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A Study of Enhancing Computational Thinking Skills through STEAM Robotics Activities

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Abstract. STEAM robotics activities are designed to be an enhancement on students' computational thinking skills, which are claimed to be essential for the 21st century. The aims of this study were to examine the learning outcomes of secondary students' computational thinking skills through the use of STEAM robotics activities, and to investigate the students' satisfaction after the implementation of STEAM robotics activities. A quasi-experimental research design was deployed in this study. The research participants were 37 eleventh-grade students of Private Islamic Schools in Yala province, Thailand. A quiz with pre- and post-test and satisfaction questionnaires were employed as data. Descriptive statistics – including mean, standard deviation and a pair sample t-test – was used to analyse the collected data. The findings were that students' learning outcomes indicated a significant improvement in their computational skills after the use of STEAM robotics activities as compared with before, with the statistical level of significance of 0.05. In response to the second research question, the overall satisfaction of the students after the use of such STEAM robotics activities was high (mean=4.01; SD=0.54).

1. Introduction

One of the possible ways which makes indigenous students feel highly enthusiastic about learning science, technology, engineering, and mathematics (STEM) studies is through the delivery of culturally responsive enrichment activities in which science, technology, engineering, art, and mathematics (STEAM) are implanted in a classroom [9]. Two main objectives of the STEM approach are defined: it first aims to expand a number of students who are eager to be employed by a prospective employer upon the completion of their high school and whose decisions on career paths are based on science, technology, engineering, art, and mathematics. Secondly, it enables to enhance their competence with fundamental STEAM skills [3]. As employers in the 21st century have demanded practical computational competence from their employees, certain skills in relation to such competence are expected to be required by learners through education. In this matter, a number of applications, including programming training, are said to be of particular importance for K-12 students [5].



Since there is a realisation that computational thinking (CT) skills are valuable in today's society, it is said that foundational CT skills should be addressed to individuals of any age so that they can become digital citizens who not only possess CT skills but also keep up with the developments of technology [6]. In relation to its term, CT is defined as a comprehensive thinking in which mathematical thinking, engineering thinking and scientific thinking are focused. This means that by acquiring CT, it can enhance innovative thinking ability of individuals. One of the tools which is claimed to support the development of such skills is educational robotics. This is because it promotes individuals to have better engagement with technology. In many schools, for instance, educational robotics has been implemented to increase not only a better learning atmosphere for students, but also a higher level of their order thinking and problem-solving skills. In this case, the advantages of robotics are considered. Some researchers reported that the use of robotics could potentially strengthen students' problem solving and CT skills, which could later develop a practical application in their real life activities based on the programming used in STEAM concepts [4],[6].

Using CT concepts; namely decomposition, pattern recognition, abstraction and algorithm design, this current study hypothesised that the implementation of STEAM robotics activities could improve CT skills of secondary students. The study aimed to answer the following research questions:

- 1) Does the use of STEAM robotics activities improve students' computational thinking skills?
- 2) To what extent is the students' satisfaction with the use of STEAM robotics activities?

2. Theoretical Background

Computational Thinking (CT) is considered as an application in which represents a high level of thought and an algorithmic conception of individuals in order to tackle all kind of difficulties in life. In other words, it is what computer scientists call a matter of reasoning [7]. This conceptualisation is part of computer science where the intellectual skills are considered to be essential for improving algorithmic thinking, abstracting, decomposing and pattern recognising of individuals [8]. This includes the use of robotics in that it is claimed to enhance CT skills of students based on the abilities of how they can process tasks systematically and how they can develop coding commands in which sequences step-by-step are seen for programming a robot. This shows that by allowing teachers to introduce the use of robotics (e.g. its visual programming tools and robotics platforms) to young children, it helps to increase the development of their coding and CT skills. To exemplify this, Christina Chalmers's study of Australian primary school teachers who integrated robotics and coding in their classrooms found a promising improvement in students' CT abilities. Allowing four primary school teachers who taught students between years one and six within four different schools to use LEGO 2.0 robotics kits in their classrooms as well as using questionnaires, journal entries, and semi-structured interviews as part of the data analysis, the study found that the teachers became more confident in introducing young students to computational thinking. It was suggested that having appropriate robotics-based STEM activities also be emphasised as it helped promote teacher professional development, computational concepts, practices, and perspectives of the teachers [4].

Based on a number of research into CT, computer programmers as well as experts on STEM and STEAM have realised how much important and necessary CT has been [11]. To illustrate this point, a pilot study conducted by Leonard et al. on the use of LEGO EV3 robotics and games using Scalable Game Design software for improving CT strategies of 124 middle school students found that the scores of pre- and post- efficacy of the student regarding the construct of computer use dropped considerably, whilst there was no explicit change in the constructs of videogaming and computer gaming. However, considering the analysis of such constructs based on the type of learning environment, there was a significant increase in self-efficacy on videogaming in the combined robotics/gaming environment compared with the gaming context alone. In relation to student attitudes towards STEM, there was no significant change in the study. There is a varying degree of students' CT strategies according to methods of instruction because there were higher CT ratings among students who took part in holistic game development (i.e., Project First). In conclusion, this study has as a great impact in the STEM education literature in terms of how the use of robotics and game design affects self-efficacy in

technology and CT. In the meantime, it also provided some suggestion for the research team in terms of some necessary adaptations to ensure research trustworthiness over the years remained for the study [10].

3. Methods

The study employed the purposive sampling technique to select participants. There were 37 eleventh-grade students (20 males and 17 females) whose ages were between 16 and 17 years old at the time when data collection took place from Science Mathematics programme (SMP) at Private Islamic Schools in Yala province, Thailand. A quiz with pre- and post- test. Regarding the quiz, there were 20 multiple-choice questions, all of which were created to measure student achievement on computational thinking skills – including decomposition, pattern recognition, abstraction, and algorithm design. The quiz was used as targeted skills in part of STEAM robotics activities. The validity of the test was determined to be at an average of 0.88 (SD=.05). A satisfaction questionnaire was used in this study. The satisfaction questionnaire was divided into three sections: the first section concerned general information of respondents; the second was a 5-point Likert rating scale (1 = very high, 2 = high, 3 = average, 4 = fair and 5 = poor) for respondents to select their level of satisfaction with 25 items (five sub-sections, each one had five items) about STEAM robotics activities; and the last section of the questionnaire was an open-ended question which allowed respondents to provide any further thoughts and suggestions they might have optionally. The satisfaction questionnaire had high reliability (the Cronbach's Alpha of 0.87) which could be used as samples in the study. Descriptive statistics (mean, standard deviation and a pair sample t-test) was used for data analysis.

Table 1 presents the scope of STEAM robotics activities and the targeted skills. STEAM robotics activities (robotic Programming learning, decorating sumo-robot vehicles, and sumo-robot competition) were shown in Figures 1-3.

Table 1 the scope of STEAM robotics activities and the targeted skills

Activity	STEAM	Purpose of activity	Targeted skills (Computational Thinking)
Robotic Programming learning	Science (S) Technology (T) Mathematics (M)	To program robot according to situations	Decomposition, Pattern Recognition, Abstraction, Algorithm Design
Decorating sumo-robot vehicles	Science (S) Technology (T) Engineering (E) Art (A) Mathematics (M)	To beautifully decorate a vehicle suitable for the sumo-robot Competition	Pattern Recognition, Abstraction, Algorithm Design, Algorithm Design
Sumo-robot competition	Science (S) Technology (T) Engineering (E) Mathematics (M)	To create a hands-on application designed for daily-life and enjoyable activities	Pattern Recognition, Algorithm Design



Figure 1. Robotic Programming learning

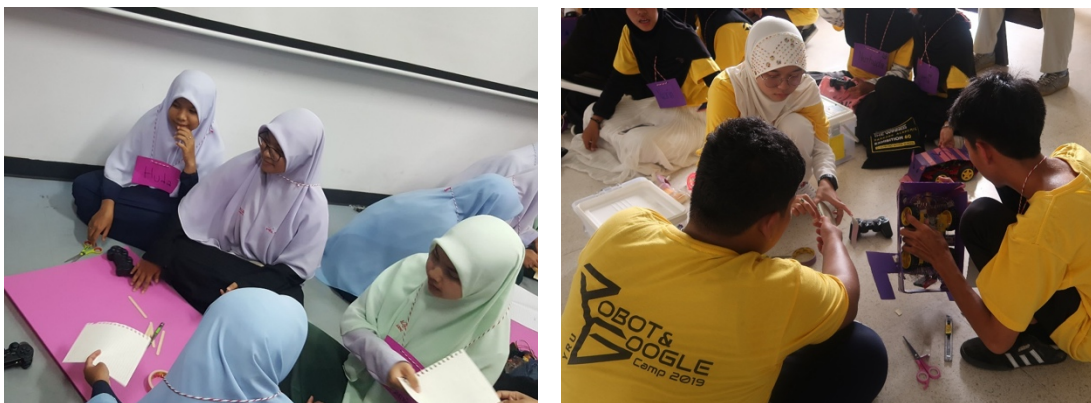


Figure 2. Decorating sumo-robot vehicles



Figure 3. Sumo-robot competition

4. Results and Discussion

This section presents assessment results for the students' learning outcomes and the satisfaction of STEAM robotics activities.

Table 2 Pre- and post-test scores of the experimental students on CT skills

	Score of experimental group (n=37)		t	p
	Pretest	Posttest		
Computational thinking skills	7.05 (1.98)	14.68 (2.23)	16.84*	.000

* p < 0.05

As seen in Table 2, it shows the results of the students' improvement after learning through STEAM robotics activities with a significant difference in CT skills condition ($t=16.84$, $p=.000$). The results were aligned with the findings of the case of development and evaluation of STEM learning with robotics course for junior high school students. Such findings indicated that the students' learning achievements in assignments according to the P3 Task Taxonomy practice, problem solving, and projects were at a good level according to the study hypothesis and showed high learning motivation [2].

Table 3 shows the results of the validity scores of the satisfaction on STEAM robotics activities; robotic programming with Arduino IDE and sumo-robot competition for two days (15 hours in total).

Table 3 The validity scores of the students' satisfaction on STEAM robotics activities

aspects	\bar{x}	S.D.	levels of the students' satisfaction
1. Processes and procedures of STEAM robotics activities	3.94	0.60	High
2. Content delivery of the instructors	4.03	0.59	High
3. The organizing of sumo-robot competition	4.17	0.69	High
4. Media and equipment for STEAM robotics activities	4.05	0.65	High
5. The appropriateness of the location of the STEAM robotics activities	3.87	0.75	High
Total	4.01	0.54	High

Regarding Table 3, the total mean score of overall satisfaction on STEAM robotics activities was high at 4.01 ($\bar{x}=4.01$, S.D. = 0.54). Considering each aspect, the result shows that the third aspect, the organising of sumo-robot competition, had a highest mean against other aspects ($\bar{x}=4.17$, S.D. = 0.69). Although the mean was stated as high, it suggested that STEAM robotics provided a very rich and attractive learning environment. This is in accordance with the study of the opinions of teachers and students who participated in FIRST LEGO League competitions during a course 2017-2018 about the impacts on learning processes. The results of the study revealed that both teachers and students believed this project could promote learners' interest in STEAM, scientific curiosity and social skills through teamwork [1].

The following are the overall thoughts and further suggestions which some respondents made.

1. The instructors were able to perform their teaching very effectively.
2. The computer labs were equipped with proper equipment.
3. The competition was enjoyable and could be applied to real-life situations.
4. There should be more robot equipment during the training.
5. Due to limited time of training, participants could not assemble the robot by themselves. However, they managed to decorate the robot which could be used in the sumo-robot competition. Therefore, the training period should be extended longer than two days.

Moreover, the after-school extracurricular activities on STEAM robotics activities should also be offered to secondary students as the study has revealed the promising findings regarding the

implementation of such STEAM robotics activities. These include the enhancement of students' CT skills as well as the increase of their learning motivation. In recent years, using robotics to stimulate students' interest in STEAM fields has been empirical since there has been an increasing amount of funding provided for STEAM programs. The reason is that they are stated to be an alternative possibility for enhancing students' CT skills, which results in yielding better student performances on STEAM subjects [10]. In this matter, STEAM robotics activities are considered to be innovative teaching tools in which better student learning can be achieved. Along the borders of the 21st century skills and computational competence, using STEAM robotics activities is claimed to help students to possess high-order thinking and problem-solving skills [6]. However, the limitation of the study was the insufficient time over the training period of the study, which caused the students to be less engaged with the robotics programming in STEAM robotics activities.

5. Conclusion

Based on the test and the students' satisfaction results, this current study reveals that STEAM robotics activities had a positive impact on students in which their CT skills were considered improving. It also appears that such activities were effective to be used as an aid in a classroom to support students' learning because, as claimed in this study in particular, STEAM robotics activities helped to stimulate, engage, and teach students effectively. For further studies in the future, there should be an emphasis on using qualitative approaches, such as interviews and focus groups, as it could provide in-depth insights into the benefits of such activities.

Acknowledgements

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