Journal for the Education of Gifted Young Scientists, 8(3), 1201-1212, Sept 2020
e-ISSN: 2149- 360X
jegys.org

Young Wise Publishing
youngwisepub.com

Research Article

STEAM education for preschool students: Patterns, activity designs and effects

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Article Info

Received: 08 March 2020
Revised: 25 July 2020
Accepted: 17 August 2020
Available online: 15 Sept 2020

Keywords:
Learning activities
Pattern
Preschool students
STEAM education

2149-360X/

Abstract

Organizing STEAM educational activities which integrate different knowledge areas in order to create an innovation for primary school students that uses many skills is difficult. This is because children aged 6 are different in terms of intelligence, skills and mood. There is a lack of a set of activities that make students happily learn together by playing and get involved with creative and innovative thinking, practice planning and decision skills, and work together as a team. Therefore, encouragement is needed to create a set of learning activities by applying the STEAM educational concept and to evaluate their learning success also using the STEAM educational concept. The result of this set of activities was the design of three different moveable robot inspired by a breed of dog called Beagle. The Beagle set of activities were then evaluated by three experts in the area. The outcome was that the first design had the highest mean ($\bar{X}$= 4.88, S.D. = 0.17). The mean from the structure & control system evaluation of this set of activities was at a very good level ($\bar{X}$=4.83, S.D.= 0.39). Finally, the learning achievement from using this set of STEAM educational activities with the sample had a mean of 16.07, which is 80.33 %. This means that the proposed set of activities is able to help students to improve the process of their thought. However, the outcome is based on the nature, experience and learning method of each student.

To cite this article:

Bureekhampun, S., & Mungmee, T. (2020). STEAM education for preschool students: Patterns, activity designs and effects. *Journal for the Education of Gifted Young Scientists, 8*(3), 1201-1212. DOI: http://dx.doi.org/10.17478/jegys.775835

Introduction

Education is important for developing countries because it is essential if countries are to advance. Education has changed a lot in the present day compared with the past. The state of the economy and society in the technological era are part of what has caused education to change. The old education system is now insufficient to support the new generation throughout their lifelong careers. This problem is related to the different attitudes, tests and judgements of individuals which result from improvements in skills, analytical thinking, self-study and work experience. Adjusting attitudes and accepting differences is able to help by creating communal learning (Office of Knowledge Management and Development (Public Organization) (OKMD, 2018)

A new Thai government policy related to economic development has been employed in order to improve the economy by driving innovation. The policy focuses on developing many aspects of the country through the advances in education afforded to twenty-first century Thailand. Education which focuses on creating learning skills for children is very important because children today will be the main influence on the country's development. According to article 12 of the National Economic and Social Development Plan (Office of the National Economics and Social Development Council, 2018), the next step of knowledge improvement is to pay attention on creating a foundation of human development that instils Thai people with attitudes and behaviours in accordance with helpful societal norms and a high-quality education in line with international standards. The focus of the Thai education

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system from the past until the present, in both private and public institutions, has been STEM (Committee on Mass Communication of Science Technology and Information, National Legislative Assembly, 2018). The idea of STEM education is to make children proficient in all four STEM subject areas. However, STEM education alone does not help children fully understand and remember what they are taught. In light of this, (Orapiriyakul, 2019) proposed STEAM education as an integration of five different subject areas: science, technology, engineering, art and mathematics. Adding art endows students with adaptable knowledge they are able to use when studying society and economics. A summary of the importance of STEAM can be seen in Table 1. Such knowledge can also be used to improve the learning process at educational institutions. An education system that supports creative thinking matches children's natural behaviour, especially that of very young children who are unreservedly artistic. If those children were supported they would be able to think freely and differently in accordance with the attitudes of present society, which focuses on allowing children to use their imagination fully. This process will lead to the improvement of creative thinking in children, allowing them to develop new ideas and technologies that can help in everyday life (Boonthanom & Butkatunyoo, 2015). However, research (Sriboon, 2018; Santipaiboon, 2018) (Plodpluang et al. 2018) has found the following problems with STEAM education which should be addressed: planning cooperation to set and adjust times for teaching and learning, the process of design and evaluation, evaluation standards, the process and strategy of employing in real life what the children have been taught. All the things mentioned above are things students must be taught about so they can overcome these issues. When they become adults, they will have the ability to solve problems in a positive way using creativity, which contributes to a happy life, and this will be a result of the experiences they had when they were younger.

Table 1.

The Importance of STEAM

Science	Thinking and explaining in a scientific way. Understanding things that happen and what you see.
Technology	Knowledge in selecting materials and tools in order to work more easily.
Engineering	Seeing the goal, thinking logically and solving problems systematically.
Art	Employing knowledge from architecture to design beautiful shapes and colours and to present the results to people in ways they understand easily and concretely.
Mathematics	Knowledge about quantitative data; the relationship between areas of study can help in the analysis and designing with purpose.

The highlights of a comparison of the analysis of STEM and STEAM education can be concluded as follows.

- The process of STEAM education pays more attention to bringing knowledge to create products more than STEM education.
- STEAM education also gives more importance to the process of thought, which is the process of mind expression (Nasera, 2019) which leads to self-learning and creative self-improvement. STEAM education also focuses on experience more than STEM education.
- Adding art into STEM education helps support creativity, inspiration and happiness throughout the learning process so students can achieve balanced growth. Scientific problem-solving with creativity may lead to a career in science. A scientific mind and problem-solving skills are also able to be used in real life (Connor et al. 2015; Ramli et al. 2019).
- Art can be used as a tool to practice students' creative thinking skills (Ramli et al. 2019) in order to integrate scientific and technological knowledge together with holistic thinking (Belbase, 2019). This will allow students to solve difficult things more easily, beautifully and happily.

From the ideas and information above, we propose ideas to create an activity which support STEAM learning for children aged six as a starting point for them to improve their thinking and problem-solving skills by focusing on independent analytical thinking. The activity integrates four skills in scientific areas and one in art according to the nature and psychology of children. The activity encourages learning through play in all five areas and provides a foundation for lifelong success for the children.

Problem of Study

The objective of this research is to create a set of learning activities according to the STEAM educational concept for children aged six. This set of activities will help solve problems in primary school education by encouraging students to improve their skills in thinking, problem solving, planning, making decisions and creating, and will

integrate many areas of knowledge. Students will learn and play at the same time in order to evaluate the learning outcome of using the set of STEAM educational activities.

Method

Research Design

This research uses a pre-experimental design method. The research design used is a one shot-case study design. (Campbell & Stanley, 1963).

Research Sample

Participants of this research is composed of 5 groups of 15 children aged six, divided further into groups of 3 children using purposive sampling and the sample is student primary schools in Ladkrabang district, Bangkok, Thailand, in 2019.

Data Collection Tools

The tools which were used in order to collect data during the process of designing this set of activities for children aged six had three parts, as follows:

- A playing behavior observation form for children aged six in order to compare the different types of play children engaged in, which were imitation, observation, testing and creation. The form also compared the children's developments in body, intelligence, mood, mind and society. This information was taken as a guideline for designing the set of activities.
- An observation form for the set of activities according to the STEAM educational concept. This form was given to the experts and asked their opinions on the three models. The form was composed of a set of 29 questions in seven categories. The expert opinions were divided into five levels according to the Likert scale. There were three sections in the form, which were general information on the status of the experts, opinions on the children's activity models, and additional suggestions on the activities.
- The evaluation form for the structure and the control system of the set of STEAM educational activities. This form was composed of a set of 12 questions in three categories. The opinions were divided into five levels according to the Likert scale. This form had three sections, which were the general information on the status of the experts, opinions on the children's activity models, and additional suggestions on the activities.

These forms were checked by the specialists (IOC-Index of Items Objective Congruence)

The tool which was used in order to collect data in the process of evaluation of this research was the realness behavior evaluation form, which was used for the planning, analyzing, problem solving, working in groups and integrated working. The criteria in this evaluation is a Rubrics score which was adapted from the evaluation form of Payne, D.A. (2007). This form was checked by the specialists (IOC-Index of Items Objective Congruence)

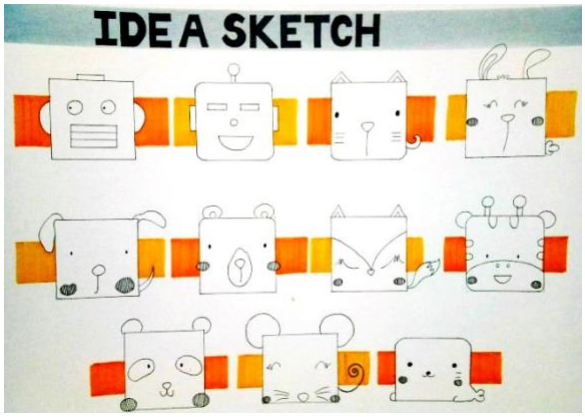
Data Analysis

To analyze the data, the researcher used statistical software called SPSS in order to calculate the mean and standard deviation, and to use the interpretation criteria for the Likert Scale.

Results

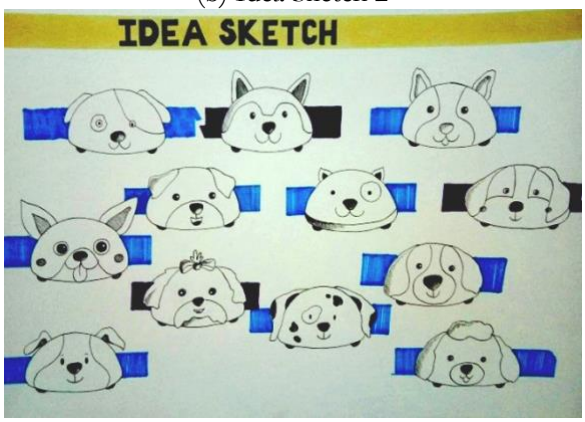
First Problem of Study Results: Design a STEAM Learning Activity

In order to design the activity, the researcher chose playing as the learning activity. As inspiration, the researcher took existing geometric shapes such as rectangles and circles and they combined them to design a sketch of a robot using AI, according to the learning skill of the twenty-first century (Bellanca & Brandt, 2010) in (Thanormchayathawat et al. 2016). This method was used to create a variety of idea sketches which can be seen in Figure 1.



(a) Idea Sketch 1

(b) Idea Sketch 2



(c) Idea Sketch 3

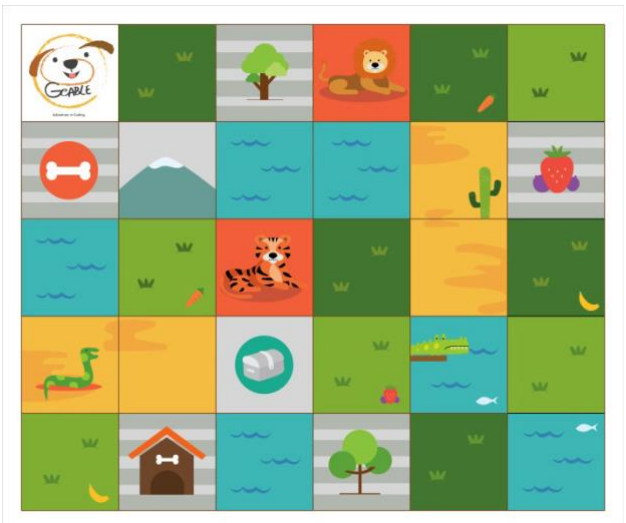
Figure 1.
Idea Sketches of Designs 1, 2 and 3

From the study and information collected on the playing behaviour of children, the design specialists suggested analysing the behaviour of animals that are appropriate for children at age six in order to create an activity with a more interesting design. Based on that suggestion the researcher analysed the behaviour of animals including dogs, cats, rabbit, monkeys and elephants which were selected based on their popularity with twenty children who were shown Figures of them. The top three animals were dogs, cats and elephants respectively. From that result, the researchers then chose a dog as the inspiration for the activity and created sketches of dog robots from many different breeds. Ten popular breeds of dog were analysed (The Smarter Wa, 2019) and they were selected because they had the benefits of being friendly and gentle towards children, but they also had disadvantages such as some breeds being too big or small, making them inappropriate compared to the size of children aged six. However, the medium-sized breed of the Beagle was considered the most appropriate for children based on its lovelier face and more beautiful colour than other breeds. Therefore, a Beagle served as the inspiration for the design demonstrated in the next step and illustrated in Figure 2.

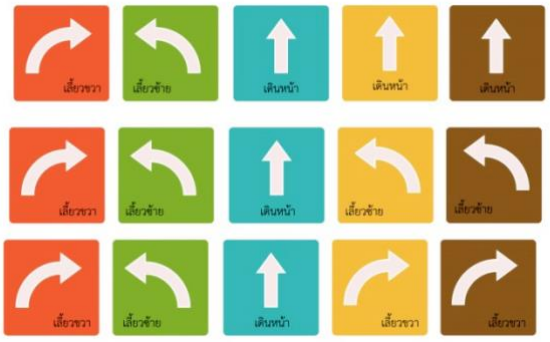
Figure 2.
Idea Sketches of Beagles

After designing the idea sketch, the researcher designed other illustrations by applying a framework of the research: the learning standards and criteria from science subjects (Office of the Basic Education Commission, Ministry of Education, 2017). This illustration can be divided into four parts, which are the map, order cards, animal cards and the manual for playing, as can be seen in Figure 3.

(a) Animal Cards



(b) Map



(c) Order Cards

(d) Playing Manual

Figure 3.
Order Cards, Animal Cards, Story Manual and Playing Manual

After creating all the illustrations, the researcher put the illustrations together in models to send to the specialists. Three models were sent to the specialists and these can be seen in Figure 4. The mean and standard deviation of models 1, 2 and 3 can be seen in Table 2.

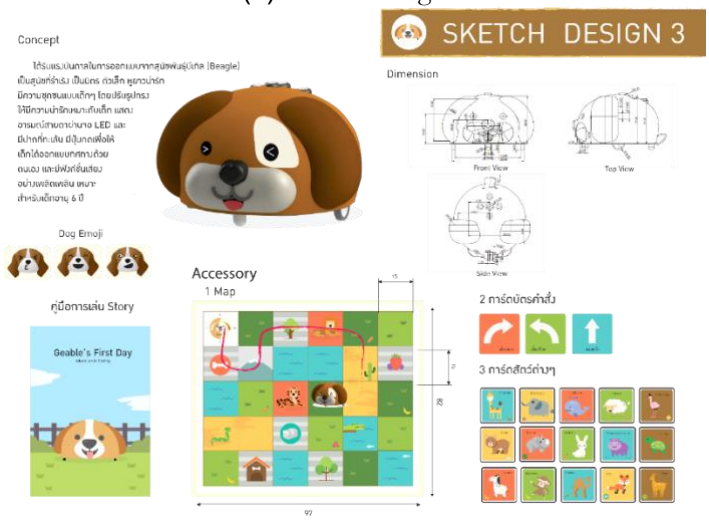
Model 1: The beagle robot was designed to look cheeky, bright and playful by having the tongue sticking out, which made it look more childish.

Model 2: The beagle robot's ears were designed as floppy, making the dog look cute, soft and sensitive. The design on the mouth focused on making the dog look well behaved.

Model 3: The beagle robot's ears were designed to be longer, which makes the dog look loyal and easy to tame, but they can be folded to make the robot more compact and easier for children to play with.

(a) Sketch Design 1

(b) Sketch Design 2



(c) Sketch Design 3

Figure 4.
Three product designs

Table 2.
Analysis of the Mean and Standard Deviation of Product Designs 1, 2 and 3 from the Specialists' Opinions (N=3)

Evaluation aspects	Design 1		Design 2		Design 3	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
1. Function						
1.1 Suitability for user	5.00	0.00	4.33	1.15	4.67	0.58
1.2 Proportion suitability for user	5.00	0.00	4.33	0.58	4.67	0.58
1.3 Weight suitability and ease of moving around	4.67	0.58	4.00	1.00	4.33	0.58
1.4 Comfort ability of use	4.67	0.58	4.00	1.00	4.33	0.58
Average	**4.83**	**0.29**	**4.17**	**0.93**	**4.50**	**0.58**
2. Material						
2.1 Choice of Material	4.67	0.58	4.33	1.15	4.67	0.58
2.2 Choice of colours which are not harmful for users	5.00	0.00	4.00	1.00	4.67	0.58
2.3 Choice of Material which is easy for manufacturing	5.00	0.00	4.67	0.58	5.00	0.00
Average	**4.89**	**0.19**	**4.33**	**0.91**	**4.78**	**0.38**
3. Durability						
3.1 Durability and strength	5.00	0.00	4.67	0.58	5.00	0.00
3.2 Robustness	4.67	0.58	4.33	0.58	4.67	0.58
3.3 Harmlessness for the user	5.00	0.00	4.67	0.58	5.00	0.00
Average	**4.89**	**0.19**	**4.56**	**0.58**	**4.89**	**0.19**
4. Ergonomic						
4.1 Uncomplicated	5.00	0.00	4.67	0.58	5.00	0.00

4.2 Size suitability for the users	4.33	0.58	4.67	0.58	4.33	0.58
4.3 Size of equipment and ease of use	5.00	0.00	5.00	0.00	4.67	0.58
Average	**4.78**	**0.19**	**4.78**	**0.38**	**4.67**	**0.38**
5. Safety						
5.1 Safety for the users	5.00	0.00	5.00	0.00	5.00	0.00
5.2 Suitability and harmlessness of product weight for the users	5.00	0.00	5.00	0.00	5.00	0.00
5.3 Difficulty of swallowing the product for children	4.67	0.58	4.67	0.58	4.67	0.58
Average	**4.89**	**0.19**	**4.89**	**0.19**	**4.89**	**0.19**
6. Beauty						
6.1 Suitability of proportions	5.00	0.00	4.67	0.58	4.67	0.58
6.2 Modernness	5.00	0.00	5.00	0.00	4.67	0.58
6.3 Beauty and attractiveness	5.00	0.00	5.00	0.00	4.33	0.58
6.4 Creativity and artistic quality	5.00	0.00	5.00	0.00	4.67	0.58
6.5 Beauty of colours	5.00	0.00	4.33	0.58	4.00	0.00
6.6 Elaborateness	5.00	0.00	4.67	0.58	4.33	0.58
Average	**5.00**	**0.00**	**4.78**	**0.29**	**4.44**	**0.48**
7. STEAM Education						
7.1 Integration of all 5 areas	5.00	0.00	5.00	0.00	4.67	0.58
7.2 Suitability for children aged 6	5.00	0.00	4.67	0.58	5.00	0.00
7.3 Accordance with core curriculum	4.67	0.58	4.33	0.58	4.67	0.58
7.4 Interest and connection to other areas in children's lives	5.00	0.00	4.67	0.58	5.00	0.00
7.5 Support of the creative thinking process	5.00	0.00	4.67	0.58	4.67	0.58
7.6 Support of teamwork skills	4.67	0.58	4.67	0.58	4.67	0.58
7.7 Stimulation of children's curiosity	5.00	0.00	4.67	0.58	4.67	0.58
Average	**4.90**	**0.16**	**4.67**	**0.49**	**4.76**	**0.41**
Total Average	**4.88**	**0.17**	**4.60**	**0.54**	**4.65**	**0.38**

Table 2 shows the result of the model analysis according to the design principles from (Office of the Basic Education Commission, Ministry of Education, 2017). From the analysis of the three models sent to the specialists, model 1 achieved the highest evaluation from the specialists. All specialists had the same opinions. Model 1 had the highest mean, 4.88, and a standard deviation of 0.17 when each aspect was analysed. It can also be seen that the specialists think Model 1 is the most beautiful, with the highest mean at 5 and standard deviation at 0.00. Model 1 had the second-highest score for suitability to STEAM education, with a mean of 4.90 and standard deviation of 0.16. As for the other suggestions section of the form, the specialists advised dividing Figures on the map according to children's awareness (Saengpongpittaya, 2013), for example the river, desert and jungle should be together.

In the design structure and control system for the activity, the researcher used a microcontroller called ARDUINO NANO as the main controller. The system had two wheels using two DC motors plus two free wheels to be used for steering. The direction was controlled using four buttons, and a sound system created sounds when buttons were pressed to gain the children's interest. OLED lights were used in the eyes such that feelings could be expressed through the eyes. The power came from two 3.7v cells. The battery of the robot can be charged, as seen in Figure 5. This model was sent to be evaluated by the specialists, in order to analyse the mean and standard deviation, as can be seen in Table 3.

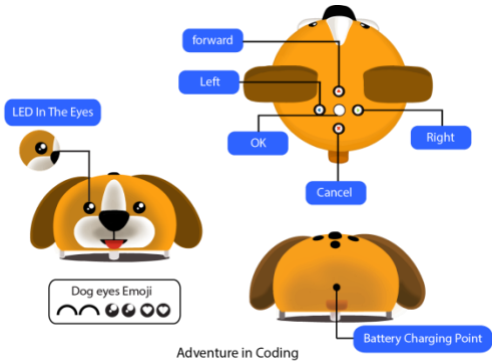


Figure 5.
Control System of the Robot

Table 3.
Analysis of the Mean and Standard Deviation of the Structure and Control Design from the Specialists' Opinions (N=3)

Evaluation aspect	Mean	S.D.	Description
1. Structure			
1.1 Suitability of circuit position	4.67	0.58	Very good
1.2 Suitability of circuit size	5.00	0.00	Very good
1.3 Suitability of the design	4.67	0.58	Very good
Average	**4.78**	**0.44**	**Very good**
2. Control system			
2.1 Suitability of the power supply	4.67	0.58	Very good
2.2 Suitability of the input device	5.00	0.00	Very good
2.3 Suitability of the output device	5.00	0.00	Very good
2.4 Steering control system	4.67	0.58	Very good
2.5 Display system	5.00	0.00	Very good
Average	**4.87**	**0.35**	**Very good**
Evaluation aspect	**Mean**	**S.D.**	**Description**
3. Usability			
3.1 Ease of use	4.67	0.58	Very good
3.2 Ease of use of the input device	5.00	0.00	Very good
3.3 Safety of use	5.00	0.00	Very good
3.4 Ease of maintenance	4.67	0.58	Very good
Average	**4.83**	**0.39**	**Very good**
Total Average	**4.83**	**0.39**	**Very good**

Table 3 shows the results of the structure and control system analysis. It can be seen that overall the mean is very high at $\bar{X}$= 4.83, and the standard deviation is 0.39. When analysed by aspect, the control system had the highest mean from the specialist evaluation which is $\bar{X}$= 4.87, and a standard deviation of 0.35. The second-highest evaluated aspect is the utility, having a mean of $\bar{X}$=4.83 and standard deviation of 0.39, followed by the aspect of structure with a mean of $\bar{X}$= 4.78 and standard deviation of 0.44.

Second Problem of Study Results: Evaluate the Learning Result of the STEAM Educational Activity

The researcher divided 15 children into groups of three children who were then tested group-by-group. There were tasks for the children to do, and a score was assigned by observing the children's behaviour before starting the activity. When children saw the activity for the first time, the researcher observed the children's expressions, for example excitement, interest and curiosity. Then, the researcher explained how to do the activity. During the activity the researcher read out the manual explaining how to play. The children's behaviour during the game can be summarised as follows: (1) telling the story to children in order to provoke their interest and make them want to try and find a solution to the problem (Liliawati et al. 2017), (2) the children start the process of thought, showing their creative thinking freely by trial and error, and (3) emotional awareness. The children presented stories using the animal cards they collected when they completed tasks. The students used the cards to create stories following their imagination and experience of playing (Laoviriyarat, 2009). The researcher found that children had much imagination when creating stories.

Table 4.
Learning Achievement from Completing the STEAM Learning Activity

Experiment	Full score	N	Mean	S.D.	Percentage
Learning achievement	20	15	16.07	1.28	80.33

Table 4 shows the result from the STEAM education activity for children aged six. It can be seen that the mean of children who learned from the activity is 16.07 and the standard deviation is 1.28. In percentage terms, the mean is 80.33%. This shows that the activity successfully leads to learning within STEAM education.

Discussion and Conclusion

The following section will conclude the research with regard to the research objectives. The goal of applying STEAM learning in the education system is to integrate knowledge, skills, scientific methods, technology, engineering, art and mathematics in order to increase students' interest in science by expressing knowledge through the form of art and making study more fun. Students can use their imagination to make new things, share ideas and

work together, which supports creative innovation as it relates to (Guyotte et al. 2015). The processes of STEAM education are: (1) Context presentation – Presenting a situation or story in order to provoke students' interest in solving the problem, (2) Creative design – Students begin the process of thought and develop many methods to show their creativity, while the teacher stimulates the students to join the activity creatively and freely by focusing on experience, process of thought and product creation. (3) Emotion touch – the process of students presenting the result of their work and feeling happy that the project is completed. The most important aspect is to inspire the students.

STEAM education is an integration of five areas: Science, Technology, Engineering, Art and Mathematics. The most important focus is to inspire students to solve problems themselves using creativity. Students will go through STEAM education according to the educational concept developed by (Yakman & Lee, 2012).

The result from designing the STEAM educational activity for children aged six was that integrating both science and art to design the activity supported students' thinking and imagination regarding physical science, animals, the environment, coding, planning and solving problems, completing tasks and the relationship between numbers. Learning the relationship between numbers included counting cells on the map and the colours and shapes of the toys. In designing the activity, the researcher applied the following principles of product design (Rerngwansasak, 2017); 1) function, 2) safety, 3) enhanced learning, 4) durability, 5) ergonomic and 6) material. Four design principles were not used by the researcher, these were economic, ease of maintenance, cost and finally transportation and levying. The researcher brought the draft design to receive suggestions from three specialists, then they selected the most-appropriate design to be refined and used to create the product prototype.

The learning achievements from using the STEAM learning activity can be concluded as follows in this section. The children's behaviour before the activity was introduced to them exhibited excitement, curiosity and interest. When the researcher introduced how to do the activity, the students could play the game using their process of thought, making decisions by using their imagination in order to complete the task. In order to evaluate the academic achievement, the mean score of children's learning from this activity was measured as 16.07, and the standard deviation was 1.28. As a percentage, the mean of children learning from the activity was 80.33%. This activity is suitable for children aged six onwards because it develops their process of thought, however it may seem difficult at the beginning. The students need time to practice gaining more understanding about the activity. The length of time required depends on the nature, experience and learning process of each individual student, as per the research of (Plodpluang et al. 2018). If students practice or play often, the process of thought in according to STEAM education will be developed. This is the beginning of children's development in the future, which they can further by using their experience, playing and learning. Some children might behave aggressively, therefore this activity needs to be supervised by parents because the robots are electronic.

Recommendations

Suggestions in Applying this Research:

- Charge the battery of the robot before use.
- To select colours, there should be a reference saying the meaning of each colour.

Suggestions in Order Improve this Research:

- In terms of the map, it can be made as a jigsaw so that the children can design it by themselves. Therefore, they can practice their process of thought at the same time.
- Design a robot into which the direction card can be inserted instead of using the buttons attached to the robot.

Limitations of Study

This set of learning activities needs to be used under the supervision of parents or teachers at all times. It is not recommended for the children to use these activities on their own because there are some electrical parts of the robot that could be easily damaged.

Acknowledgments

The authors thank the students and schools who participated in this study. The author also thanks the editors and reviewers for their comments to improve the quality of this article.

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