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Research paper

Robotic Prototype and Module Specification for Increasing the Interest of Malaysian Students in STEM Education

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Abstract

The aim of this paper is to develop a robotic prototype and module specification for STEM programs through survey with STEM teachers in Malaysian schools. The target ratio for the number of students enrolling for STEM programs was not met in Malaysia for the 2015/2016 academic year. The main contributing factor is due to fear and low self-esteem although the students were qualified to pursue the STEM stream. The main objective of this paper is the development of a low-cost robotic prototype and module specification for increasing the interest of Malaysian students in STEM based on the Malaysian school curricula. To achieve this, survey forms were collected from the teachers to determine the main requirements for the modules. The main requirements identified from the survey were based on the quality of the module such as interesting, related to the Malaysian school curricula, easy to understand and implement, and low in cost. Based on these requirements, a low-cost robotic prototype and module specification were developed to promote deep learning through hands-on activities. This robotic kit has the capability to increase and sustain the interest of Malaysian students in STEM programs by providing learning-by-doing approach.

Keywords: *Game-based learning; Robotic Module; STEM education; Survey; Teacher Perception.*

1. Introduction

Robot programming involves designing the controller that governs robot behaviour. The growth of robotics is considered very important as it pools the whole areas of STEM that engages students in hands-on experience and to apply the knowledge in STEM. In Malaysia, the STEM program was launched in the 1970 by the Ministry of Education. However, based on the 2014 findings, the current ratio between STEM and non-STEM students is still far away from the targeted ratio (60:40) due to the lack of awareness among the students of the value in STEM learning and its relevance to everyday life and content-heavy curriculum. Article from [1] shows that the current ratio in Malaysia is 21:79, where only 21% of the students have enrolled in STEM courses. According to MIT, USA, coding has become the new literacy, where children must learn to design and create digital technology via honed skills such as programming. This is where robotics play a role in STEM education because apart from honing STEM skills, it also adds fun and creativity into the mix.

Robotic programming module can improve the skills and ability of the students in terms of their cognitive, affective and psychomotor domains. Many researchers have studied and found that robotics is an ideal platform for the learning and teaching of STEM, and also in enhancing the students' interest in STEM. In [2] study, there has been an increase in achievement in students aged 9-11 who are exposed to robotics compared to students who are not exposed to robotics. Through Primary School Standards-Based Curriculum (KSSR) and Secondary School Standards-Based Curriculum (KSSM), a robotics- based education program was implemented by the Ministry of Education and Ministry of Science Technology & Innovation (MOSTI). This robotic program was conducted at the primary, secondary, matriculation, and university level. However, the robotic module should not only be tailored to the current school curricula as it is one of the main issues in implementing the module in the schools [3] and the robotic kit that is used with the module should also be affordable, but also that the module should be designed to be edutainment. Therefore, the main objective of this paper is the development of a low-cost robotic prototype and module specification based on games for increasing the interest of Malaysian students in STEM based on the Malaysian school curricula.

2. Literature Review

Increasing the number of Science, Technology, Engineering and Mathematics (STEM) graduates is currently a national priority for many governments worldwide, not only in the United States [4] and the UK [5], but also in Malaysia. The country needs to increase the promotion about STEM education since the target ratio of 60:40 for the number of students enrolling for STEM and non-STEM programs in Malaysia has not been met[6]. It is important to capture the students' interest in STEM content at an early age because it can ensure that the students are on track through middle and high school to complete the needed coursework for adequate

preparation to enroll in STEM degree programs at institutions of higher learning [7]. This interest could also lead the students to pursue their careers based on STEM education [8]. In order to meet the challenges in increasing and sustaining the interest of Malaysian students in STEM, a lot of work has been done such as organizing programs to promote STEM for example, PestaBentara STEM [9] and Perkhemahan Klik dengan Bijak [6] and developing mobile applications for Science textbooks for example iSains [10] and E-Star [11]. In addition, one of the effective ways to engage young minds in STEM disciplines is to introduce the robotic kits into the primary and secondary education [12]. Robotics is seen by many as offering major new benefits in education at all levels [13] and the emphasis should be on robotic courses based on learning-by-doing approach as it can increase the effectiveness of the course [14]. The most widely used robotic kits are for example LEGO Mindstorm [15], VEX Robotics [16] and Fischertechnik [17] which are quite expensive. However, since affordable robotic kits can be designed such as eSMAC robotic kit [4] and AERobot [18], there is a need to design an affordable, low-cost robotic kit to be used with robotic programming module so that it is accessible to many students.

The module to be used with the low-cost robotic kit must also be interactive. [19] had designed a programming environment with three levels of complexity for mobile robotics and [20] also had designed a workbook for students at all levels. However, their modules did not consider the element of gamification which is also crucial to get more engagement from the students. Gamification is an emphasis on the teaching and learning process to be more engaging, interactive, edutainment and to increase students' involvement using game methods. In addition, the generation of students now is more interested in learning based on games. They are more interested in learning something by using game-learning concepts as found in many applications developed today. Furthermore, most of them have been exposed to game-based applications since childhood. Game-based learning is also found to increase the reaction, movement of the hands and eyes and the imagination of children. Their curiosity will also grow and this is a positive impact on the growth of children. So, this study will adapt the game-based learning concept using robotic technology. However, before designing the module, the survey forms were collected from teachers in Malaysia to determine the main requirements for the modules.

3. Methodology

The main phases of this study are:

Phase 1: Conduct survey for STEM teachers to identify the requirements for the STEM modules.

This study was conducted by distributing questionnaires to teachers when the teachers attended the STEM workshop at the National Science Centre. A total of 70 questionnaires were distributed, however only 67 returned the questionnaires. The sample consisted of female teachers (N=47) and male teachers (N=20). Five Likert-type surveys including their opinions about the STEM program were given to the teachers.

Phase 2: Develop robotic prototype and module specification. The development of this specification is to achieve two main purposes of teaching and learning STEM as stated in [21] which are, (1) to apply and integrate knowledge, skills and STEM values with correct and deep understanding in their lives, community and environment through inquiry or problem solving and, (2) to encourage students to cooperate as a team.

4. Results and Findings

This section will present four parts: Demographic Analysis, Teacher perception, Discussion, Robotic prototype and Module specification.

4.1. Demographic Analysis

70% were female teachers while 30% were male teachers from the 67 respondents. According to the statistics by [22], the number of female teachers in schools is higher than the number of male teachers in the elementary school, secondary school and matriculation. Based on Figure 1 below, majority of the teachers are aged between 36-40 years (40%), followed by teachers aged between 31-35 (34%). Teachers aged 40 and above are 24% while the rest are between 25-30 years old (2%). Figure 2 shows that majority of the teachers have over ten years of experience (61.2%). Meanwhile, teachers with experience between 6-10 years are 29.9% while the rest is between 1-5 years, which is 8.9%. Most of the teachers were from normal high schools as shown in Table 1.

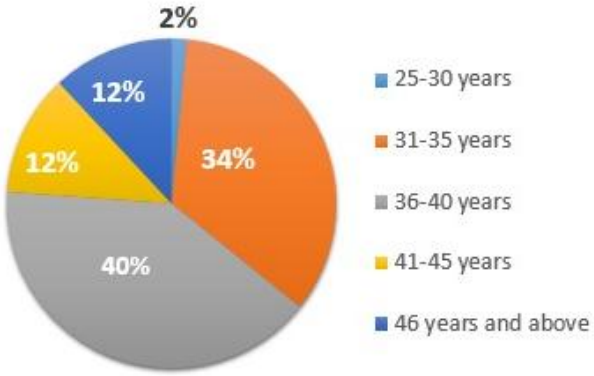

Fig. 1: Percentage of Teachers' Age

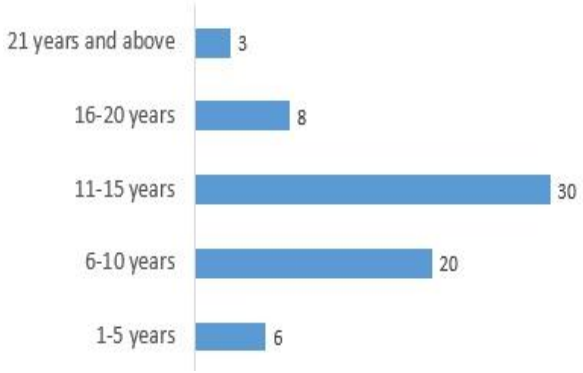

Fig. 2: Percentage of teachers' experience

Table 1: Number of teachers and types of school

Type of School	Frequency
National School	2
National-type Tamil School (T)	0
National-type Chinese School (C)	1
Religious school	7
MARA Junior Science College (MRSM)	0
Normal High School	55
Boarding school	0
Technical secondary school	1
Vocational school	1
Total	67

All of the teachers were from schools in Peninsular Malaysia as shown in Figure 3. 24% of these teachers taught in rural areas while the remaining 74% taught in urban areas. On the academic basis, these teachers indicated that they were diploma graduates (3%), bachelor's degree graduates (93%), while the rest had a master's degree (4%). These teachers have specialisation in STEM programmes. Figure 4 shows that majority of these teachers have specialisations in mathematics, followed by science while the rest are in Engineering and Information Technology (IT).

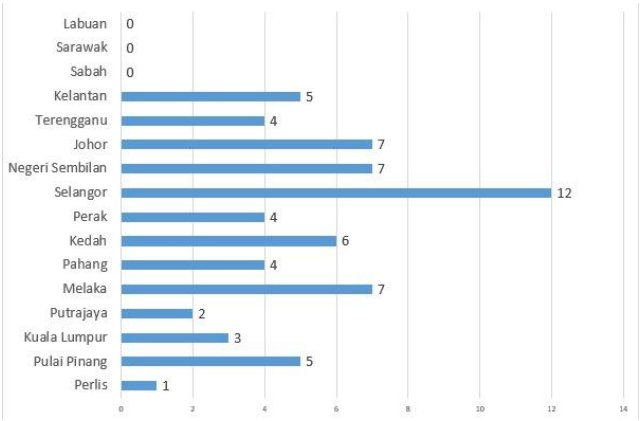

Fig. 3: Number of teachers from each state

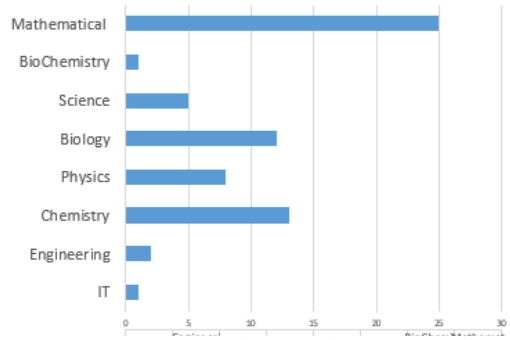

Fig. 4: Number of teachers for each STEM field

4.2. Teacher perception

The data obtained showed that 75% of the teachers stated that learning in schools has increased the students' interest in STEM. Meanwhile, 25% of the teachers denied it. These results might be related to the availability of STEM modules in school. As many as 43% of the teachers said that they did not have any STEM module. Meanwhile, 57% of the teachers stated otherwise. Modules available in school are HEBAT modules, KBAT modules, 21st Century Modules and a number of modules provided by the school and the District Board of Education (PPD). However, most teachers stated that although the modules were given to them, due to the constraint of time to be spent on the syllabus, activity modules that might increase the interest of students in STEM could not be implemented in the classroom.

Table 2 shows the perception of teachers towards the factors that influence students to choose the science stream. The factors that discourage students from choosing the science stream are shown in Table 3. In addition, an experienced teacher added that one of the reasons which discourage the students is the thinking ability of the students which does not reach the critical thinking level and hence makes it difficult for them to master the concept of science. The teachers also had their own specifications towards the STEM modules as stated in Table 4.

Table 2: Factors that influence students to choose the science stream

Item	%
1) STEM courses are COMPULSORY	32.4
2) STEM courses are fun	16.2
3) The students have the ability and qualification to enroll in the STEM stream	28.6
4) STEM courses benefit the students	22.9

Table 3: Factors that discourage students from choosing the science stream

Item	%
1) Difficult courses	29.3
2) Not qualified to take the courses	24.4
3) Not interested	41.5
4) Burdensome courses	4.9

Table 4: Module specifications based on teachers' perspective

Specification for STEM modules
• Easy
• Compact
• Attractive
• Hands-on
• Appropriate to the syllabus of learning
• Modules according to specific courses
• Can be applied both inside and outside the classroom
• Cheap by using used items
• Conceptual DIY and affordable
• Graphic Informative Module
• Design and innovation modules
• Robotic modules
• Creativity modules
• Modules that make mathematics and science easy
• Modules that include videos
• Modules for different levels of students (Low and high)
Low level module - helps students to identify with STEM
High level module - explore more about STEM
• STEM modules based on games
• Interactive modules

4.3. Discussion

The results showed that the teachers are composed of experienced teachers. This is important because teachers' factors also plays a role in increasing the students' interest in STEM. According to [23], the teacher is the second major factor affecting the difference in students' achievement after the students' own self-esteem. According to [24], teachers' quality has influence and teachers play an important role in increasing the students' commitment to their education.

The study conducted by [25] found that there is a positive impact in the use of the cartoon module method where students' achievement is higher and statistically significant compared to the achievement of students involved in the learning of textbook method only. This is because, the module is suitable for the students' interest. Therefore, an appropriate approach for the students needs to be done to increase their interest in the learning of STEM, as well as to increase their achievement in the subject.

However, robotics learning in schools has not been formally applied. The researchers found that there are several school criteria related to robotics. First, schools have LEGO robots yet do not optimize the use of the robots since they do not have directional modules. Second, schools have LEGO robots but students are required to pay a fairly expensive fee since teachers would use the service of private companies for teaching LEGO robots at school. Third, schools do not have LEGO robots but students are interested in robotics since schools do not have the funds to buy the LEGO robots. Therefore, the need for modules needs to optimize the use of robotics in schools and other methods that need to be considered in order to replace the robotic LEGO with a cheaper and more affordable robot.

Based on the research findings, the researchers feel that there is a need for a module that includes the specifications of the module. The module will be based on the Arduino robot which have the following specifications:

- Hands-on
- Conceptual game
- In accordance with the syllabus of the lesson
- Cheap and affordable
- Interactive and extendable modules
- Can be applied outside class time

To ensure that the momentum of the students' interest in STEM is maintained, the researchers feel the need for a continuous learning method from high school to the university level. Hence, the continuous modules need to be built with a low cost using robotic Arduino. The reason why the researchers feel that it should be continuous from the low level (Form 1-3) is to help them choose the science stream rather than arts stream. Meanwhile, its imple-

mentation in the upper secondary (Form 4-5) is to help them choose the STEM stream at the university level. Its implementation at the university level will help those involved in programming and empowering STEM. The advantages of this module are to have a direct relationship with the Malaysian curriculum and the concept of game. Prototype robots have also been developed which is to build 4 tanks (based on the Arduino robots) by applying mathematical learning which is the use of angles. Students will learn the use of angles by using this robotic game concept. This game can make the module more effective since the students are able to apply and integrate the knowledge, skills and STEM values with this robotic module, and thus be an effective module. Furthermore, effective teaching and learning of the STEM programme can attract more students into the STEM field at the school level, higher education as well as in addressing the challenges and competitiveness in global ranking [21]. This effort is in line with the aim of the Malaysian science education which is to make science more appealing to the students and indirectly invite more students to pursue their studies in science-related areas to realize Malaysia's goal in becoming an industrialised country [26].

4.4. Robotic Prototype and Module Specification

In the beginning, this study focuses on the basics of computer science and mathematics. The title of the first module is Save our robots! In this module, mathematics (angle) and computer science knowledge will be applied in order to win a robotic game. The outcome of this module is that the students can apply the concept of mathematics and basic programming in solving problems in a real situation. The details of the module are given in Table 5.

Table 5: Module specifications for Save our robot! game

Step	Activity	Note
1	State the problem according to the given situation: how to properly set the robots.	Integration of knowledge in mathematics (angle), computer science (logic in programming) and problem solving skills.
2	Generate ideas to solve the problems: Identify the value of angle in order to defeat their enemies based on their location. Identify the flow of logic in implementing the value in an Arduino editor.	
3	Generate creative ideas in the form of sketches in designing an Arduino-based robot.	Integration of knowledge and deep skills in technology, engineering and maths
4	Choose a sketch for the Arduino-based robot.	
5	Identify the type of tools and materials based on the requirements to build the Arduino-based robot.	Integration of knowledge and deep skills in technology, engineering and mathematics.
6	Build, test and improve the Arduino-based robot.	
7	Build robotic programming using mBlock and test it using the developed Arduino-based robot.	
8	Start the Save our robots! game using the Arduino-based robot. The rules of the game are: 1. Each player needs to place their robots on the field which is the game board (Figure 5).	

Fig. 5: The Game Board for Save our robots! Game.

Only one corner value is allowed per round.
The players must upload their angle as soon as the referee gives the directions.
A player will be knocked out if another player shoots.
If two players collide with each other, no player will be eliminated.
The referee will measure and determine whether a player is knocked out or not.
The winner is the last player to survive on the playing field.

The specifications of the robotic prototype are given below:
1. Arduino Nano
2. Extension for Arduino Nano
3. Servo Motor
4. Jumper wire
5. 3D Printed casing for Arduino and Servo Motor

Figure 6 illustrates the robotic prototype in this study. This robotic prototype works by rotating at the predetermined angle of the program. A servomotor is a rotary actuator or linear actuator which allows for precise control of angular or linear position, velocity and acceleration. It consists of a suitable motor coupled to a sensor for position feedback. The servo motor used in this robotic prototype can turn to 180 degrees rotation.

Besides the Arduino platform, the robotic prototype has a web-based application called mBlock. This block programming can generate the Arduino code automatically through the blocks. Once this application is opened, students can choose the block depending on what Arduino function is needed. For example, once a servo block is choosen, the Arduino code will be automatically generated in the provided text area. For additional looping or selection statement (for example if, for), the students may type the instructions by themselves. The code can be used and uploaded to Arduino without any error. All the declarations are also automatically generated.

Researchers hope for the further research, robot designs are more attractive than current robot. Robots that will be developed next will be more robotic components used and allow students to use the component for another course.

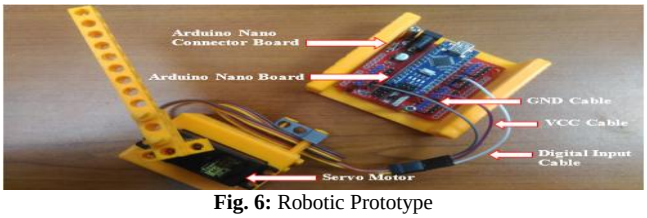

Fig. 6: Robotic Prototype

5. Conclusion

With robotic modules that meet the specifications and fulfill the needs of the students and teachers expect, robotic usage can help the learning of STEM and can attract students to choose the science stream. It is hoped that the 60:40 policy could be achieved and the Malaysian Education Blueprint 2013-2025 [27] could be implemented well. The output of the research is robotic programming module specifications and robot prototype specifications. The significant outcome of this research is that it can efficiently raise students' interest that meet the Malaysia Education Blueprint 2013-2025.

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