Promoting Students' Interest in STEM Education through Robotics Competition-based Learning: Case Exemplars and the Way Forward

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Received first draft 16 February 2019. Received reports from first reviewer (16 May); second and third reviewers (13 and 16 December). Received revised draft 24 December. **Accepted** to publish 24 December 2019.

Abstract

Robotics Competition-Based Learning (R-CBL) is transformed from project-based learning, while involving teams of students in an open-ended project with competition as the outcomes. The integration of competition components into project-based-learning is to enhance the interest and motivation of students to present the best product. The main aim of this study is to examine whether Robotics Competition-based Learning in the context of International Robot Olympics Malaysia 2019 (IROM'19) would impact on students' interest towards STEM learning. The sample size consisted of 200 participants aged 10-16 who answered the survey voluntarily to show their interest towards STEM. The data were collected through open-ended responses of survey, formal and informal observations as well as semi-structured interviews. The study indicated a positive change in students' attitude towards STEM specified in engineering and technology constructs after the Robotics Competition-based Learning.

***Keywords**:* Robotics; Competition; STEM education

Introduction

Background and Rationale

Malaysia may soon experience a serious human capital deficiency in the STEM field, where the same problem is faced globally. Thus, it is important to practise a new pedagogy in Malaysian education system to fulfil the industry revolution needs. In 2005, Ministry of Education of Malaysia introduced the robotics education through co-curricular activity that emphasized the creativity and innovation among the school students from primary to secondary school (Jawawi, Mamat, Ridzuan, Khatibsyarbini, & Zaki, 2015). The initiative was then enhanced by annual National Robotics Competition (NRC) which was aimed to encourage participants to apply higher-order thinking skills (HOTS) to solve problems and to promote science and technology education among the students. Recently, robotics education in Malaysia has an important role in STEM education by providing resources that are engaging the young learners, which enable the educators to deliver integrated STEM and hands-on curriculum (Hussin, Pang, Rosly & Omar, 2019).

The robotics education encourages creativity and problem solving while strengthening the abilities and skills needed for students to be successful in the core classroom (Eguchi, 2015; Khanlari, 2013). Informal Integrated STEM education through project-based learning involving the engineering design effectively increase students' interest towards STEM subjects (Shahali, Halim, Rasul, Osman, & Zulkifeli, 2017). Robotics competitions play a role in an informal educational context that offers a lot of opportunities for 21st century learning and it proposes a new learning pedagogy. The Robotics Competition-based Learning (R-CBL) instructional approach seems very well situated to become the primary model of instruction in the 21st century learning, and educators are well advised to get on board with this innovative approach to teaching (Grover, Krishnan, Shoup & Khanbaghi, 2014; Usart, Schina, Esteve-Gonzalez & Gisbert, 2019). Achieving excellent student learning outcomes has been the driver behind how the Robotics Competition-based Learning is planned, defined, and implemented.

Educational robotics involved in the robotics project served as an educational tool to provide a long term, and progressive learning activity, to cater to different age group (Ngit, Kok, & Andrew, 2016). Educational robotics can promote creative thinking and critical problem-solving in the contextual learning. It was proven that the primary and secondary school students had been benefitted from the educational robotics (Danahy et. al., 2014; Jung & Won, 2018). This emerging 21st century tool highlighted the students' potential to transmit key skills for future citizens and equip them with important 21st century skills (Afari & Khine, 2017; Eguchi, 2015). Educational robotics is popular among students of all ages however, it is mainly being applied in informal learning context due to the curriculum constrain (Alimisis, 2013). To promote STEM education, it is important to consider the experiences of young students through their engagement in STEM outreach activities and, subsequently, support the development of STEM interest. This case study proposes the Robotics Competition-based Learning (R-CBL) to connect the four STEM disciplines: Science, Technology, Engineering and Mathematics as outlined the integrated STEM curriculum (Pang, Hanipah, & Sharifah, 2018) thus assess students' STEM interest through hands-on activities.

Objectives of Study and Research Questions

The purpose of designing the integrated STEM curriculum through robotics education is to enhance students' learning in STEM subjects and to embed their interests towards STEM (Hussin et al., 2019). This newly enhanced project is an emerging 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, Casado, Fernandez, Guijarro, & Olivas, 2019; Chen, Chang, Tseng, 2015; Hoe, 2019; Remijan, 2017).

The Robotics Competition-based Learning (RCBL) educators have focused the integration of 21st century competencies in the subject in the scope where robots are deployed (Pang, Hussin, Tay, & Sharifah, 2019). In this case study, the event "International Robot Olympics Malaysia 2019" is aligned with the STEM integration idea. The vision of this competition is to gather the students who are interested in robotics to demonstrate their creativity, design ideas and develop problem-solving skills through challenging and educational robotics competitions.

The purpose of this study was to examine the effectiveness of the R-CBL on students' interest towards science, technology, engineering, math and teamwork. Interest in STEM is defined as an individual's positive attitudes toward science, technology, engineering, and mathematics subjects; in other words, an individual who has developed an interest in the content area of these subjects and activities (Sahin, Ayar, & Adiguzel, 2014). According to the literature and for the purpose of this study, "interest in" refers to students showing and responding with an observable triggered or maintained situational interest (Renninger, Bachrach, & Hidi, 2019). The following are two research questions raised as guide for the framework of this study:

i. What are the creative robot designs developed in the International Robot Olympics Malaysia 2019?
ii. Does robotics project increase students' interests toward STEM?

Methodology

Research Design, Data Collection and Analysis Techniques

One of the strengths of qualitative data is the manner of understanding what real life is through observing natural and regularly occurring events offer (Miles, Hubberman & Saldana, 2013). Case study with qualitative data analysis involving observation (Appendix A outlines the observation rubric) and interview is the research design and exemplary cases will be reported with illustrations and verbatim transcriptions (Writing Center, n.d.) of interviewees who were participants of the R-CBL. Exemplary projects from each case are reported to demonstrate the learning outcomes of the proposed pedagogy when students are using robotics to study STEM concepts.

Sampling and Implementation of Activities

This case study was conducted over a four months period, from August to October 2019. As aforementioned, the purpose of this study was to examine the effectiveness of the R-CBL on students' attitude towards science, technology, engineering dan mathematics. The participants consist of 200 students (135 Male and 65 female) aged 10-16 from 5 countries, which is Malaysia, Indonesia, Cambodia, Vietnam and Singapore, The final round of competition was conducted in a secondary school in Malaysia. The students voluntarily answered the survey before the competition in August and after the competition in November.

An informal semi-structured interview were conducted during the competition with ten students to explore their views, emotions and experiences related with robotics project. The interview protocol is attached in Appendix B.

The survey was adapted from the instrument developed by the Friday Institute for Educational Innovation (2012). Unfried, Faber, Stanhope, and Wiebe (2015) modified and developed the surveys for measuring student attitudes toward STEM (S-STEM) and interest in STEM careers for both upper elementary (4th through 5th grade students) and middle/high (6th through 12th grade students). The rationale for selecting this S-STEM survey is based on the evidence that this survey was produced on theoretically and empirically sound basis by adopting a deductive scale development process (Luo, Wei, Ritzhaupt, Huggins-Manley, & Gardner-McCune 2019).

There was an additional open-ended question in the post-survey to study the students' interest towards STEM after the R-CBL.

There were a total four projects in International Robot Olympics Malaysia 2019. Each participated team received the guidelines to carry out the R-CBL as shown in Table 1 that summarized the four-robotics project to be completed by the participants.

Table 1
Robotics Project Simple Guideline

Project 1	Drag Race
Goal	To race the robot in a straight lane within 30 seconds
Objective	To build a stable, fast-moving robot to reach the finish line in the shortest time
STEM concept	Speed, stability, friction, gear ratio, momentum
Project 2	**Syracus**
Goal	To throw ping pong ball into a group of cups to gain highest point
Objective	To build a catapult robot which can aim at the target
STEM concept	Projectile, angle of projection, energy of the catapult
Project 3	**Pick & Mess**
Goal	To clear all the ping pong balls from team area to opponent's area using remote.
Objective	To build a remote-controlled robot which can collect and send the most balls to opponent's field
STEM concept	Bluetooth controller, pushing force, storing mechanism
Project 4	**SUMO**
Goal	To push the opponent out of the specified ring.
Objective	To build an autonomous robot which has greatest strength to push the opponent and to avoid the attack of the opponent
STEM concept	Force, power, ultrasonic and color sensors, stability

The participants were given three months to prepare the robotics project at own schools guided by a mentor, using the integrated robotics STEM module (Pang et al., 2018). In this case study, the robotics kit used is limited to Lego Mindstorms NXT or EV3. The students are encouraged to design the artifact first with paper and pencil; or they can also use Lego Digital Designer to design a virtual model of their robot; finally, the students construct the model using the Lego Mindstorms kit (Alimisis, 2013).

The mentor guided the students to work in teams of three to five, so the students become familiar with the parts of the robots included the sensors. After the construction of the robot, the students were required to program their robot to complete the projects. Each project was built around a real-life problem situation that students had to investigate, test and learn the STEM concepts. One of the projects in the module is outlined in Table 2

Table 2
Exemplary Integrated STEM Lesson Plan

Project 1: Drag Race Robot			
Science	**Mathematics**	**Engineering**	**Technology**
Analysing linear motion. Understand the centre of gravity in stability. Understanding the concept of inertia. Determine the factors affecting the friction.	. Understand the concept of ratio of two quantities. . Understand and use the concept of ratio of three quantities to solve problems. Calculate speed and velocity using formula.	Engineering design process: . *Ask:* How to design a robot racing car that moves with the greatest speed? *Imagine:* Design of the fastest racing car. *Create:* Use gears to increase and the speed. *Test:* Test the racing car by calculating its speed. *Improve:* Make changes on the design to increase its speed.	1. Program the robot using computer software. 2. Code the robot using different variables. 3. Use of various sensors to make the robot more intelligent. 4. Use remote sensors to control the robot.

Findings and Discussions

This section discusses analysis of data in response to Research Question (RQ) 1 and 2.

What are the creative robot designs developed in the International Robot Olympics Malaysia 2019? (RQ1)

To answer the first research question, the following figures illustrate the observation of various creative robot design to achieve the competition goal.

The following are summaries of Project 1 and Figure 1 illustrates the Robot design for Drag Race Project.

Project 1: Drag Race

Goal:
To race the robot in a straight lane within 30 seconds.
Objective:
To build a stable, fast-moving robot to reach the finish line in the shortest time.

STEM concept:
Science: Speed, stability, friction, gear ratio, momentum.
Technology: The robot is set at highest power.
Gear system to increase the speed. Lower center of gravity and smaller mass. Small side wheels to prevent collision.
Mathematics: Calculation of the speed and gear ratio.

Figure 1. Robot design for Drag Race project.

The following are brief accounts of Project 2 and Figure 2 illustrates the Robot design for Syracus Project.

Project 2: Syracus

Goal:
To throw ping pong ball into a group of cups to gain highest point.

Objective:
To build a catapult robot which can aim at the target.

STEM concept:

Science: Projectile, angle of projection, energy of the catapult
Technology: The catapult is programmed to move at highest rate
Engineering: Mechanism of throwing more balls in one shot. Auto-reload of the catapult.
Mathematics: Probability, calculation of the maximum range the ball falls with various angle.

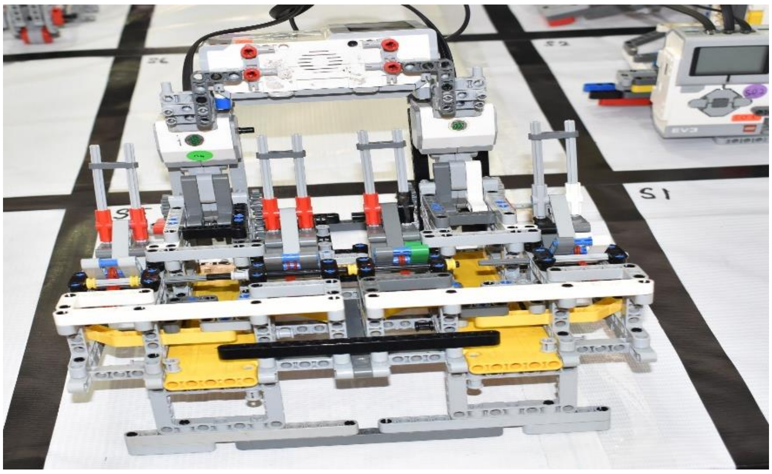

Figure 2. Robot design for Syracus project.

The following write-up describes Project 3 and Figure 3 illustrates the Robot design for Pick & Mess Project.

Project 3: Pick & Mess

Goal:
To clear all the ping pong balls from team area to opponent's area using remote.

Objective:
To build a remote-controlled robot which can collect and send the most balls to opponent's field

STEM concept:

Science: Speed, rotation
Technology: Programming on Bluetooth remote control
Engineering: Large storage tank to transport more balls.
Continuous rotating mechanism to collect more balls. Advance design of the robot to release the balls in short time.
Mathematics: Probability of the balls collected and delivered

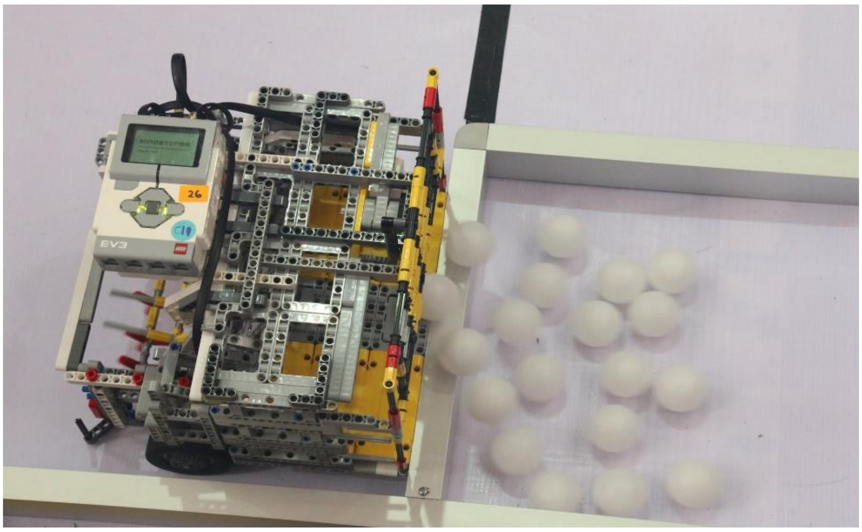

Figure 3. Pick & Mess robot collecting and delivering balls.

The following are descriptions for Project 4 and Figure 4 illustrates the Robot design for SUMO Project.

Project 4: SUMO project

Goal:
To push the opponent out of the specified ring.

Objective:
To build an autonomous robot which has greatest strength to push the opponent and to avoid the attack of the opponent

STEM concept:

Science: Force, power, ultrasonic and color sensors, stability
Technology: Programming of Bluetooth remote control, ultrasonic sensor and colour sensor
Engineering: Expandable to bigger size to be more stable.
Able to detect the opponent and can avoid from falling off the battlefield.
Mathematics: Calculation of the ultrasonic range and the intensity of colour.

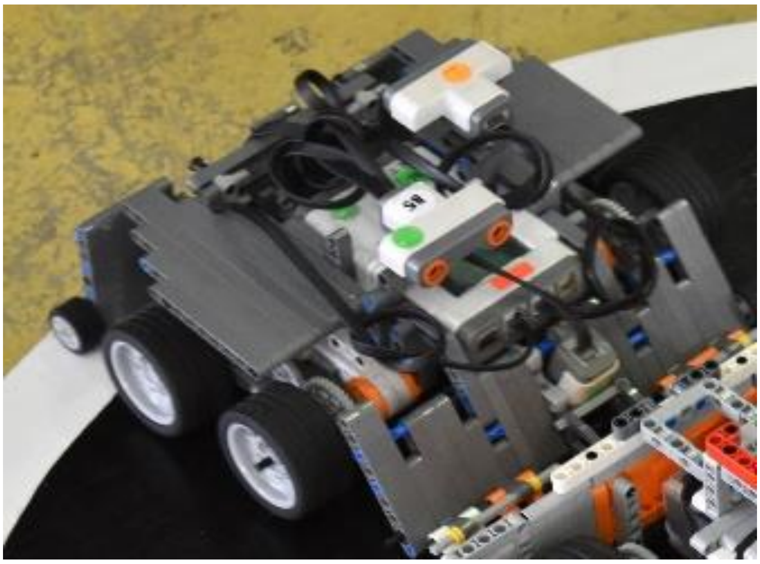

Figure 4. SUMO robot is pushing the opponent.

Does robotics project increase students' interests toward STEM? (RQ2)

The descriptions, codes and categories were extracted to find the emerging themes throughout the analysis of the data from the following open-ended survey questions:

1. To what extent would you say you are interested in robotics project?
2. Why are you interested (or not interested) in robotics project?
3. How does robotics activities impact on you?

Table 3
Coding Scheme for Analyzing Students' Open-ended Responses

Category	Subcategory	Code
1.Triggering interest	1.1 Internal	1.1.1 Pleasant feelings
		1.1.2 Fun
	1.2 External	1.2.1 Teachers and parents
		1.2.2 Friends
2.Immersing interest	2.1 Attitude	2.1.1 Curious
		2.1.1 Excitement
	2.2 Behavior	2.2.1 Hands-on
		2.2.2 Teamwork
3.Extending interest	3.1 Attitude	3.1.1 High Confidence
		3.1.2 Self-motivation
	3.2 Skill	3.2.1 Application of technologies
		3.2.2 Solve real-life problem
	3.3 Knowledge	3.3.1 Good science and math results in examinations
		3.3.2 Challenging
		3.3.3 Creative
	3.4 Application	3.4.1 Pursue STEM career
		3.4.2 Useful in daily life
		3.4.3 High employment rate

Analysis of the student open-ended survey questions revealed that all the 200 students were interested in robotics project, irrespective of gender, grade level, and countries. The analysis of their open-ended responses indicated positive responses.

There was a total of 94 of them showing responses ranging from Category 1 'Triggering interest' (N=20) to Category 2 'Immersing interest' (N=74). Students who were categorised as 'Triggering interest' consisted of younger age participants (10-11 years old). They were mostly first timer who participated in robotics competition because they were influenced by teachers, parents or friends. Category 2 'Immersing interest' showed that higher level of interests was cultivated among participants through intensive practice and great achievement in robotics.

To successfully sustain students' interest in STEM, the process 'Extending interest' (Category 3) must be cultivated. The results showed that 106 participants who were categorised into 'Extending interest' demonstrated self-motivation to learn robotics because they claimed that robotics can help in their mathematics and science achievement. These participants would choose STEM career in the future. Most of the participants in this category had longer experience in robotics competition and they spent longer time in robotics activities.

Hence the findings concur with the valid theoretical proposition of interest loop of Interest-Driven Creator (IDC) theory (Kong & Wang, 2019). According to the IDC theory, in order to cultivate lifelong interest, it is important to design robotics learning project that trigger, immerse, and extend interests of students towards STEM, to achieve the research objectives.

The following Figures 5 to 8 show the scenario during the competitions. Students' interest towards STEM fields are also reflected in these figures, for example they showed teamwork (Figure 5), commitment to produce diverse creative output (Figure 6), have fun (Figure 7) and excitement (Figure 8) during competition.

Figure 5. Teamwork to solve the problem.

Figure 6. Robotics promote creativity.

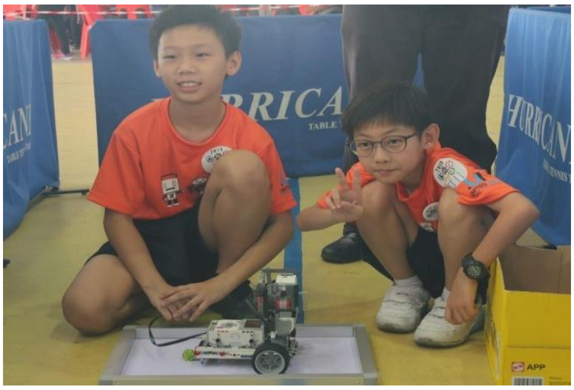

Figure 7. Students have fun during the competition.

Figure 8. Excitement during the competition.

The informal semi-structured interview was used to clarify the students' interest towards STEM education integrating robotics. Among the 10 participants being interviewed, 8 of them claimed that they joined this competition based on their own interest. While another 2 participants were influenced by their friends.

> *I never miss any chance to join robotics competition. Is my initiative to find the opportunity to participate in every robotics competition because I really interested in robotics. I feel happy when doing robot especially the robot can follow my command to complete the task.*
>
> (Verbatim transcription of interviewee Participant 3)

Five out of ten participants admit that robotics activities helped in their study especially in science and mathematics subjects.

> *I join robotics club since I was 7 years old, and now I am 13 years old. I can do well in science and mathematics and I believed that robotics improved my science and mathematics results a lot. In robotics, I wanted to have fun with friends.*
>
> (Verbatim transcription of interviewee Participant 6)

One of the participants explained the various benefits he gained from the robotics competition.

> *I am very interested in robotics because there are a lot of benefit by participating in robotics competition. I learned how to cooperate with friends to build a robot. In the competition, it helped me be able to see other more creative robot design. This can improve my skills and encourage me to explore more. While compete with others, I feel very excited and always want to win. I always observe the opponent's robot to see its strength and weakness.*
>
> (Verbatim transcription of interviewee Participant 1)

A participant detailed the importance of robotics in STEM careers.

> *Before I involve in robotics, I always wanted to be a lawyer because I like to fight for the truth. However, after I join the robotics program, my interest path has switched more towards engineering, either electrical or mechanical engineering. It is very cool to become an engineer which can create and solve problems using technology, like what I did using the robot.*
>
> (Verbatim transcription of interviewee Participant 7)

Another participant expresses the same opinion.

> *I never think of pursuing STEM careers until I join robotics club because all the while, my results in science and mathematics are not very excellent. But last year since I get some achievement in robotics competitions, I had changed my mine. I want to be an engineer in the future because it is very interesting to work with robot.*
>
> (Verbatim transcription of interviewee Participant 5)

Conclusion

Summary and Implication

The primary purpose of this study was to examine whether the use of Robotics Competition-based Learning would increase students' interest on Science, Technology, Engineering, and Math learning. Data analyses revealed that Robotics Competition-based Learning increased participating students' interest in STEM fields and encouraged them to pursue STEM related careers. The findings support the Robotics Competition-based Learning (R-CBL) as an emerging pedagogy to teach integrated STEM curriculum to fulfil 21st century educational needs. After the intervention of R-CBL, students able to apply what they have learned in the design process, present their design through the construction of robot, and finally make modification on the design, based on the results of their trials.

Based on the analysis, several implications for practice and further research are identified. One of the implications of the research is to propose a model for teachers and researches to teach STEM using educational robotics with the excitement during competition. The results of competition suggested that teachers may refer to the winning robotics design to achieve the goal of each project and to enhance the teaching and learning activities in the classroom. The researchers plan further competition-based project which are expected to propose more valuable ideas and suggestions for the successful integration of robotics in the STEM education. We believe that the positive outcomes from the case study on robotics competition-based learning indicate that educational robotics can be used to promote integrated STEM education. .

Limitations and Suggestions for Future Research

Like any other research, the limitation of this study will be discussed as follows. Firstly, all participants are self-rated on the S-STEM survey to report their learning attitude towards STEM before and after the intervention, which may result in the social desirability bias. Therefore, longitudinal study can be adopted in the future research to ensure the students' positive attitudinal change is prolonged. Secondly, the educational robotics kit used in this research is limited to LEGO MindStorm kit, which is still somewhat limited in RAM and number of sensors and highly cost. We believe that other open source robotics kit would allow students to have access to a better knowledge, as this is one of the pillar of the next robotics revolution, thereby allowing the use of these inexpensive, durable robots in school levels.

Our suggestion for future research is to repeat this study to manipulate the other variables such as gender difference, socioeconomics levels, and prior academic achievement. Furthermore, a quantitative research design is suggested to investigate the impact of R-CBL towards students' science and mathematics achievement. Finally, the influence of other factors on the implementation of R-CBL could be determined, such as mentors' attitude and teaching styles, school administrator's empowerment and education policy by stakeholders. Insight into these factors could help to improve the implementation of integrated STEM education through educational robotics, therefore contributing to students' increased motivation in pursuing STEM fields related studies. In fact literature revealed that PBL supported by ICT tools was able to enhance students' motivation as evidenced from the pre-/post-tests before and after PBL through scaffolded instruction (or abbreviated as PBL-SI) using the motivation scale developed as reported by Ng, Soon and Fong (2010). In addition, the analysis of data collected from the study on the effect of PBL-SI on students' 'Fluid Intelligence Test' (FIT) also showed that PBL-SI was effective to discriminate students with various aptitude levels as reported by Ng, Fong and Soon (2010). Hence, more research should perhaps be conducted to explore if well-planned R-CBL incorportating project-based activities, scenario-based or PBL could enhance students' thinking skills with research or evidence-based findings.

Acknowledgements

The authors acknowledge the organizers (SMJK Yok Bin Melaka and Universiti Teknikal Malaysia Melaka) for devising the competition format, themes, rubrics and photos during International Robot Olympics Malaysia 2019.

References

Afari, E., & Khine, M. S. (2017). Robotics as an Educational Tool: Impact of Lego Mindstorms. *International Journal of Information and Education Technology, 7*(6), 437–42. https://doi.org/10.18178/ijiet.2017.7.6.908.

Alimisis, D. (2013). Educational robotics: Open questions and new challenges. *Themes in Science and Technology Education*, *6*(1), 63-71.

Bermúdez, A., Casado, R., Fernández, G., Guijarro, M., & Olivas, P. (2019). Drone challenge: A platform for promoting programming and robotics skills in K-12 education. *International Journal of Advanced Robotic Systems*, *16*(1), 1729881418820425.

Chen, Y. K., Chang, C. C., & Tseng, K. H. (2015). The instructional design of integrative STEM curriculum: A pilot study in a robotics summer camp. In *2015 International Conference on Interactive Collaborative Learning (ICL)* (pp. 871-875). IEEE.

Danahy, E., Wang, E., Brockman, J., Carberry, A., Shapiro, B., & Rogers, C. B. (2014). Lego-based robotics in higher education: 15 years of student creativity. *International Journal of Advanced Robotic Systems, 11*(2), 27. https://doi.org/10.5772/58249

Eguchi, A. (2015). RoboCup Junior for Promoting STEM Education, 21st Century Skills, and Technological Advancement through Robotics Competition. *Robotics and Autonomous Systems*, *75*(B), 692-699.

Friday Institute for Educational Innovation. (2012). *Upper elementary school STEM-student survey*. Raleigh, NC: Author.

Grover, R., Krishnan, S., Shoup, T., & Khanbaghi, M. (2014). A competition-based approach for undergraduate mechatronics education using the arduino platform. In *Fourth Interdisciplinary Engineering Design Education Conference* (pp. 78-83). IEEE.

Hoe, L. S. (2019). A Framework of Project-Based Learning for Enhancing Student Competencies through Digital Video Production. *International Journal of Human and Technology Interaction (IJHaTI), 3*(1), 95-100.

Hussin, H., Pang, Y. J., Rosly, R. N. R., & Omar, S. R.(2019). Integrated 21st Century Science, Technology, Engineering, Mathematics (Stem) Education Through Robotics Project-Based Learning. *Humanities & Social Sciences Reviews, 7*(2), 204-211. https://doi.org/10.18510/hssr.2019.7222

Jawawi, D. N., Mamat, R., Ridzuan, F., Khatibsyarbini, M., & Zaki, M. Z. M. (2015). Introducing computer programming to secondary school students using mobile robots. In *2015 10th Asian Control Conference* (ASCC) (pp. 1-6). IEEE.

Jung, S. E., & Won, E. S. (2018). Systematic review of research trends in robotics education for young children. *Sustainability, 10*(4), 905.

Khanlari, A. (2013). Effects Of Robotics On 21st Century Skills. *European Scientific Journal, ESJ*, *9*(27), 26–36.

Kong, S. C., & Wang, Y. Q. (2019). Nurture interest-driven creators in programmable robotics education: an empirical investigation in primary school settings. *Research and Practice in Technology Enhanced Learning*, *14*(1), 20. Retrieved from https://doi.org/10.1186/s41039-019-0116-1

Luo, W., Wei, H. R., Ritzhaupt, A. D., Huggins-Manley, A. C., & Gardner-McCune, C. (2019). Using the S-STEM Survey to Evaluate a Middle School Robotics Learning Environment: Validity Evidence in a Different Context. *Journal of Science Education and Technology*, 1-15.

Miles, M. B., Huberman, A. M., & Saldaña, J. (2014). *Qualitative data analysis: A methods sourcebook*. London: Sage.

Ngit, C. L., Kok, W. W., & Chiou, A. (2013). Framework for educational robotics: A multiphase approach to enhance user learning in a competitive arena, *Interactive Learning Environments*, 21(2), 142-155.

Ng, K.T., Fong, S.F. & Soon, S.T. (2010). *Design and development of a Fluid Intelligence Instrument for a technology-enhanced PBL programme.* Global Learn Conference Proceedings, pp.1047-1052. Association for the Advancement of Computing in Education (AACE). Retrieved December 22, 2019 from https://www.learntechlib.org/p/34305/

Ng, K.T., Soon, S.T. & Fong, S.F. (2010). Development of a questionnaire to evaluate students' perceived motivation towards science learning incorporating ICT tool. *Malaysian Journal of Educational Technology*, 10(1), 39-55. Retrieved December 22, 2019 from https://scholar.google.com/scholar?oi=bibs&cluster=17170875076542775051&btnI=1&hl=en

Pang, Y. J., Hanipah, H., & Sharifah, S. S. A. (2018). Integrated Robotics STEM Curriculum Towards Industry 4.0. *International Journal of Human and Technology Interaction (IJHaTI), 2*(2), 17-23.

Pang, Y. J., Hussin, H., Tay, C. C., & Sharifah, S. S. A. (2019). Robotics Competition-Based Learning For 21st Century STEM Education. *Journal of Human Capital Development (JHCD), 12*(1), 66-80.

Remijan, K. W. (2017). Project-based learning and design-focused projects to motivate secondary mathematics students. *Interdisciplinary Journal of Problem-Based Learning*, *11*(1), 1. Retrieved from https://doi.org/10.7771/1541-5015.1520

Renninger, K. A., Bachrach, J. E., & Hidi, S. E. (2019). Triggering and maintaining interest in early phases of interest development. *Learning, Culture and Social Interaction*, 23, 100260.

Sahin, A., Ayar, M. C., & Adiguzel, T. (2014). STEM Related After-School Program Activities and Associated Outcomes on Student Learning. *Educational Sciences: Theory and Practice*, *14*(1), 309-322.

Shahali, E. H. M., Halim, L., Rasul, M. S., Osman, K., & Zulkifeli, M. A. (2017). STEM learning through engineering design: Impact on middle secondary students' interest towards STEM. *EURASIA Journal of Mathematics, Science and Technology Education*, *13*(5), 1189-1211.

Unfried, A., Faber, M., Stanhope, D. S., & Wiebe, E. (2015). The development and validation of a measure of student attitudes toward science, technology, engineering, and math (S-STEM). *Journal of Psychoeducational Assessment*, *33*(7), 622–639.

Usart, M., Schina, D., Esteve-Gonzalez, V., & Gisbert, M. (2019). Are 21st Century Skills Evaluated in Robotics Competitions? The Case of First LEGO League Competition. In *Proceedings of the 11th International Conference on Computer Supported Education* (Vol. 1, pp 445-452). SCITEPRESS – Science and Technology Publications, Lda.

Wahab, A. F. A., Azahari, M. H., & Tajuddin, R. M. (2016). A Preliminary Study of Robotic Education in Malaysia. In *Proceedings of the 2nd International Colloquium of Art and Design Education Research* (i-CADER 2015) (pp. 351-358). Singapore: Springer.

Appendix A

International Robot Olympics Malaysia 2019 Engineering Design Observation Rubric

Project 1: Drag Race

	Level 1	Level 2	Level 3	Level 4	Score
Inquiry (Wiring Diagram and Programming)	Is able to solve the problem with limited success	Is able to solve the problem with moderate success	Is able to solve the problem with considerable success	Is able to solve the problem with exceptional success	**/4**
Imagine/ Create Design (Sketches, Draft of Construction)	Is able to create sketches of racing car and construct an appropriate model with limited success	Is able to create sketches of racing car and construct an appropriate model with moderate success	Is able to create sketches of racing car and construct an appropriate model with considerable success	Is able to create sketches of racing car and construct an appropriate model with exceptional success	**/4**
Test Application (Drag Race Result)	Is able to work through the car racing programming with limited success	Is able to work through the car racing programming with moderate success	Is able to work through the car racing programming with considerable success	Is able to work through the car racing programming with exceptional success	**/4**
Improve/ Making Connections (Documentation, Project Write Up, Cover Page, Conclusion)	Project meets requirements with limited success	Project meets requirements with moderate success	Project meets requirements with considerable success	Project meets requirements with a high degree of success	**/4**
				TOTAL SCORE:	**/16**

Comment:
1.

2.

3.

4.

Appendix B

Interview questions

1. How long have u been participate in robotics activities?

2. Why are you joining this competition?

3. What types of benefits do you think you gain the most from this program? Can you give examples?

4. What types of skills do you think you develop or learn?

5. Do you think that participation in program can boost your career interest towards STEM subjects?

6. Does this program improve your curriculum achievement in school?

7. Overall, how do you evaluate your experience in robotics competition?