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Fostering High School Students' Innovative Thinking and Design with STEM: Smart School Projects on IT Maker Day

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Abstract: Technology and engineering have disrupted our daily lives and provided a better quality of lives through innovation. In the school system, students are not well promoted to integrate the knowledge from different subjects; consequently, they could not take this potential to address the real context of problems and situations. To enable this, it not only involves the strategy to integrate such subjects, but it also requires the innovative thinking and design. Based on this direction, therefore, this study endeavored to propose an approach that integrates the advantages of technology, STEM, and innovation through the means of constructing projects. In this study, the annual program of IT Maker Day on the smart school project theme has been implemented based on the proposed model. The participating students went through many hands-on experience workshops, design and developed their project in order to address their school or nearby community issues. The evaluation of this study has been made through their presentation on the final competition day where the committee investigates their works and gives suggestions on two dimensions of innovative thinking and design, and STEM. The results have shown that those who were awarded had better ideas and understanding on both dimensions. The implication of this study can be applied in other schools while the activities can be changed in their context; moreover, more investigation could be carried out for a better understanding of this learning phenomena.

Keywords: STEM, IoT, multimedia, engineering, information technology, innovative thinking

1. Introduction

In the past, there were very few computers and electronic devices that could connect to the Internet. Nowadays, the technology that can spread the internet is more extensive and more accessible. As a result, use of the Internet has played an essential role in many aspects of human life, whether to receive news or information. The idea of a technology called the Internet of Things (IoT) is a technological concept that needs to connect everything to the internet, whether it is cell phones, washing machines, lamps, and to the use of components. For example, a jet engine or drilling rig (Morgan, 2017). In addition to the Internet technology that humans can use, in order to innovate in order to work with the Internet, humans will have to be creative and would be able to apply the knowledge. To invent new things happen and to make the human life better, innovative design is necessary as a concept that helps to develop things to be true. Richard Florida, a founder of the Creative Class Group, defines Innovative Design "The design must be outstanding and elegant. However, simple and easy to use" (LaBarre, 2018). Therefore, the internet of Things technology and Innovative Design, it is indispensable to apply them together to create innovative, easy-to-use and better quality of life.

In school learning systems, students learn each subject separately. They are good at solving the exercises or problems related to that particular subject; however, these are not the real-life situations. In addition to that, they are not encouraged to learn how to think innovatively in order to tackle the real facing problems. They even have limited ideas to think, design and develop innovations meaningfully; furthermore, they could not link those thinking process with the

knowledge learned from each subject. As a result, they cannot explain the thought process of that newly created works or projects.

Advantages of training workshop with STEM are participants have to work methodically and can solve the problem systematically. The participants would apply the knowledge of Science, Technology, Engineering, and Mathematics to solve the problems by practicing trial-and-error. Moreover, another advantage of the training workshop is when participants have the problem, they can ask the lecturer immediately, which is better than self-learning participants. Advantages of a training workshop for the lecturer are the lecturer can know the potentiality of the participants in order to adapt the instructions based on the ongoing understanding of the participants.

Based on this particular perspective, this paper aims to address such issues by proposing a novel solution to fostering students' innovative thinking and design process. The STEM is adapted to facilitate this proposed solution. In this study, a workshop called IT Maker Day was designed and run with many school participants, in the meantime, several training activities were given to them in order to develop innovative thinking process to design smart school projects to solve their encountered problems/situations. Throughout their project development, they are encouraged to follow STEM approach in order to learn and address any issues found during the process. To investigate the effectiveness of this proposed approach, the final competition was used to not only present their projects but also to collect data for this study. The findings of this paper would enlighten many other school practitioners, teachers and administrations to address the mentioned issues by considering this study as an example. To reach this aim, the authors have formulated following research questions to direct this study precisely: (1) What are the over structure and activities of this workshop to help foster students' innovative thinking and design? (2) What are the smart school projects developed by students by taking STEM approach? And (3) What are the results of their innovative thinking and design and STEM understanding based on their developed projects?

2. Related Study

2.1 STEM

STEM is an integrated learning style based on four subjects: Science, Technology, Engineering, and Mathematics by focusing on bringing knowledge to solve real-life problems, including new process or product development, helping students to build links between four interrelated disciplines, real-life activities, and work. Learning is a process that is not focused solely on memorization, theories or scientific rules, but to understand those theories or rules through practice, along with the development of problem-solving skills and the discovery and analysis of new findings, which can be used or integrated with the daily life.

STEM is the process of learning which consists of six steps: 1. Identify real-life problems/innovations that need to be developed before we do any experiment or develop something. 2. Collect relevant information and ideas. When we make a problem or know the problem to do. The next is to try to close to our problem. Due to some problems we encountered, other people may have met before us, so study what he does. It is a combination of information that should be close to what we are going to do. 3. Design a solution (Science + Math & Technology). Next is designing a solution from what we have studied and compiled. We have to design our way to match the situation we encounter the most. 4. Plan and implement solutions (Engineering). The next is planning how to test and run the solutions in order to investigate the initial results. 5. Test, evaluate and improve every trial (Engineering). Often not successful at first, the results of each trial will be evaluated to improve the experiment to be able to solve the problem precisely as we want. 6. Provide a solution. Solution or the results of innovation when we tested the results and improved the test method to satisfactory results. The next step is to present all that has been done to be useful to others to study.

From the six steps of STEM above, we can give an example. 1. The problem of feeding fish which require human labor to feed. If a man is busy or forgets to feed food, it may cause damage to the fish. 2. To do research and gather information about such solutions. Has anyone else in the world had this problem? He used any method to solve the problem. 3. Then to adapt to suit the environment

and the problem, we are experiencing is that sometimes the main problem we encounter may be the same problem. However, other factors, probably not the same, as the solution to A's problem may be used to feed indoor fish. However, our environment is required in the notification. Therefore, it must be adjusted to meet our problems, etc. 4. Plan and carry out how to build fish feeders. 5. Next is the trial. To know that what we designed can fix the problem. If the experiment is not successful, I have to come back to solve the problem. The solution is to continue. 6. When we test the results and improve the fish feeders, the results are satisfactory consequently. The next step is to present all that has been done.

In a literature review, some research used robotic with STEM and did a workshop (Charoenchai W. et al, 2018; Sasithorn C. et al, 2017; Jacqueline L. et al, 2016; Santi H. et al, 2017; Pauline M. et al, 2016), while some research used JuxtaLearn, a popular education model in England (H. Ulrich HOPPE et al, 2016; Nils MALZAHN, 2016). From the above literature review, therefore, this study runs a training workshop with several activities by following STEM process. After the workshop, there will be a competition for each group to apply what they have learned in the workshop as a response to problems in the school.

2.2 Innovative Design and Thinking

Creative thinking is the basis for our progress and evolution in the world. The basic of creativity is placed on the generation of high-quality, original, and elegant solutions to complex, novel, ill-defined problems. To analyze the cognition that makes creative problem-solving possible, creative thinking involves a systematic thinking process that requires a design process or design thinking to drive the thinking process smoothly and minimally (Mumford, Medeiros & Partlow, 2012). The design is a human attempt to develop the way, the situation or the environment in the present to be desired or expected in the future. Design thinking is a thought process that requires analyzing the problems encountered, while design process principles are user-centric, which take the creativity from the perspective of many people, who may be in the team. Before the solution can be used, it must be tested and developed to get the best solution or the best innovation that responds to the user or situation.

For inventors, there is a need for a design thinking process designed to reduce the uncertainty and risk of innovation, which can be modeled on three main parts: Inspiration, Ideation, and Implementation. In the process of inspiration, it is a step to understanding the problem and the principle of innovation that needs to be created. After that, it will explore information from sources or innovations that are close to the solution. After that, it will be stepped onto the stage of development. Ideation, which is the introduction of information that has been developed and applied to solve social problems or create their innovations. Starting from the idea of "idea" started in the first stage and then create a "prototype" when the prototype is completed. Then test the prototype with a problem and use it in real situations to check an error or what should improve. After that, it will be a process of Implementation. This is a step in the process of applying it to the society and developing it into a future business model (Hobcraft, 2017).

The Rotman School of Management studied the use of design thinking to dealing with administrative problems and the potential impact of educational management under the concept of Design Thinking, which will allow students to think in a broader perspective, develop a deep understanding of the relationship between the problem and the user. Moreover, recognize the value of engaging with others more (Dunne & Martin, 2006). In term of business, the concept of design thinking is applied to business problems. The result of Design thinking in business is well received and praised as a solution to the problem. New to the challenges that business organizations often face in promoting innovation and business growth (Liedtka, 2015).

The important thing to design innovation to solve problems in society, small as a school or a more abundant society like in the community is the thinking process. It is necessary to have a design thinking or design process to be used as a step in designing the innovation to respond to problems that occur in the most direct and beneficial.

3. Description of IT Maker Day

3.1 Overall Structure of IT Maker Day

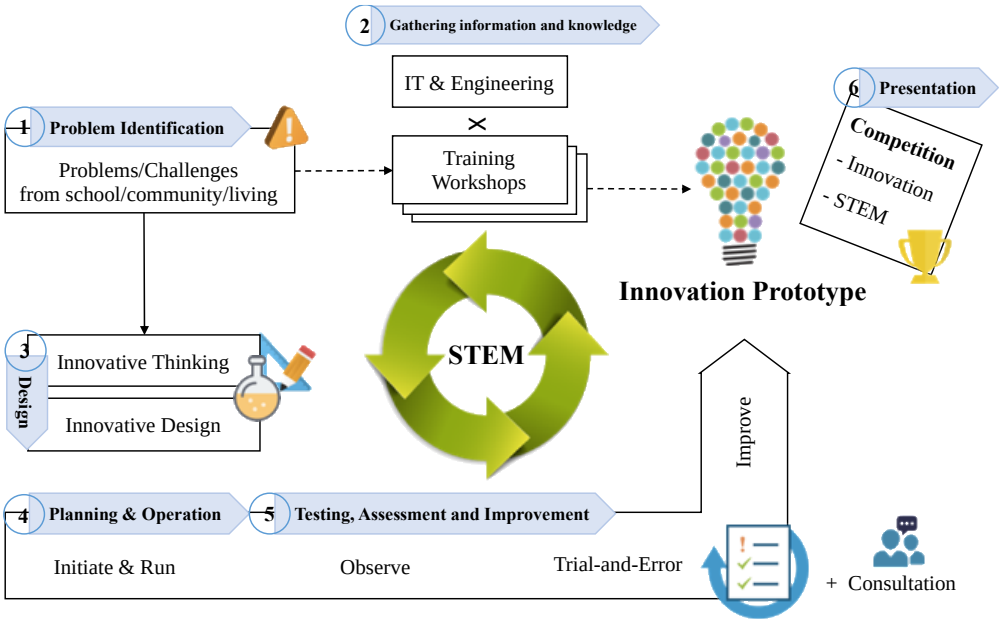


Figure 1. Overall Structure of IT Maker Day.

IT Maker Day is an annual program with a series of training workshops and competition related to Information Technology and Engineering. This program aims to equip the participating students with innovative design and thinking through several workshops with hands-on experiences; consequently, they designed and developed their innovation prototypes based on the trial-and-error process, for the competition on final day of the program. This year, the concept of STEM has been adopted for students learning process under the broad theme of Smart School Project. This theme encourages students to think, design and develop innovative projects to address any issues/problems/situations found in their school contexts or nearby communities.

As shown in Figure 1, IT Maker Day integrates STEM in students' learning process from problem identification, gathering information and knowledge in relevant with IT and Engineering-focused training workshops (workshop activities are described later), design in which the students need to relate their first two steps in order to think innovatively. After that, they reach the essential part of STEM which require their efforts and time to test, run, improve their projects until they have reached the successful innovation prototype. Consequently, they meet the final step of presentation in the means of competition to not only present their works, but also were evaluated for innovation and STEM dimensions.

3.2 Training Workshops

In this annual program, a series of workshops are given to all participating students and teachers to prepare them with the basic knowledge and skills following topics. (1) Introduction to STEM and innovative thinking and design, (2) training workshop of Internet of Things (IoT), (3) training workshop of Augmented Reality (AR), (4) consultation session. After participating these workshops, each participating team have several weeks to design and develop their smart school projects by taking what they have learned from the workshops to apply with their solutions. See Table 1 for training workshop activities.

Table 1

Training Workshop Activities on IT Maker Day.

Picture	Activity Description
	This introductory session provides a basic understanding of the significance of STEM in learning and creating innovation to solve any problems, six steps of STEM process which can be practically applied when developing your work. A real example of automatic fish-feeding machine was presented as it was developed by following such six steps. This would draw a clear point of views for students. Followed that, another session of introducing innovative design and thinking was given. This would inspire the students how innovation evolved from their surrounding issues, how to think innovatively and how to design for innovation.
 	This workshop provided a hands-on experience of basic understanding of IoT, how to use these devices and materials, how to assemble and program them to function as needed. All of the workshop problems and practices are related to the project. During the workshop, students were asked to do a brainstorming, which could come up with the initial problem in mind. The challenge is to solve the problem. When did the actual practice, the results will be obtained precisely as the lecturer told, or have problems with programming, or that the circuit? If the students write the wrong program, the result will be a mistake. Because the device does not have a single hole or just one connection, so if the wrong programming found, the students need to adjust the problem to meet the needs. As shown in the picture, the trainer helped solve the problem when the students encountered problems beyond their ability.
 	In the IT Maker Day event, an Augmented Reality training program was introduced to incorporate the work of the participating student. The first step is to explain what Augmented Reality Technology is, the Augmented Reality workflow. After introducing the steps of augmented reality process, the next step will be the test by lecturer give the student a chance to practice creating their Augmented Reality. The topic of the test is to create augmented reality to introduce your own team, which is displayed in the form of the 3D object, Image, and Video. In the Augmented reality training, the problems most students encounter are: The image used by the students as an image trigger is not as bright as it should be, making it difficult for the application to detect the image and display it. The solution to solve this problem for students is finding the excellent quality of the image. Image Trigger must be clear and have the proper size.
	The lecturer advises on the problems that the students encountered after the test such as the wrong circuit, wrong programming. This consultation included the idea that the students want to do, but have the device or sensor error. For example, use a light sensor with alternating temperature sensor caused by the similarity of two sensors, etc. Apart from that, the students need to experiment and adjust the problem itself.

Now, all of the students, particularly in team, were ready to go back to their school and develop the innovative project by considering STEM approach as a means in develop the project

systematically. Meanwhile, each team are fostered to develop their innovative design in relevant with their contexts, which were challenging. After a few weeks, they are required to present their finished projects and will be evaluated on mainly two aspects which are innovative thinking and design (INV), and STEM learning process (STEM).

4. Method and Results

4.1 Experimental Design and Instrumentation

This study adopted a simple experimental research design. All of the participants took the same activity of IT Maker Day throughout this study. The participants of this study are the students and their teacher who work in team. Only top three achieving teams who were awarded are treated as a high innovative thinking and design group (H-INV), while those three teams who were not awarded are treated as a low innovative thinking and design group (L-INV).

The data collected for this experiment is from the scores, comments and suggestions from a group of ten invited committees who are specialize in IT, engineering, STEM and innovation. The data was collected during the presentation of students' project as a final competition on IT Maker Day. The committees use the evaluation form to score each team, which consisted of five items on two dimensions: INV from the complete of project, the novelty and originality of project, the possibility of actual implementation, while STEM from the discussion and relevancy to the project. Each dimension contributes ten scores in this study.

4.2 Experimental Results

4.2.1 Description of Projects with Higher Innovative Thinking and Design (H-INV)

(a) Wastewater Management Boat

(b) Globe-based Mobile Learning for Geography

(c) Smart Restroom

Figure 3. Results of Smart School Projects (Higher Innovative Thinking and Design).

As presented in Figure 3 (a), it is a wastewater management boat. The concept for the construction of the boat for wastewater is derived from the fact that the school has a pool with water problems rotten and smelly. Team members took this problem to solve the problem by building a boat that can treat water. Students design a boat to suck up wastewater on the boat and filter the wastewater on the boat and release the water back to the water. This boat uses solar energy to power the system. To control the boat, there are two systems to control it. The first one is automatically movement. The ship has a sensor system connected to the moving system to avoid obstacles by the ship itself. The second one is a manual system to use in case of need is to focus only on the area of the water source. This team

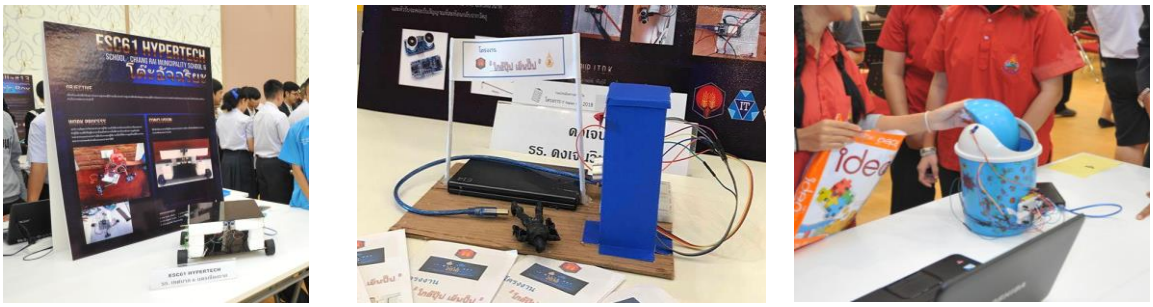
has taken the problems that occur within the school and has systematic thinking in the team. Regarding the STEM concept and presentation, this team could present the problem, and the solution of the problem follows the concept of STEM very well. (INV = 9.16, STEM = 9.25)

As shown in Figure 3 (b), it is a globe-based mobile learning for geography. Students in the class cannot remember the geographic location. This team has brought the problems in this classroom to use in the invention of innovation. This project can display the selected country information on the mobile application to educate students in geography class. This team has taken the problems from their classroom to create an innovation, but this team is a lack of design thinking. Concerning the concept and use of STEM ideas, this team can apply the knowledge to use in this project very impressive. (INV = 8.50, STEM = 9.75)

Figure 3 (c) is a smart restroom prototype. This project was awarded for popular vote. The concept behind this project is to prevent the falling in restroom due to the floor wet. This innovation can detect the wet from general humidity from the sensor and request the ventilation fan to operate accordingly to help dry the floor; meanwhile, the system sends an alert to the cleaning staff to clean the room as needed. This team has used the sensor improperly to detect the humidity in the restroom. (INV = 8.40, STEM = 6.30)

In summary, these three teams were awarded since they have outperformed than other teams by the evaluation of committees regarding two dimensions: INV and STEM. This can be implied that they have improved while constructing the projects both innovative thinking and design by strongly following STEM approach. Based on the suggestions, these teams had a systematic learning process in which they can well integrate all of the key components in Figure 1.

4.3 Description of Projects with Lower Innovative Thinking and Design (L-INV)



(a) Automatically Adjusted Table for Better Ergonomic (b) Automatic Cooling System (c) Smart Bin with Display

Figure 4. Results of Smart School Projects (Lower Innovative Thinking and Design).

As shown in Figure 4 (a), it is an automatically adjusted table for better ergonomic. When people walk closely to the sensor detection area, the table will adjust itself to match the position and height of the users. This project has not yet completed since the table could not accurately adjust the table; however, the members of this group could not find the solution to address this point. The committees reclined positive to this group due to their creativity. Furthermore, if they have more time and integrate STEM approach better, they will definitely improve their work for the actual use. (INV = 7.17, STEM = 6.75)

In Figure 4 (b), it is an automatic cooling system. The principle of this work is when there are objects or anything near the motion sensor, the fan will automatically run to cool down the surrounding. Even though the functionality of this project is good, the project could not demonstrate the novelty. Besides, they have limited ideas of how to improve this work and could not explain how this project is associated with the STEM approach. (INV = 7.00, STEM = 9.25)

In Figure 4 (c), it is a smart bin with display. When there is a person approach to drop any trash or object into the bin, the bin will check before is the bin has some room, then the lid will turn out for use. The user can put waste into the tank. The committees strongly suggested this group to rethink about the user experience since it may give discomfort to the users; while the display when the bin is full should be reconsidered. Critically, the position of sensors is greatly not impropriated since they would be damaged easily by heavy garbage. Regarding STEM, the work requires the

better calculation of the ultrasonic range, and improvement for the stable functionality. (INV = 7.11, STEM = 4.00)

These three groups had tried their best in developing the projects for their schools; however, the notable limitations still exist. These issues could involve the thinking and design process that students may not consider carefully. By following STEM process, the students could understand and improve their in-progress works continuously, which could lead to the better results of the project.

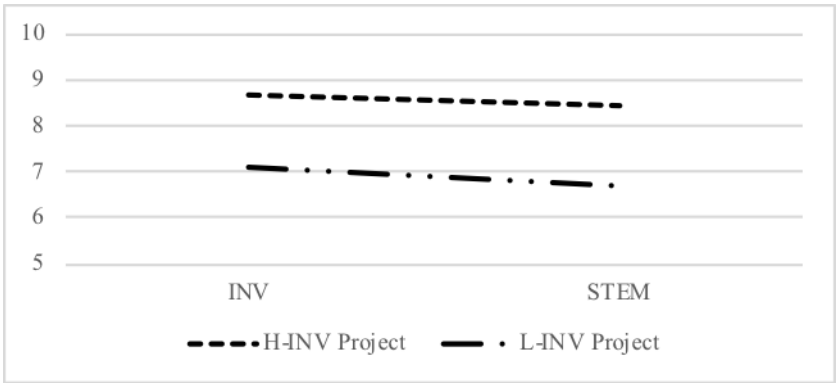


Figure 5. The Average Score of H-INV and L-INV Projects on INV and STEM

5. Conclusion

This study presents a novel solution to fostering high school students' innovative thinking and design by integrating with the STEM approach. The overall structure of this proposed approach has been illustrated in Figure 1. To reach this aim, the annual program known as IT Maker Day has been used in this study. A series of workshop activities were given to the students in focusing IT and Engineering on creating smart school projects. While constructing their projects, each team was encouraged to improve their innovative thinking and design to meet the school context and linking with six steps of STEM. The results of their project were presented, while the evaluation has been made on innovation and STEM aspects. All of the projects have enrolled in the final competition. Based on the evaluation, we have found that the awarded projects have higher scores on both aspects than those who were not. This indicates and reflects the significance of the making process which relates to the innovative thinking and the integration of STEM knowledge.

However, this study is limited with the result presentation due to the data collection. There was no collection of the data while they are working (work-in-progress), this data is crucial to explain the phenomena of this study. Therefore, the findings of this study would not be generalized due to the lack of ongoing activity and the limited number of participants. Nevertheless, the proposed approach can be applied in various school workshops, while further investigations can be carried out. The findings would be interesting to explain how to improve this workshop model in the future.

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