ROBOTICS COMPETITION-BASED LEARNING FOR 21ST CENTURY STEM EDUCATION

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ABSTRACT

This article proposes the Robotics Competition-based Learning (R-CBL) in the 21st century learning environment to integrate Science, Technology, Engineering, and Mathematics (STEM) education. This study has an attempt to highlight the connections between the STEM disciplines as well as the integration of 21st-century competencies to spark students' interest towards the STEM. The problem statement revealed in this article is Malaysia may soon experience a serious human capital deficiency in the STEM field. Thus, it is important to practice a new pedagogy for 21st century integrated STEM education. The objectives of this study is to investigate the effectiveness of R-CBL to increase students' interest towards STEM in "Robot Olympics Malaysia 2018". The finding in this research shows the educational robotics as the digital tool can promote STEM learning among secondary school students. In conclusion, by practising Robotics Competition-based Learning in 21st century STEM classroom, learners are expected to have attentiveness in the integrated STEM curriculum. The implication of this pedagogy is to bridge the gap between the expected curriculums, written curriculum, and taught the curriculum.

Keywords: *robotics, competition, STEM education, 21st century*

1.0 INTRODUCTION

Since the 21st century, Malaysia economy moves from a manufacturing-based economy to an information and service-based economy, thus the demand for a workforce well educated in science, technology, engineering, and math (STEM) is growing. Unfortunately, the number of students who choose STEM fields continues to decline has to impact on the shortage of high-quality human capital (Goy et al., 2017; Meerah, Halim, & Nadeson, 2010; Selvaratnam, 2016). In Malaysia, the targeted 500,000 skilled STEM workers would only make up 3% of our expected total workforce of 15 million in 2020 (Ministry of Science, Technology and Innovation, 2015). According to the report, only 28% of the country's workforce comprised highly skilled STEM workers in 2015. The ministry also revealed that only 21% of students in the country were eligible to take up STEM-related courses. Therefore, research on integrated instruction that focuses on Science, Technology, Engineering, and Mathematics (STEM) is important, because the jobs of tomorrow are rooted in STEM fields. Although the written curriculum developed by the Ministry of Education (MOE) specifically states that STEM education includes three main components which are knowledge, scientific skills and scientific attitudes (Education, 2016), however, there is a gap between the aspired curriculums, taught the curriculum and examined curriculum. The taught curriculum does not reflect these three focuses very well and the examined curriculum did not reflect this balance in integrated STEM education either.

Educators are always searching the best pedagogy to improve students' achievement, skills, and attitude toward learning STEM subjects, however, there are few quantitative studies showing the effectiveness of using Robotics Competition-based Learning and even those few often conclude by stating the need for further studies. This paper is intended as a reflection with many unanswered questions. This paper presents the sustainable Robotics Competition-based Learning program, its implementation, development, and evaluation highlighting the process recommendations to apply the program to Malaysia institution. It is hoped that this will initiate a discussion, and if it emerges that robotics has a useful place in a sustainable world, and increased attention from education policymakers.

Competition-Based Learning is transformed from project-based learning, while still involving teams of students in an open-ended project. The purpose of integrating competition components into project-based-learning is to generate motivation in the students to have the best overall project and eliminate the tendency of just doing enough to get by. This paper highlights the first Robot Olympics Malaysia 2018 organized by SMJK Yok Bin, Melaka, which is aligned with the vision of World Robotics Olympiad (WRO) (WRO, n.d.). The project includes design, analysis, and laboratory components in order the promote STEM learning. A brief summary of the learning styles results is presented with some qualitative data for justification, while the results of the post-survey provide some quantitative data on the effectiveness of the project.

This paper proposes two questions about the framework.

1. How does the Robotics competition-based Learning impact on 21st-century STEM education?

2. What are the 21st-century competencies developed in the "Robot Olympics Malaysia 2018"?

2.0 LITERATURE REVIEW

In recent years, robotics education is commonly used as an attempt to motivate, engage, and increase the retention of students in the process of learning especially in STEM education(Alimisis et al., 2010; Cappelleri & Vitoroulis, 2013; Eguchi, 2014; Sklar, Eguchi, & Johnson, 2015) To maximize the learning experience, a new strategy is introduced to promote the intellectual development (Murphy, 2000) of the students from elementary to university level, which is robotic design competitions(Fike et al., 2016; Krithivasan, Shandilya, Arya, et al., 2014; Krithivasan, Shandilya, Lala, & Arya, 2014). Figure 1 illustrates a conceptual framework of Robotics Competition-based learning to enhance integrated STEM education in 21st century classroom. Practicing Robotics Competition-based Learning in STEM classroom calls for a considerable social interaction; thus, allowing the students to refine one another's ideas, to articulate their own and to achieve new and valuable insights. This Robotics Competition-based Learning framework is the result of a combination of project-based learning in STEM education and Robotics competition. Below is the description of each component in detail.

2.1 Integrated STEM Project-based Learning

This framework describes the integrative STEM disciplines in term of knowledge, and attitudes and skills which the students should master to succeed in work and life in the 21st-century. By using the planetary gear system, it is believed that the integrative STEM education in the 21st-century classroom could be enhanced. In engineering, a planetary gear is one of the epicyclical gears, which is a gear system consisting of one or more planet gears, revolving about a central sun gear. The planetary gear is a widely used industrial product such as automation system with outstanding power transmission efficiencies. Figure 1 presents a planetary gear with four planets, in this case, is a scientific concept, engineering design, mathematical thinking, and technological literacy. The sun (central) gear is illustrated as project-based learning. The outermost gear which is the ring gear meshes with each of the planet gears is considered as a 21st-century classroom. The four disciplines of the STEM are applied in the classroom to embed 21st-century skills in students.

To complete this system, the planet gears are held to a cage or carrier that fixes the planets in orbit relative to each other. Thus, the cage in this design is described as the integrative STEM education. In a simple planetary setup, input power turns the sun gear at high speed. The planets, spaced around the central axis of rotation, mesh with the sun as well as the fixed ring gear, so they are forced to orbit as they roll (Cooley, C. G., & Parker, 2017). A complex relationship between the gears system must work in harmony to ensure the integrity of the entire system. STEM educators should have a strong understanding of the relationship that can be established across domains and by engaging a practice using robotics as a tool. The advantages of planetary gears are only been realized if the individual planets carry the nearly equal load. Thus, this framework proposes the equality of each STEM disciplines and the harmony among them towards an effective 21st-century STEM classroom.

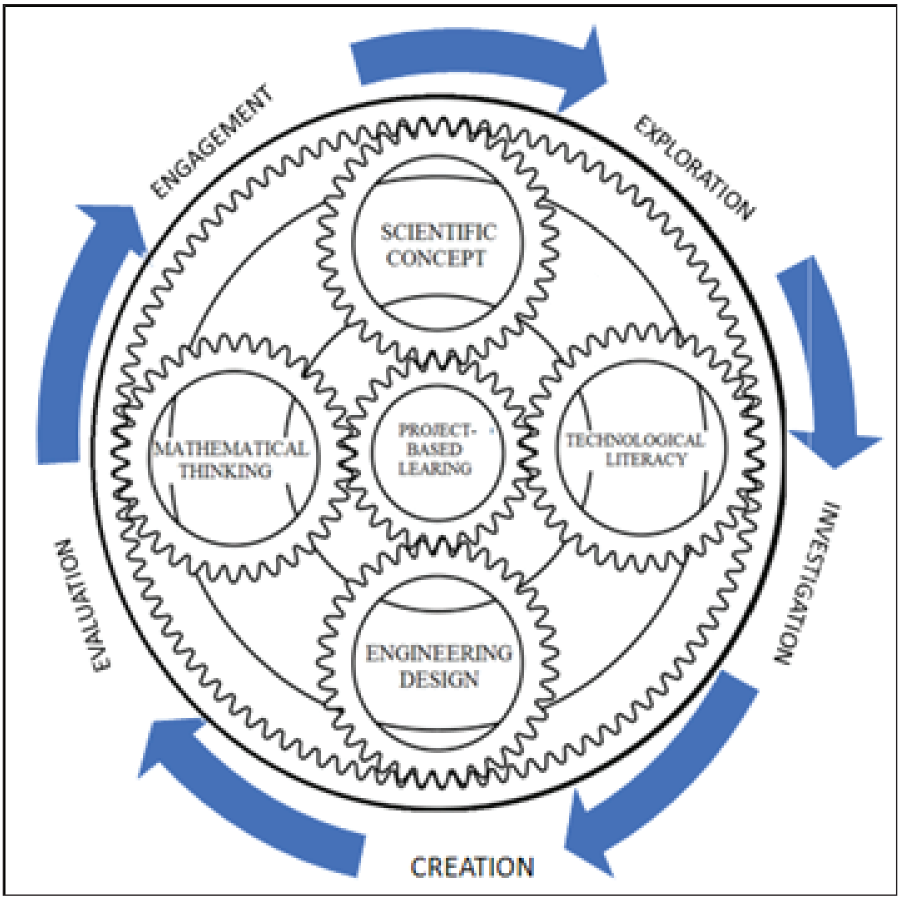

Figure 1: Robotics Project-based learning framework

2.2 Robotics Competition-based Learning

In the new Malaysia Education Blueprint 2013-2025, a new standardized curriculum is introduced, known as Primary School Standard Curriculum (KSSR) and Secondary School Standard Curriculum (KSSM), which emphasize the effective teaching and learning of STEM (Division, n.d.; Harris, 2014; Issa et al., 2014).A range of pedagogical approaches has been recommended as the most effective ways to engage learners in developing this STEM education. The Robotics Competition-based Learning instructional approach seems very well situated to become the primary model of instruction in the next century, and educators are well advised to get on board with this innovative approach to teaching [13]. Achieving excellent student learning outcomes has been the driver behind how the Robotics Competition-based Learning is planned, defined, and implemented.

The purpose of designing the robot is to enhance students' learning in STEM subjects and to embed their interests towards STEM. This newly enhanced project is a powerful learning platform to enable students to cope with skills that are essential for success in the 21st century. This project can strengthen the 21st century problem-solving and social skills that are critical for success in further studies and future careers including creative and critical thinking, collaborative teamwork skills, interpersonal communication, and problem-solving (Bermúdez et al., 2019; Chen et al., 2015; National Education Association, 2014; Remijan, Remijan, & Township, 2016). Through competition-based Learning, students are trained to work together with spirits of creative collaboration and solve challenging problems through hands-on experience or investigation. In the process of building a robot, students can develop systematic thinking as they plan and implement programs and at the same time, to promote their logical thinking skills through the programming of robots. On the other hand, this project can enhance students' creativity in problem-solving and raise their awareness to the many possible ways of arriving at the desired results by self-reflection on the outcomes.

3.0 METHODOLOGY

The Robotics Competition-based Learning educators have focused the integration of 21st century competencies in the subject in the scope where robots are deployed. The project "Robot Olympics Malaysia 2018" is aligned with the STEM integration idea. The vision of Robot Olympics Malaysia is to bring together students from all over Malaysia to develop their creativity, design and problem-solving skills through challenging and educational robot competitions and activities (WRO, 2017.).

There are total five projects in Robot Olympics.

Project 1: Robot Racer

The students need to build a robot to climb up slope at maximum speed and knock down three plastics balls. Students can design the robot with gears to increase its speed while maintain its stability.

Project 2: Robot Bowler

The students need to build a robot capable of shooting one plastic balls towards the bowling pins. The robot which can make the most pins collapse is the winner.

Project 3: Robot Archer

The students need to build a robot to drive forwards and stop in the center of a bull's eye. The closer the robot to the center of the bull's eye, the highest the score.

Project 4: Robot Tug of War

The students need to build a robot to pull another robot when connected with a string in a tug of war contest across a center line. The concept learned in this project is the friction, tension and stability.

Project 5: Robot SUMO

The students need to build an autonomous, self-contained mobile robot that can push its opponent out of the specified ring. The concept learned in this project is force and power.

In this research, the treatment group consists of 280 students who participated in Robot Olympics, while comparison group consists of 120 students of same age/grade level who were not participate in Robot Olympics. the Participant Attitudes towards STEM Survey (S-Survey) is used. The survey was developed by the Friday Institute (2012) and is intended to measure changes in participant confidence and efficacy within STEM subjects of different level of students. The survey investigates students' interest in STEM careers as skill-based learning within the following constructs (including construct reliability levels using Cronbach Alpha): Math (6 questions, 0.860), science (6 questions, 0.824, engineering and technology (6 questions, 0.848). The survey was administered and scored by a clerk who works for the school who was not directly involved with the study.

4.0 FINDINGS AND DISCUSSION

Project 1:	Robot Racer
Mathematics Concept	gradient, angle, ratio
Science Concept	Friction, centre of gravity, speed
Technological Literacy	Turn on the motor(s) for 180 degrees Use 100% power on the motor to make the robot goes faster
Engineering Design	Design a robot with lower centre of gravity
Results	The winner of this project reached the destination and hit all the balls in 3.5s

Figure 2: The best Robot Racer

Project 2	Robot Bowler
Mathematics Concept:	Probability and percentage , Robotic aim and accuracy
Science Concept	Force, momentum
Technological Literacy	Turn on the motor(s) for 180 degrees Use 100% power on the motor to make the ball go farther.
Engineering Design	Hitting the ball straight on, like a billiard/pool cue Throw the ball, as a human (or catapult) would Either a motor powered kicker or a spring loaded system can be used.
Results	The winner of this activity could target the pins accurately and hit all the pins within 1.2s.

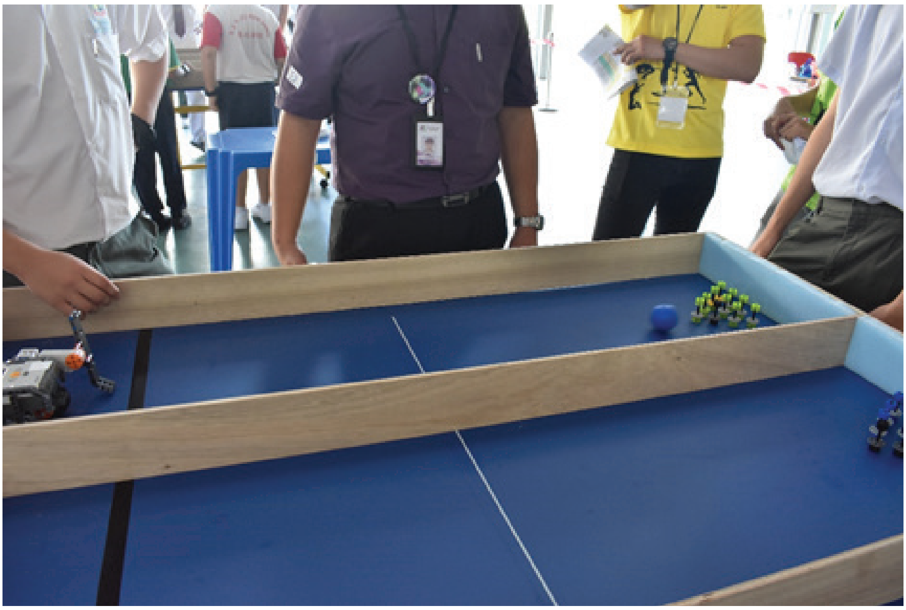

Figure 3: The robot is striking the ball to the pins

Project 3	Robot Archer
Mathematics Concept:	Rotation, ratio, circumference
Science Concept	Distance, speed, stability
Technological Literacy	Turn on the motor(s) for 180 degrees Use suitable power on the motor to make the robot moves in a straight line and stops at a fixed distance. .
Engineering Design	Small and stable robot
Results	The winner of this project is the small-sized robot which can move at fastest speed and stop completely inside the bull's eye in 4.2s. .

Figure 4: The robot is moving towards the center of the bull's eye

Project 4	Robot Tug of War
Mathematics Concept:	Equilibrium
Science Concept	Force, tension, friction
Technological Literacy	Turn on the motor(s) for 180 degrees Use 100% power to drive the robot backwards .
Engineering Design	Large and strong robot which can produce a large pulling force and prevent slipping
Results	The winner of this project is a strong, large-sized, heavy robot which can pull the opponents towards it.

Figure 5: Two robots are pulling at the greatest power

.Project 5	Robot Sumo
Mathematics Concept:	ratio
Science Concept	Force, power, speed, momentum
Technological Literacy	Turn on the motor(s) for 180 degrees Use 100% power to drive the robot forwards
Engineering Design	Large and strong robot which can produce a large pushing force and large momentum
Results	The winner of this project is a strong, heavy robot which can push the opponents in the shortest time.

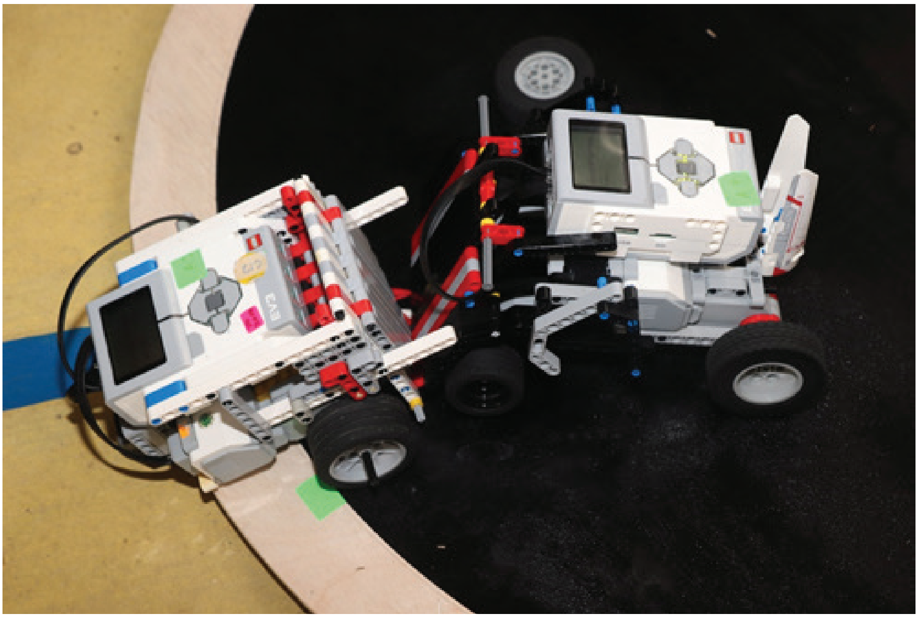

Figure 6: Two robots are pushing each other

The adoption of educational robotics as part of a curriculum development plan must be based upon documented opportunity, feasibility studies, and customized technology solutions designed for the Malaysia educational system, preferably by local engineers, educators and policy-makers. The dynamics of the 21st century presents a myriad of challenges that require education collaboration be at the core of knowledge production and technology innovation.

In this robotics competition, there is an open session which require participants to do a presentation on their robot design. The project with total 100 points is judged on the following aspects: project creativity and quality (50 points), programming (45 points), teamwork (20 points), engineering design (45 points) and presentation skills (40 points). Figure 7 summarized the weightage of each aspects in percentage.

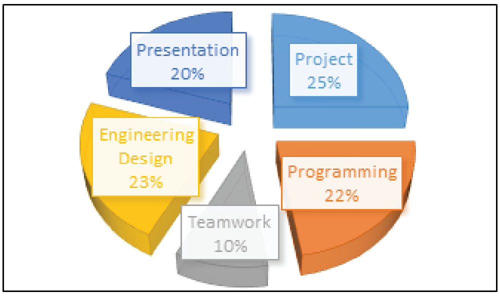

Figure 7: Judging criteria for open session

Table 1 summarized the stages in Robotics Competition-based Learning with compatible 21st Century Integrated STEM Education to enhance students learning.

Table 1: Robotics Competition-based Learning with 21st Century Integrated STEM Education

Stages in R-CBL	21st Century Competencies			
	Scientific Concept (Life and career skills)	Technological Literacy (ICT skills)	Engineering Design (Creativity)	Mathematical Thinking (Critical Thinking)
Engagement Stage	Provided with an open-ended problem	Identify the technological tools to be used	Identify problem and issues involved	Identification, representation of a mathematical problem.
Exploration Stage	Answer simple questions regarding the science concept	Get familiar with the robot, controlling devices and software.	Make hypothesis and test their validity in real conditions	Transform the questions into mathematical solution

Investigation Stage	Reconsider scientific problem and issues	Search for resources and use alternative ICT	Undertakes systematic steps to solve problem	Formulate the driving questions
Creation Stage	Share their initial ideas based on the scientific theory.	Apply alternative solutions and argument on their final proposals	Present their work on the synthesis of a final 'product'	Express their outcomes using mathematical language.
Evaluation Stage	Self-evaluation and scoring by the teachers	Solutions using software are presented and evaluated	Critically judge their work,	Compare the students' works in numerical form

To answer the second research question, the survey is analyzed quantitatively. When examining the descriptive statistics obtained from the survey results, the treatment and comparison groups demonstrate that the intervention measure lead to differences in results.

Table 2: Descriptive Statistics

	Treatment group	Comparison group
Science Mean Scores	23.5	22.8
Mathematics Mean scores	22.6	22.3
Technology and Engineering Mean Scores	24.2	20.2

The treatment group shows slightly higher scores in science, mathematics, technology and engineering aspects compared to comparison group. In general, it appeared there was a slight boost in interest in math, science, and engineering and technology associated with the robotics competition-based learning, The use of robots, especially resulted in a slightly significant difference on engineering and technology interest among students who participated in Robot's Olympics Malaysia when compared to the mean score on the same indicator for the group not participate in the event.

4.0 CONCLUSION

This paper is to promote Science, Technology, Engineering and Mathematics (STEM) education in line with Malaysia's national vision to produce highly skilled workers to meet the demand of the 21st century. The focus of the paper is on current educational provisions and what is needed to secure well-prepared, creative and innovative high-quality human capital to become a developed nation by 2020 (Hussin & Ali, 2016). The impulse of the science education community and policy-makers is to grab hold for entire life or be marginalized from subsequent discussions about the necessity and consequences of using STEM initiatives to prepare and inform our next generation of citizens (Zeidler, 2016). However, the prior challenge to implement this framework is the shortage of quality STEM educator with educational robotics skills. 21st century communities face intensifying development challenges and competing priorities for finite resources. Robotics for sustainable development is an exciting challenge where research and industry in both developed and developing countries can equally contribute and benefit (Grau Saldes, Bolea Monte, & Sanfeliu Cortes, 2014). Thus, the solution for the practitioner is to initiate new transdisciplinary activities in technology-sustainability-education, to achieve excellence in technology-sustainability-education, and to graduate the first-grade engineers with sustainability as a generic competence. As a jump-start, by using educational robotics as a tool in Competition-based Learning pedagogy, this paper suggests a solution tap into integrated Science, Technology, Engineering, and Mathematics (STEM) for secondary science stream students to engage with these subjects authentically. Finally, is it hoped that robotics could be developed from a combination of classical and sustainable technology and a new application in STEM education. It is believed that through Robotics Competition-based Learning, a quality integrated STEM education could assist students to integrate knowledge, skills and good attitude in the 21st century learning experience.

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