore, education plays an essential role in producing capable and competitive students and facing the challenges of Industrial Revolution 4.0. Cultivating interest in STEM is important in order to produce citizens who are able to use and manage science and technology resources (Vennix et al, 2018). The Malaysian Ministry of Education (MOE) (2013) has indicated an interest in improving STEM education. Many measures to reform STEM education have been made, such as the introduction of a new secondary school science curriculum in 2017 and school-based assessment in 2011. All of these initiatives are focused at transforming STEM education in Malaysian schools so that career aspiration among students increase and their motivation to continue learning Science and can compete globally (Bunyamin et al, 2020).

The Malaysian Education Blueprint 2013-2015 contains a detailed roadmap for STEM integrated education in Malaysia (Adam & Halim, 2019). Three actions are outlined in the roadmap for increasing STEM education interest. The first step is to improve students' learning strategies as well as the curriculum. The integration of higher order thinking abilities to making topic content relevant to everyday life are all strategies that might be utilized. Second, providing ongoing training to teachers to improve their skills and competencies in STEM education as teachers' understanding is one of the keys to implementing STEM education. Teachers are expected to be able to design learning that is fun and quality for students so that the learning objectives can be achieved well. Finally, the Ministry of Education has made efforts to raise student and parent understanding of the importance of STEM areas and the opportunities available to them (Khairani, 2017). However, in recent years, the number of students who have chosen STEM fields has continued to fall (Halim & Subahan, 2016). In Malaysia, just 42% of middle school students choose Science, which includes technical and vocational programmes in high school (MOE, 2016). STEM needed to be empowered because according to the World Economic Forum (2020) by 2025 most of job roles in increasing demand are related to STEM field such as data analysts, robotics engineers, artificial intelligence (AI) experts and so on. For this reason, education reform must be done in the era of world's modernization, especially to teach and to facilitate in STEM education.

Furthermore, Malaysia has struggled to meet the human capital need that will be required in STEM fields. Malaysia is not alone in having a low number of students studying STEM programmes; other countries are as well such as America, Denmark and others (Ong & Ling, 2020). Aside from that, Halim and Subahan (2016) state that Malaysia has established a goal for 60% of students to study science. STEM participation among Malaysian students, however, is falling, not only in schools but also in higher education institutions. According to Sumintono (2016), the percentage of science stream students never exceeded 30%. In addition, a study from Phang et al. (2014) stated that the percentage of art students was higher than that of the

Science students since 1981. However, the Ministry of Education is still targeting student involvement in STEM by 60% by increasing student interest in STEM education through efforts such as upgrading of science laboratories, enhancing teachers' capabilities in integrating design and creative thinking in teaching and learning activities (MOE, 2017). Therefore, this study aims to examine the developments of STEM education and challenges of the implementation of STEM education in Malaysia.

Methodology

Research Design

Systematic Review is the research methodology that is employed in this study. This research involved systematic review and focused on the developments on STEM education and challenges of the implementation of STEM education in Malaysia. Literature reviews are commonly classified as either a narrative or systematic review. A narrative review is a synthesis of literature in a specific field constructed using a specific contextual or theoretical point of view (Akhter et. al., 2019). A systematic review is guided by carefully crafted stages that direct the cumulative search strategy, filtering, evaluating, documenting and reporting process of the selected papers to resolve an important research question.

Data Collection and Analysis using Manuscript Selection Method

The collection of data involved mainly analysis of document obtained through systematic review. To get an article that is accurate and in line with its purpose, the process of filtering all the articles obtained requires several steps. First, the researchers performed searches on several electronic databases, including ScienceDirect, SAGE, JSTOR, ERIC, Springerlink and Research Gate. These database were chosen because they are well known as high-impact and high-quality journals (Bano et al. 2018). Additional database such as Google Scholar and UTM repository were also used because the lack of the papers obtained. Titles and abstracts were reviewed to determine whether they were suitable for the purposes of the study. During this examination, a set of inclusion and exclusion criteria were adopted. The eligibility criteria for inclusion in this systematic review require peer-reviewing process of the articles published in scientific journals. Research articles that were reviewed in this systematic literature were selected from those published between 2015 and 2021. The eligible studies must also be published in English or Malay with primary or secondary school students as participant. Database was searched electronically and related to the field of Education and Social Science.

Data Analysis on the Concept of STEM in Malaysia

In 2014, many stakeholders from both the basic and higher education sectors came together to define STEM in the Malaysian education system (Shahali et al, 2017). They decided that STEM education should be used as a benchmark to increase the standard of Malaysian science and technology education, bringing it in line with international standards. STEM is defined from three aspects: the STEM as a field, STEM as a package and STEM as an approach (MOE 2016).

STEM as a Field

STEM encompasses both traditional disciplines like Science, Chemistry, Mathematics, Sustainability Foundations, Technical Communication Graphics, And Computer Science, as well as more particular subjects like Mechanical Engineering, Medical, Biochemistry, and Computing and Information Systems (Maruthai, 2019).

STEM as a Package

Upper secondary students in Malaysia's educational system have the option of selecting between a Science and Arts Stream. Students who choose the Science Stream in high school studied Physics, Chemistry, Biology, Mathematics, and Additional Mathematics. With the advent of more specialized Science & Technology (S&T) subjects in school, such as ICT and Invention, MOE renamed the Science Stream to S&T. Upper secondary students in the S&T Stream were defined as those who studied at least two sciences and mathematics subjects (Razali et al, 2020). Currently, 29% of students choose to take all three pure sciences (Physics, Biology, and Chemistry) with Additional Mathematics, whereas 13% choose two S&T subjects with Mathematics. As the Malaysian Ministry of Education replaces S&T with STEM, a change in name to the STEM stream is now being discussed (MOE, 2016).

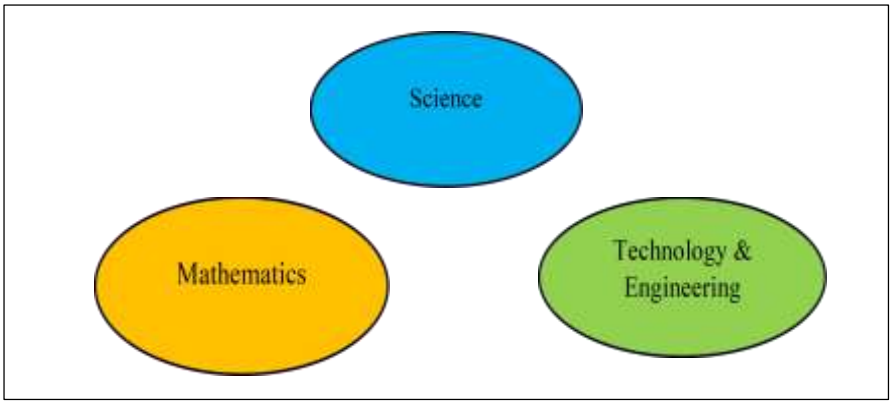
STEM as an Approach

According to (Shahali et al, 2017), STEM approach refers to a teaching and learning strategy that combines knowledge, skills, and values of Science, Technology, Engineering, and Mathematics to overcome problem in terms of everyday life, community, and environment. In the teaching and learning practices, STEM knowledge is an idea, concept, principle, theory, and understanding in the STEM field that is implemented in the curriculum of all STEM subjects. The curriculum designed and developed aims to provide students with knowledge, The curriculum designed and developed aims to provide students with knowledge, skills and values through the activities provided by the teachers inside or out of class while in the classroom (Bahrum et al, 2017).

STEM Education Approach. The STEM approach is learning and teaching involving two or more STEM elements with other disciplines. The merger of STEM elements can be done by involving various levels of knowledge from primary to secondary schools and colleges (Rukmana et al., 2020). STEM has three patterns of learning approaches that are generally better known in education, covering the silo, embedded and integrated. The difference between the three STEM approaches is applied according to the STEM content level used during teaching and learning process.

Silo STEM Approach. The silo approach is an approach that separates STEM components, where all STEM elements are taught individually or separately (Winarni et al, 2016). This approach aims to increase knowledge with the assessment as a result. The pattern for the silo STEM approach can be seen in Figure 1.

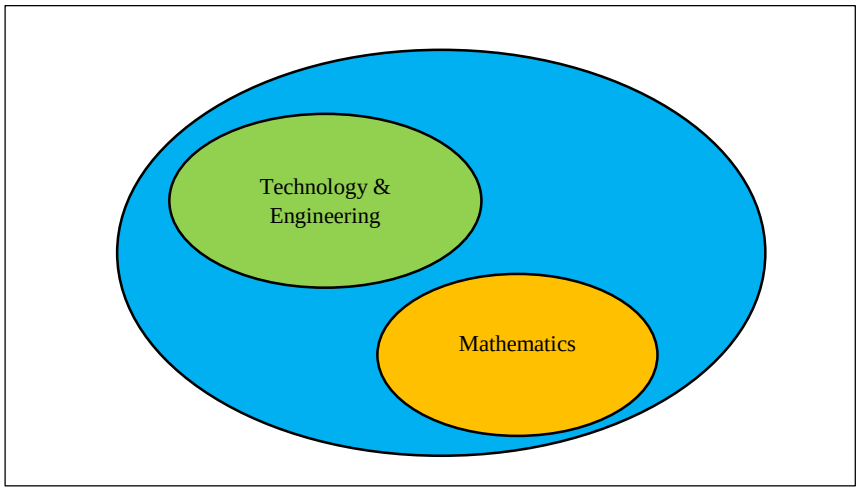
Figure 1 Silo STEM Approach Pattern



Based on Figure 1, indicating a circle representing the element in STEM in the silo approach is more focused on learning techniques in STEM subjects separately. The silo approach is more geared towards teacher-centered learning (Yadav et al., 2016). Learning that focuses on particular subjects enable students to gain a deeper understanding. However, research from (Halim et. al, 2018) shows that interest in Science and Mathematics learning among Malaysian school students is declining and reasons for the decline include learning in silo and not integrated. Through this approach, students are less likely to learn, and even students are taught more to what they have to know (Widya et al., 2019) because the primary purpose of the silo approach is to increase the level of knowledge in isolate potential STEM contributors to real life rather than understanding on perceptions of all STEM components. In addition, according to (Winarni et al., 2016) outlines three weaknesses in the silo approach: (1) the silo approach tends to reduce student interest in one of the STEM areas. For example, the study results show that female students are less interested in engaging in techniques such as engineering techniques, machinery and electricity, (2) with little opportunities to 'learn by doing', rather they are taught to know, students may fail to understand the relationship between STEM subjects in everyday life and prevent student academic growth. This is because the silo approach is more focused on a memorized teaching than practical, (3) the result of the research shows that students in learning prefer practical or hands-on. STEM learning through the silo approach is more focused on the content of learning materials and leads to the lack of knowledge applications in the students' daily life (Refer Appendix for the exemplary framework of silo approach).

Embedded STEM Approach. According to Khairani et al. (2018), STEM learning through this approach is more focused on only one STEM element, while other STEM elements are only used as additional information in complementing student understanding better against the STEM elements. This helps students' knowledge more deeply on one of the STEM elements but not on other STEM elements. For example, STEM learning with embedded approaches for Science subjects, Technological and Mathematical elements are used as a complement to show science applications in everyday life. The pattern of the embedded approach can be seen in Figure 2.

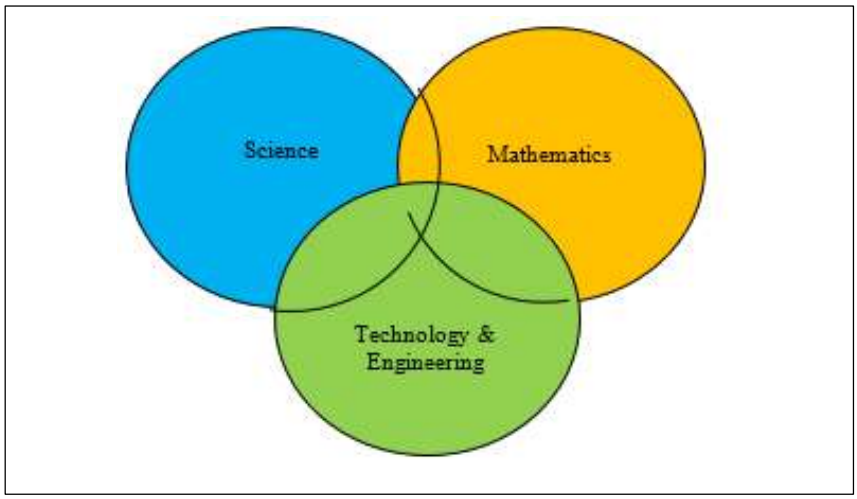
Figure 2 Embedded STEM Approach Pattern



Based on Figure 2, indicating an embedded approach in connecting the main STEM elements with other elements and promotes learning through various contexts (different with silo approach). However, the weakness in an embedded approach leads to separate learning. If students can not relate additional elements with crucial elements, students are at risk of getting only part of the entire learning process and student cannot associate the embedded content to the context of the lesson. Additionally, it is essential to ensure that students have mastered additional elements before the learning process occurs. If this situation happens, then the learning process of the student will be interrupted (Winarni et al., 2016). However, an embedded STEM curriculum is perhaps more feasible at the secondary level (Junior high school). It has possibility to be conducted without restructuring junior school curriculum. (Firman, 2015). A study from Murnawianto et al., (2017) shows that by using STEM-Based Science Learning as embedded approach has potencies that able to develop students' thinking skill that incorporate content Technology, Engineering, and Mathematic in science lesson for train students' thinking skill

Integrated STEM Approach. The integrated approach is the best approach to STEM learning (Winarni et al., 2016) because the integrated approach combined every element contained in STEM and taught in one subject. This pattern combines STEM materials in the classroom while at the same time combining them with curriculum content (Angraini & Huzaifah, 2017). An integrated approach is published to increase student interest in STEM learning, especially in the early stages of learning development. The pattern for an integrated approach can be seen in Figure 3.

Figure 3 Integrated STEM Approach Pattern



Referring to Figure 3, an integrated approach indicates the relationship between STEM elements in learning. This STEM element is not taught separately but in one unit so that students do not see STEM elements as different materials but as a union. STEM learning with an integrated approach is more easily applied in primary education and can have a high impact on learning (Khairani et al., 2018). A study conducted by Rasul et al., (2016) using this method on secondary school students age from four different zone of FELDA regions by application of project based learning (Po-PBL) in STEM education help students to integrate all three disciplines through project work. Besides, aside from problem-based learning, integrating STEM education into learning could improve students' thinking skills. In addition, based on research by Mahmud et al, (2018), this opinion argued that STEM education is vital for students to develop 21st century skills such as problem solving, innovation, creativity, communication and collaboration. For this reason, STEM education has become crucial in bringing the students to a level that can compete at the global level in the 21st century.

Discussions of Findings

This section discusses the findings in response to the research objective to examine the developments of STEM education and challenges of the implementation of STEM education in Malaysia.

Development of STEM Education

Since 1970, the policy ratio 60:40 (Science: Arts) has been practiced in the national education system until today. This policy was mentioned in the Malaysia Education Blueprint (PPPM) and STEM education is among the agendas highlighted (Rasid et. al, 2020). In Malaysia, the awareness of the importance of science has been given the necessary attention, especially in the education system to produce more labour who are skilled in STEM to supportthe country's economy (Razali et al., 2020). Furthemore, STEM education focuses on educating students and preparing them with the required skills to become productive citizens. Due to the emphasis of STEM careers, the Ministry of Education (MOE) seriously took up the suggestions

of the National Education Blueprint (PPPM) 2013-2025.The idea to change the existing curriculum to the Standard Secondary School Curriculum (SSSC) is by strengthening and introducing STEM in the education system of Malaysia as one of the pillars in the new curriculum. As a result of the new curriculum in the present system for government schools in Malaysia, a lot of work has been done (Halim, 2018). For an example, in conjunction with the STEM initiative launched in Malaysia, teaching and learning materials for STEM education have been enhanced. *Bahagian Pembangunan Kurikulum* (BPK) (2016) wrote a few structured guidelines for educators to implement STEM in science classes. Educational videos, which either act as supplementary material to the guidelines or used as learning material, are accessible via http://btp.moe.gov.my/stem/video or http://www.eduwebtv.com/. These videos are collectively known as EduwebTV video (MOE, 2015).

Currently, STEM education in Malaysia is now in the third Wave (2013-2025). However, the target of producing a ratio of 60% of science graduates was still unattainable with further decline in the number of students in the STEM field due to the lack of motivation (Wei & Maat, 2020). Besides, recent studies have shown that school science engagement and motivation among Malaysian secondary school students to choose science-related careers is alarming, as students reject science related careers as a future career option (Siew et. al, 2015). Moreover, the recently conducted Programme for International Student Assessment (PISA) and The Trends in International Mathematics and Science Study (TIMSS) assessments shows that the mathematics performance of Malaysian students was not on par with the world standards. The results indicated that the Malaysian education system is not producing the expected academic outcomes in terms of teaching and learning of science and mathematics (Abdullah et al., 2020). In the recent PISA 2018 chart, students from Beijing, Shanghai, Jiangsu and Zhejiang provinces could handle abstract concepts and discern facts for opinions from their reading (OECD, 2019). No wonder they are sitting on the top for three skills assessed in PISA. If we look at our Malaysian students, where is our education system heading to? In national level, Malaysia Ministry of Education already planned and executed the initiatives to improve the ranking in PISA throughout our participation in PISA. The state governments need to initiate their own plans and assist federal government to nurture the future STEM talents. The state governments in Malaysia may or may not have concrete plans on STEM initiatives. The public seldom heard of the related news. However, the decline in the interest in STEM subjects has been a concern for the Penang state government (StarEdu, 2019). To tackle this problem, Penang STEM formed STEM Clubs for lower secondary students in government schools. The clubs make STEM learning fun by taking practical hands-on industry to help fund the programs and mentor students towards STEM excellence (StarEdu, 2019). STEM-related knowledge and understanding is rapidly updated and outdated, and some teachers are left behind in this new understanding and advancement in Science and Mathematics (Shahali et al, 2017). Furthermore, lack of understanding and exposure of STEM application in daily life has cause students to accept STEM as a subject that solely learnt for examination purpose (Jaafar & Maat, 2020). To ensure that the STEM empowerment objective is a success, it is critical to identify the issues and challenges that students and teachers face, as well as the trainings and exposure that Science teachers require as part of their ongoing professional development.

Challenges In STEM' Learning Implementation

Motivation. The adoption of STEM education in teaching and learning process can encourage creative and innovative minded students. In addition, it can also boost the debate between students in science and technology that can produce dynamic, creative and competitive students today (Angela et al., 2015). However, the number of students pursuing STEM disciplines has decreased in recent decades, resulting in a one-to-five ratio of science classes to art classes. This ratio suggests that Malaysia has to take proactive initiatives to improve the number of students pursuing STEM subjects. The government forecasted a 60:40 ratio of Science/Technical:Arts in the Malaysia Educational Blueprint 2013-2025. However, the objective was not accomplished (Shahali et al, 2017). The decreasing number of Malaysian students pursuing science stream is due to their fear and lack of confidence in pursuing STEM field since they believe science courses have a more difficult syllabus than other courses (Ismail et al., 2019). Besides, according to Razali et al, (2019), most of Malaysia students are less motivated to learn science when they are placed in science stream class but are not interested to learn science. Other than that, past research from Narmadha and Chamundeswari (2013) shows that low attitude towards science will influence students' motivation and later the students' interest to choose science related career. Yildirim (2016) supports this and Yildirim and Altun (2015) found that student motivation levels exposed to STEM education are better than students who do not receive exposure to STEM education. In order to make sure the mission of STEM empowerment is successful, it is vital to determine and solve this issue for better STEM education among students.

Lack Interest. Teachers have a great responsibility in driving excellence in student's achievement in the classroom or outside the classroom. According to Mohd Shahali et al., (2019), the possible reason for a decrease in interest towards STEM subjects in Malaysia could be due to the quality of teaching and learning in the classroom. According to Abdullah et al. (2017) reported that teachers failed to create classroom environment that motivates students learning as they focused on following the procedure of implementing STEM education rigidly. This brings a negative impact towards the implementation of STEM education. In addition, teachers must have self-confidence (Han, 2017); it can help teachers and students achieve the learning objectives to be desired, especially in increase student's interest towards STEM. Besides, according to Kaur et al, (2020), 70% of Malaysian students has low interest in undertaking STEM subjects because the teaching methods were simply too theoretical. This study also in line with research by Radloff and Guzey (2017), when the subjects of Science and Mathematics presented separately without integrating STEM concepts involve everyday life, the student's interest in learning will fade and significantly reduce. Therefore, the learning activities that are essential STEM elements should be enhanced in teaching and learning in the school. Furthermore, learning in silo and not integrated also effect the interest in STEM learning among Malaysian school students as they unable to see the relevance of STEM in everyday situation (Halim et. al, 2018). Teacher is still weak in integrating STEM from the time factor and teaching materials in learning STEM. Moreover, this study is also supported by Ceylan and Ozdilek (2015) that the teacher's effectiveness in delivering the teaching of STEM in teaching and learning is still lacking. This may be caused by the teacher's difficulty

in making the interaction appropriate in the teaching and learning of STEM (Kelley & Knowles, 2016).

Learning Experience. For learning experience, Chong (2015) criticized learning science in Malaysian classrooms of focusing on study of factual knowledge where students do not understand the nature of STEM. For an example, STEM method in the curriculum is not fully utilized. According to Bunyamin and Finley (2016), topics in Form Four Physics subjects are standing independently without any relevance between concepts and other concepts. Apply for a strong concept and concrete requires a more explicit (expressed) teaching method. This allows students to participate in current learning activities that need a combination of STEM disciplines. In Malaysia, the science curriculum must be constructed through establishing connections between various ideas, theories, and concepts. In their research, Siew et al. (2015) said that the Science and Mathematics curriculum should be changed to be more STEM-based. Besides, as for the Malaysian teachers, Pimthong and Williams (2018) explored the understanding of STEM among teachers and found that they are aware of the importance of STEM subjects but not able to explain how those subjects integrate. Based on such studies, it can be concluded that education nowadays needs to be more centric on the quality of the teachers and STEM education because education requires prospective teachers to be ready to face the challenge of learning STEM in the future. In addition, for pre-service teachers, the education for secondary school teachers in Malaysia may consider training the pre-service teachers to have the ability to teach sev eral science subjects. This could increase the success rate in integrating STEM in their classroom lessons (Choong, 2019). Next, according to Volkinsteine et al. (2014), teachers are not aware that the scientific investigation process required active student participation in STEM teaching and learning. Moreover, the study of Pearson (2017) found that the lack of research related to the techniques and methods that are accurate in performing the learning of STEM because learning is less effective to the students. For the prospective teacher of practical and training in STEM education is very important because it can develop prolonged knowledge (Rahayu et al., 2018). This proves that the quality of the teacher becomes one of the significant issues in STEM education among students.

Conclusion

As a conclusion, although STEM has been empowered through Malaysia Education Blueprint (PPPM 2015-2025), the students still not interested to learn STEM subjects. Issues related to the low achievement of students in Malaysia in the three types of disciplines show that Malaysia's level of education still needs to be improved and developed at the maximum level. Lack of motivation, interest and bad learning experience has been identified as a challenges in implementing the STEM education. Various activities and programs should be implemented at the school level, district, state and national to ensure the student's interests in STEM can be improved. Furthermore, activities conducted in STEM also playing a major roles in this challenges. The silo and unintegrated STEM activities making STEM problem even worst. Therefore, this study suggested further research on the implementation of integrated STEM

activities that can help students to improve their interest, motivation and learning towards STEM.

Acknowledgements

This research was supported by Ministry of Education (MOE) through Fundamental Research Grant Scheme (FRGS/1/2020/SSI0/UTM/03/4).

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Appendix

Theoretical framework for instructional practices in exemplary 'Silo' STEM approach