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Integrating STEM education: A comprehensive framework for analyzing mathematics classrooms at a primary school

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ABSTRACT

This paper presents an overview of a STEM (Science, Technology, Engineering and Mathematics) project implemented at a primary school in Macao SAR, that integrated pedagogical consideration on a rocket building competition. The project adopted an analytical tool as a theoretical framework for integrated STEM education. It exploited a modified analytical tool, grounded on the in-depth analysis of design, implementation, and evaluation of the project, called integrated STEM education framework in practice (iSTEMiP). The theme of the project covered space exploration combining a real-life problem and encouraging students to respond to manageable challenges. Its design focused on providing students with hands-on experience in integrating mathematics, engineering, and science knowledge within the exercise. For the participants of the project, a class of grade four students joined the STEM competition designed by a STEM team consisting of two teachers at the school. The students formed groups and were aided by the teaching team through instructional scaffolding, while the students constructed their own design rockets, step-by-step, integrating the acquired knowledge. Implementation of the project included the design stage of the rockets, group sharing activities, and the launch of the rockets. The major findings of the study discover students' learning trajectories and teachers' teaching flows by the critical features of the modified theory of iSTEMiP. Specifically, the mathematical concepts involving angles and projectiles were prominently shown to have been used from analyzing the work done by the students. Moreover, the study found that the participants expressed positivity toward the learning experience of the STEM project.

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INTRODUCTION

STEM education, originally called as Science, Mathematics, Engineering and Technology (SMET) (Sanders, 2009), has become a local and global educational trend in countries across the world. "Although the idea of STEM education has been contemplated since the 1990s in the USA, few teachers seemed to know how to operationalize STEM education several decades later" (Kelly & Knowles, 2016, p.1). It is now indispensable that teachers become able to integrate seamlessly content knowledge about various disciplines including science, technology, engineering and mathematics into meaningful learning environments, taking into account pedagogical considerations.

Although school teachers considering the incorporation of integrated approaches of STEM subjects into instruction can be highly effective in the primary schools, more so than in colleges (Becker & Park, 2011), primary school teachers may not have ample understanding about STEM, in particular practice in accordance with a curriculum standard (Yanthi et al. 2019). Therefore, primary school teachers should collaboratively design and implement STEM lessons with contributions of subject knowledge from their area of expertise. Kennedy and Odell (2014) indicate that students can solicit science and mathematics knowledge into engineering problems and utilize technology to solve problems. Mathematics hence serves in a supporting role integrating STEM education contexts, underpinning other disciplines (Fitzallen, 2015). It is also known as an essential tool to consistently connect interdisciplinary knowledge, which is vital for mathematics teachers to implement STEM lessons with an innovative pedagogy (Abramovich et al., 2016). In addition, the selection of real-life scenarios in STEM education motivates students to inquire and to better prepare for handling challenges in the real-world aligning with the goals of the curriculum (Costa et al., 2022). Therefore, design of and implementation with innovative pedagogy in mathematics and science lessons are important for teachers to rethink in STEM education. Way et al. (2022) suggests three levels of 'STEM skills', 'Design Process', and 'Integrated STEM Projects', to escalate the STEM lessons in primary schools. It offers innovation in teachers' practices in the design and implementation of STEM lesson from various disciplines.

In Macao, the education system has been reformed, with the curriculum framework and the Requirements of Basic Academic Attainments (BAAs) for primary education implemented in 2016 (Education and Youth Development Bureau, 2016). The BAAs in primary mathematics education provide reference points and basic standards in curriculum organization and development, and the rationale of mathematics education, as well as content covered in six learning domains. In addition, student assessment has been defined so as to be implemented in diverse ways according to the learning objectives in each level and the respective BAA requirements (Education and Youth Development Bureau, 2020).

The five goals in the mathematics curriculum in primary education embrace students' mathematics knowledge, correlated with daily life mathematics and the development of society; mathematical skills and constructions with useful tools; mathematical abilities including logical reasoning and problem solving; students' interest in learning mathematics; and students' communication skills with the language of mathematics. There are six domains of BAA requirements, including (1) number and arithmetic, (2) shape and space, (3) quantity and measurement, (4) statistics and probability, (5) basic knowledge of algebra, and (6) feelings, attitudes and values. Two learning stages are defined for junior primary levels (Primary One – Three) and senior primary levels (Primary Four – Six).

The mathematics curriculum framework has been successfully implemented in all grades from 2019 onwards, providing guidelines, rationales, pedagogical considerations, contents, and other important information for teachers to cultivate students' mathematics knowledge. The embodiment of teaching and learning mathematics in STEM activities is generally shown in promotion of scaled project-based activities or competitions. Educational research is required to examine which integrative approaches most effectively put mathematics into STEM learning experiences (Fitzallen, 2015). Additionally, STEM-related pedagogies that have emerged can become a challenge to school teachers who are integrating and developing relevant pedagogical content knowledge in teaching practice (Wei, 2019). Besides, a lack of authentic scientific research and inquiry experiences causes teachers to feel unprepared for teaching STEM subjects (Nadelson et al. 2012).

Lei and Hu (2020) have shown that task design with the appropriate tools selected enables mathematics teachers to guide students towards integrating various forms of content knowledge in curriculums including high order thinking skills which include problem-solving, mathematical numeracy, and creativity. The exploration of using manipulatives serves as a lens to investigate innovative integrative approaches in STEM education.

There are two research questions in the study:

(1) What are the key elements of a STEM conceptual framework analyzing a STEM project in primary level?
(2) What are the pedagogical considerations influencing the implementation of mathematics lessons in the STEM project?

OBJECTIVES OF THE STUDY

The objective of the study is to analyze a STEM project by an analytical framework and to compose critical features of the framework with data collected from the implementation. The aims include identifying effective pedagogical practices for implementing mathematics lessons in STEM projects, and providing empirical evidence for understanding of how STEM education can be integrated into primary school curriculum.

LITERATURE REVIEW

STEM education refers to a discipline combining Science, Technology, Engineering, and Mathematics. Some scholars define integrated STEM education as the competence to incorporate some of the four disciplines of science, technology, engineering, and mathematics into a lesson based on the relationship between these subjects and real-life problems (Moore et al. 2014). Organization of training and creating unified learning materials in STEM education is essential in the holistic consideration of learning and teaching for educators (Dulay & Manuel, 2021). Kelly and Knowles (2016) propose a theoretical framework in STEM education around learning theories and pedagogies. The conceptual framework adopts a block and tackle pulley system illustrating connection between situated learning, engineering design, scientific inquiry, technological literacy, and mathematical thinking as a holistic system. It harmonizes the key elements in the STEM learning environment to ensure the complex relationships among them are integrated and unified.

Situated STEM learning

Situated cognition theory (Brown et al, 1989) emphasizes the link between social situation and activities within which an authentic practice has taken place. The main characteristic of situated cognition highlights that learners' cognition should be taken places within two contexts, namely physical and social, of interactions. It is a culturally constructed tool (Wilson & Myers, 2000). Embedded within intentional tools utilized in the situation, semiotic evolution from concrete mechanism to symbolic representations of a human (viewed as learners') mind (Norman, 1993). In practice, teachers design well-planned meaningful tasks to achieve distinctive learning objectives in STEM knowledge with clear guidance from teachers and appropriate tools available to be manipulated by students.

Engineering design

A key aspect of engineering design is providing students with a systematic approach to solve situated problems, creating an opportunity to locate intersections among STEM disciplines. The engineering design process encourages students to adopt a mathematics and science approach to conduct experiments with planned potential solutions before constructing a final prototype (Kelly and Knowles, 2016). Students legitimize and testify the design with supported content knowledge and reasons behind the approach. English and King (2020) reveal that students solve engineering problem of varying levels of sophistication consisting of initial sketches, drawings, written instructions, and calculations. They consider five design processes including (1) problem scoping: understanding a problem's boundaries; (2) idea generation: brainstorming and planning; (3) design and construct: developing a model;

(4) design evaluation: meeting constraints; (5) redesign: model redevelopment. In practice, the engineering design includes design with reasons and uncertainty to be justified in the plan. Procedures and appropriate tools are essential in the engineering design.

Scientific inquiry

Scientific inquiry helps students to raise questions, to make hypotheses, and to conduct investigations using standard science practices (Kelly and Knowles, 2016). The range of dimensions in inquiry-related activities includes posing problems, designing investigations, collecting or accessing data, generating, testing, and refining models and explanations, communicating and negotiating assertions, reflecting, and extending questions and solutions (Abd-El-Khalick et al. 2004). Students construct their own scientific questions as they emerge in the engineering processes in the situated problems where they have opportunity to explore, to plan a model of the situation, to collect useful information from the plan, to analyze the data collected, and to reflect on the model for the situation. Thus, the initiated questions raised in the scientific inquiry approach enable students themselves to investigate key contents in the case.

Technological literacy

Technological literacy is defined as the basic knowledge a person has about technology; the capability of the person to manipulate with a computer and identify and solve simple problems using the technological devices; and how the person thinks critically about technological issues and acts accordingly (Garmire & Pearson, 2006). It refers to knowledge about what technology is, how it works, what educational purposes it serves, and how it can be efficiently and effectively used to achieve goals (Turiman et al. 2012). Turiman et al. (2012) suggest that teachers be skilled in using multimedia technology or follow software blogs embracing discussion questions that foster students to communicate among themselves in cultivating scientific literacy. In addition to the social context of technological literacy, social and civic responsibility related to technology is endorsed.

Mathematical thinking

Instructional pedagogy in primary school mathematics relies on arithmetic procedures which highlight development of mathematics knowledge and skills of mathematical thinking, in particular reinventing patterns and structures including recognizing patterns, decomposing, abstracting, creating algorithms, extracting structures and forming generalizations (Miller, 2019). Mason et al. (2010) have introduced four processes underlying mathematical thinking, which are specializing, generalizing, conjecturing, and convincing. Specializing refers to understanding a particular instance with an example, which is generally a starting point for a bunch of questions. In contrast, generalizing is the other side of the coin, and makes sense of an underlying pattern applicable to other similar cases. Specializing is for gathering evidence upon a generalization is to be made (Mason et al. 2010). Conjecturing is a researching process for the accuracy of a hypothesis by estimating what may be true, emerging in the processes of specializing and generalizing (Mert Uyangor, 2019). Therefore, conjecturing is viewed as initiation of generalization process. To seek why and to explain why, convincing can justify arguments referring to conjecturing (Mason et al. 2010). Convincing involves justification in both the formal and informal mathematical senses, which also underlies structures and patterns preventing contradiction and false deductions.

In mathematics classrooms, the four processes underlying mathematical thinking are critical for mathematics teachers in designing tasks from a pedagogical aspect. Tasks designed with rich mathematical thinking elements should allow students to specifically focus on certain questions. The mathematical skills should be adopted clearly in the questions which critical mathematics knowledge should be generalized from through conjecturing structures and patterns. The justification process is required to legitimate students' claims with reasons.

Integrated STEM education framework in practice

STEM education refers to Science, Technology, Engineering, and Mathematics. Collaboration across the four domains is crucial to integrating key knowledge in a STEM activity. An integrated STEM framework in practice (iSTEMiP) grounded on the conceptual framework for STEM education, shown in Figure 1, is established as a systematic structure for illustrating the critical elements underlying the four domains. iSTEMiP captures the essential ideas discussed in each of the four domains.

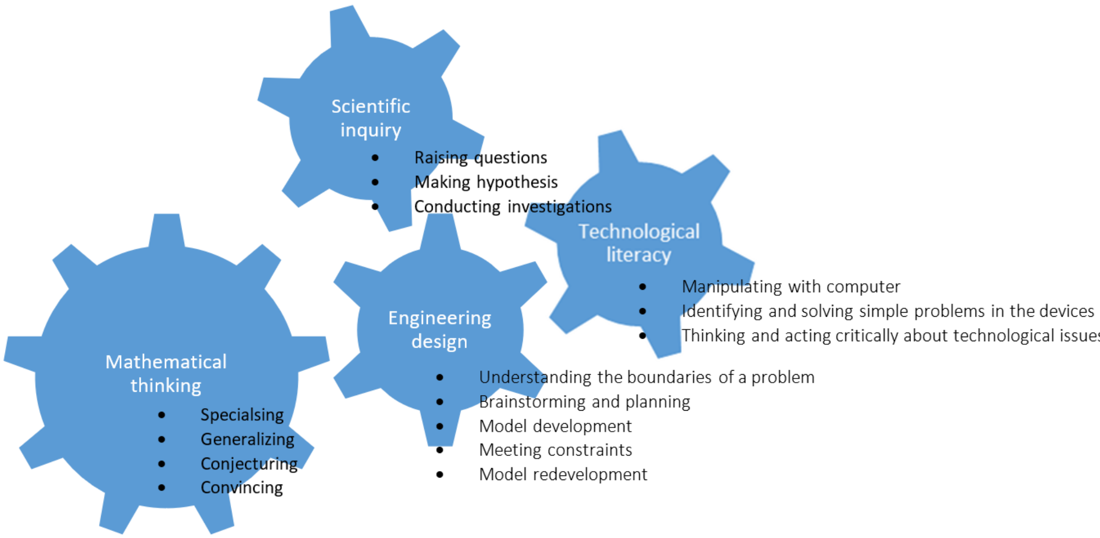

Fig. 1. Integrated STEM Education Framework in practice (iSTEMiP)

The iSTEMiP is put forward to be used as an analytical tool to depict STEM activities. More importantly, in the analytical process, interrelation among the critical ideas in the domains can be examined, for example, the co-construction of knowledge among the domains.

METHODS

This qualitative study adopted single case study design employing holistic analysis on the implementation of the STEM project as a specific context guiding by iSTEMiP. The project was titled as "Three, Two, One, lift off" having a goal of developing students' knowledge in science, technology, engineering, and mathematics in curriculums. A qualitative case study is an appropriate design to describe a bounded experience within a period (Creswell, 2014). Previous research (Nowikowski, 2017; Ghergulescu, et al., 2019) utilized case studies analysis to investigate STEM-related issues depicting the educational practices (Merriam, 1998). Merriam (1998) added, in the family of qualitative research methods, case study serves as an intensive and holistic descriptive research method to analyze a bounded system. In the study, bounded system was defined as a STEM project adhering rich mathematics, scientific knowledge, and collaborative learning as the main objectives. A single case study approach was utilized to explore in nature with the analytical framework known as iSTEMiP on the STEM project integrating mathematics, science and technology in a primary school. A group of grade four students and a teaching team designing the project were the participants in the study. The teaching team including an experienced teacher who is interested in developing STEM pedagogy in various subjects, was formed to implement the STEM project grounded on mathematics classrooms where key mathematics knowledge was embedded.

The design of the lessons including lesson plans, was well-studied. The lessons were implemented and video-taped and transcribed for analysis. The key ideas and descriptors shown in the analytical framework, i.e., iSTEMiP, were used to be the codes to illustrate the features of the transcribed implemented lessons. In addition, the worksheets done by the students were collected and analyzed to triangulate the findings of the study, mainly depicting the cognitive development of the students in mathematics and science knowledge.

RESULTS

From the observations conducted in the STEM project, the key ideas of the iSTEMiP framework were adopted to analyze the implementation of the lessons. The findings are depicted as follows.

The STEM project

The project sample in this case was entitled "Three, Two, One, lift off" and was designed as a STEM project with Mathematical elements for a thematic learning day for grade four students in 2020. Instead of introducing the Mathematical concept in isolation, the project was designed to combine math and science into a real-life problem-solving situation that challenges students to apply the knowledge they already knew. The theme of the project was an extension of the Student's General Studies curriculum (Solar System) and Mathematics curriculum (Different angle). By combining these two curricula, a STEM project was created to utilize student's pre-existing knowledge of different angles and their passion about space exploration. Students were challenged to create a working paper rocket with minimum materials and then launch the rocket at different angles to achieve maximum altitude and distance. The project was broken down into two sections, beginning with the introduction of basic rocket physics and then the step-by-step creation of the rocket itself. Students were grouped into different project groups by themselves and worked together to solve any problem they might encounter. Throughout the two thematic learning days, students were very engaging and passionate about putting their interest into practice and the result was overall very positive.

Design

The project was designed as a STEM project that incorporates the subject knowledge students learn in their regular curriculum and combined it with real-life problem-solving challenges. STEM education can be defined as "the approach to teaching the STEM content of two or more STEM domains, bound by STEM practices within an authentic context for the purpose of connecting these subjects to enhance student learning." (Kelly and Knowles,2016, p.3). In this case the focus of the project was mostly on Mathematics (Different angles), Engineering (Construction of a working rocket) and Science (Physics).

The project had three learning objectives:
1. Reinforce the Mathematical concept of different angles.
2. Enhance students' interest in Science, Engineering and Mathematics.
3. Improve students' knowledge, integration skills and problem-solving skills.

At the conceptual phase of this project, the pulley system as mentioned by Kelly and Knowles (2016) was considered and put into practice. For example, the engineering design aspect was fulfilled by the creation of a working rocket and rocket launcher. By allowing the students to create a rock that could be launched into the sky, it gravitated their interest to an intense level which also greatly enhanced their intrinsic motivation in completing the project. The students could make a draft model with softer materials and modify their design before crafting the final model. In the project, the teacher guided the students with some basic engineering ideas and allowed the students to make mistakes within a reasonable margin so that they could both experience the fun in engineering and ensured a successful launch event.

Other theories such as Vygotsky's scaffolding were also considered in the design of this project. Since the project required the students to integrate many generic skills, it was essential for the teacher to provide scaffolding so that the challenge could be maintained at a manageable level. Revisiting prior knowledge on human space exploration as well as the concept of different angles gave the students a sense of security as they could link to something they experienced. The creation of the paper rocket and launcher were also broken down into manageable steps with detailed instruction so that the students could handle the crafting mostly by themselves. The formulation of groups also embraced peer learning so when some students were in doubt, the groups could come up with a solution together. Visual aids such as video and printed guides were also available to help the students to revisit the steps designed and/or implemented.

Other than the instruction from the teacher and some videos used to explain the abstract concepts, the launch reports which were in the form of worksheets served as a essential guide for the whole project, was essential. For primary students to stay focused on the task, the teacher relied on a tool that helped the students to keep track of their works. Students were instructed to read and to follow the worksheets as the teacher coordinated the flow of the project and allowed the students to gain a point of reference in terms of the progression.

Implementation

A typical thematic learning activity was last two consecutive school days. Therefore, the project was split into two consecutive days. Thematic learning was part of the school curriculum, where the students applied their learning from their primary subjects (English, Mathematics and Chinese) using a different approach. The subject teacher created different engaging activities for the students to experience the knowledge they learned during regular lessons.

Introduction

The project started with a story of human space exploration. It acted as an introduction as well as an attention grabber to increase the students' interest and to set the theme of the project. The teacher began with a short lecture about human space exploration history, followed up by a short video showing the launch of the first rocket to the modern-day Space X program. The introduction was kept short (within 30 minutes) to ensure the information was delivered within the students' attention spans. The students were then invited to get into groups of four or five and each group was given a worksheet as the launch report along with all the necessary printed reference materials for the project.

Driving question

After a short break, a driving question was asked to stimulate the students to scientifically think about the design of their rocket, which was "what kind of shape makes the best rocket?". The students were reminded of the 2D and 3D shapes they learned in their Mathematics curriculum and invited to discuss within their group and came up with an answer. The teacher served as a stimulator while the students were discussing in groups and talked to each group to see if they were on the right track. It corresponded to the Scientific Inquiry aspect of the pulley system as mentioned by Kelly and Knowles (2016) as the students were encouraged to keep asking which shaped to make a better rocket with reasons. A short video about aerodynamics was shown to the students and a conclusion was drawn by the teacher.

Hands on engineering

After the discussion the students were given some printed paper with 2D shapes and instructed to cut them out to make cylinders and cones. The shape was given to the students because it helped to ensure a successful launch experience, but the tail fin shape was only given as a guideline and the students were encouraged to experiment with different shapes because the effect on the launch was not significant. The students were then introduced to the simplified anatomy of a rocket and created the three main components: Head (Cone), Body (Cylinder) and Tail (a variety of tail fin shapes). The group were then instructed to glue or tape the component together and created their test model rockets. After another short break, the group was to finalize their rocket design and to create the final versions of their paper rockets with thicker craft papers. The teacher concluded the morning with the students and the main activities of the first day were completed. The afternoon session aimed at showing the thematic movie for the students to relax and expand their understanding of rocket science.

Mathematical thinking

The beginning of the second day started with a briefing talk on the schedule. The groups were introduced to the launch task in the afternoon and learned about the concept of altitude (how high) and distance (how far). Here, the students are presented with another question which was "How do we measure the altitude of a rocket?" followed by a discussion, while the teacher continued to explain that altitude could be measured by using mathematical model. The students then learned the distance between the observer and the launch pad, as well as the peak launch angle of the rocket. The mathematical terminologies in trigonometry, e.g., sine and cosine, were briefly explained and the students were introduced the use of the altitude tracker that allowed them to record the peak launch angle of the rocket. The teacher supervised the crafting of the launcher and then the groups were introduced the tangent formula as well as the tangent table. After the break the groups completed the worksheets with the final component of the project – the rocket launcher. The launcher could be able to change the launching angle so that the students could record both the altitudes and distances of the rocket with the same launcher. A brief introduction of Newton's third law was given to the students and the teacher explained that the air rocket's ability to be launched off the ground coming from the air of the launcher. After that the students were given some PVC pipes and invited to create a launcher that they used. Extra pipes and connectors were given to the students to make one efficient launcher so there was the opportunity for the students to explore different combinations. The first round of crafting was free for students to explore, and because the pipes and connectors were attachable without glue, they had the freedom to assemble and disassemble as they observed. After about 20 minutes of trial and error, the teacher demonstrated a more efficient way to create a launcher that encountered both altitude and distance launching as the students were required the change of the launch angles. The students were then encouraged to perfect their launcher and prepared in the afternoon. Some students applied the concept of power and were able to convert that knowledge into practice as their launcher was made with not one but two water bottles as the source of power.

Use of technology

Before the launch event in the afternoon, the students were brought to the computer lab to try the online projectile simulator. In the process the teacher briefly talks about the effect of launch angle on the altitude and distance of the projectile. The students were encouraged to try different angles under the same conditions to see which angles were the best for achieving maximum altitude and maximum distance. A conclusion was not drawn to leave a room for exploration about the actual launch event.

Rocket launch

The launch was carried out on the school plaza. Before the start of the activity, the teacher gave a safety briefing to all students and showed them how to use the safety goggles. Since the rockets had a pointy head, the instruction was essential for safety and served as an exemplar for the students to respect any experiment they might conduct in the future. After the briefing a lucky draw deciding the sequence of the launch and each group member had to perform a certain role. The operation of the rocket launcher was straightforward which the students stepped on the water bottle, while the air inside was compressed and pushed through the connecting pipe until it reached the paper rocket. The scientific concepts including air pressure and force were examined in the activity.

The pilot was the one who transferred the air from the water bottle into power for the rocket by stepping on the bottle firmly. Two observers stood five meters away from the launch pad on each side and used the altitude recorder to trace the peak angle of the launch. The commander was the one who held the launch report, serving as both the coordinator of the groups and the recorder of all data. To enhance the thematic experience, the teacher also used a two-way radio to communicate with the commander from a distance. After the altitude launch each group was given a space in the plaza to do the calculation of the altitude from the measurement they made. When all groups finished their first launches, they were then challenged with the distance launch. The distance was measured by a 20-meter tape set on the floor and two groups compete to increase the fun. The launches were filled with joy and laughter.

Closure

After the launch event, the students had an experience sharing section with the teacher back in the classroom. The teacher summarized key STEM knowledge including how angles affect the launch altitude and distance as well as how the rocket gain power and move by the air flow. The teacher then asked the student to discuss within their groups and reflected on the process of the activities in order to reflect and improve the rocket launch. At the last part of the lesson, the teacher illustrated the process of the students' work with four key stages: Design, Create, Test and Record. The students were encouraged to share their experience in the four key stages as the conclusion of the STEM project.

An insightful finding including the importance of the test process was highlighted. A group initially created a "twin engine" rocket which had twin rocket bodies but was still powered by one water bottle. Due to the design of the rocket, it was not gained enough power to launch at the first time. After testing for couple of time, the students noticed that the "twin engine" should be on the launcher instead of the rocket and decided to change the design of their launcher into a real "twin engine" by adding another tube which was connected to a second water bottle. Then they realized that they needed two pilots to operate the launcher by stepping on the water bottles simultaneously to maximize the effect of the "twin engine" therefore the command joined the pilot and worked out a way to synchronize their movement. The other group greatly appreciated their sharing as the "twin engine" rocket having one of the highest altitude records. The group then shared their thoughts on creating another prototype with even more engines to testify the launches which reached the rooftop of the school building. It demonstrated the engagement of the students in the trials of designing and testing the rockets in the activities.

Use of tools

Some tools were used to cope with the knowledge gap of the students so that they could complete the project by themselves.

Tools for mathematical concepts

The aim of the first launch activity was to record the altitude of the rocket and instead of using an electronic altitude tracker the teacher equipped the students with the tools and knowledge that enabled them to use simple calculations to manipulate the collected data. Since the launch platform was set on a flat surface in the school plaza, the students used trigonometric formulas to calculate the launch distances. To make it smoothly, the teacher introduced the tangent formula and provided a simple tangent table of zero to 90 degrees to each group. Although not all students fully understood the concept of trigonometric formulas, with the help of the given formulas and the tangent table, the students quickly learned how to use the recorded data to complete the calculation. As for the angle itself, in the launching field, a larger angle meter was provided to each group so that they clearly measured the launch angles for the rocket every time, also allowing them to see the abstract idea of an angle in a more tangible way.

Tool for physics concepts

The concept of a projectile was also briefly introduced to the students so that they understood the meaning of the second launch. Instead of a physical tool, the projectile simulator was used to give students a simulation on how the angle could affect the launch distance of the projectile. The simulator served as a perfect lab simulation to teach the students the effect of angles to a projectile's distance. The effect of angle was isolated by the students with all other variables remaining constant in the simulation, meaning that the students experienced the effect of angle in a simulated lab environment with controllable variables. The students had unlimited chances for trial and error until they found 'the best angle' for the final launch event at the end.

DISCUSSION

The results of the project were measured by an informal interview with the students about three months after the project. Most students commented that the experience they had was lots of fun and they wanted to do it again. Some students said that they had learnt a lot about rockets and felt like they could be a rocket scientist in the future. However, it was worth that some students were able to recall the detailed aspects of the project and the answers given about the concept of angle which was one of the intended learning outcomes. This means that the launch itself was so attractive to the students that they might not forget the importance of the data and calculations in the project. It was clear to see that the intended learning outcome of increasing the students' interest in Science, Engineering and Mathematics was achieved. For the follow up study based on the project, the measurement of the improvement of problem-solving skills could be done in the next project as a follow up study on the progress of the same group of students, but the results will be unable to give a very quantitative measurement of the mathematical concepts as experienced during the project and in the future, perhaps a short quiz could be included as part of the project to collect more data.

IMPLICATION

This study has revealed some directions for further studies. With regards to the participating students in this project, a suggestion is to provide more time for them to explore the construction of the rocket launcher. The required skills and knowledge of multidisciplinary STEM projects is challenging for young students therefore scaffolding activities that involve science and engineering should be increased to equip students with such skills. Further exploration on students' knowledge-building process in STEM projects such as this study will help practitioners understand how to help students to achieve success more systematically. Furthermore, practitioners should note that this study has a limited sample size which reflects only a very small portion of the student in a particular setting. Conditions between schools can vary depending on the teaching philosophy, so further studies should explore and compare students from different settings to find out the more effective ways to cultivate students' interest in STEM learning while using the iSTEMiP framework. Educators have the responsibility to create opportunities for students to apply what they have learned in STEM education to solve real world problems. It is also important to explore the possibilities of using ICT tools such as artificial intelligence (AI) to increase the effectiveness of student learning. Using artificial intelligence to help personalized learning targets for students with different learning capabilities may help improve the effectiveness of STEM learning projects and allow teachers to be more accurate when helping individual students. Future studies should also look into the effect of teachers' background on the effectiveness of cultivating students' STEM learning interest. The practical aspect such as motivation for teachers to adopt STEM learning activities into their curriculum should also be studied to understand how schools can promote STEM education in a more sustainable way. Lastly, administrators who would like to promote STEM education should understand that STEM learning is more than just making a science model but a process of developing creativity, critical thinking, collaboration, and communication skills. For the limitation of the study, the sample size is limited as one class of students. It leads to the difficulty of generalizing the findings to other settings.

CONCLUSION

For implementing STEM projects in primary school, based on the major findings of the study, it is recommended to design a rich content task for students so that multidisciplinary knowledge could be embedded as an integrated STEM subject. Time allowed for students to explore, to guess, and to testify their constructions, is critical that it takes time for the students to develop knowledge by doing. Moreover, the collaboration among groups is important for students to have peer supports. In the study, almost six months after this STEM project, the students were still talking about how excited they were when they launched their rocket higher than the tallest building of the school. As the first STEM project in the primary school, this was nowhere near perfect, and a lot of adjustment needs to be made for the next academic year. From the interview, we could see that despite the findings and challenges of the project, most of the students gave very positive comments about the experience. As enhancing the students' interest in science, technology, engineering and mathematics was one of the intended learning objectives we could claim that the results showed that this project was successful. The students enjoyed the learning experience, and it definitely enhanced their learning motivation. Perhaps this kind of project could be further considered to be embedded into the regular curriculum in which the critical features of iSTEMiP framework could be used to guide teachers to analyze, to reflect and to design STEM activities in classrooms.

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