K-12 STEM Education
Vol. 2, No. 4, Oct-Dec 2016, pp.107-116

STEM Holiday Activity: Designing for Flood Crisis

Sonthi Phonchaiya
Raksapol Thananuwong
The Institute for the Promotion of Teaching Science and technology (IPST)
Bangkok, Thailand
Corresponding author: sopho@ipst.ac.th

Abstract

STEM Holiday is a project initiated by the Institute for the Promotion of Teaching Science and Technology (IPST) to develop LEGO™-based STEM activities in which students could participate during weekends or holidays. Designing for Flood Crisis is one of the activities developed to teach Thai secondary school students about simple machines through an engineering design process within the context of a flood crisis. The activity was piloted with twenty Thai students in 9th grade. Direct observations were employed to evaluate students' understanding of simple machines and their performance in designing and constructing a LEGO™ model. Questionnaires were used to evaluate students' opinions about the activity and their improvement in creativity and teamwork skills. We found that most students could complete their LEGO™ models within the time limit. They could also give clear and accurate explanations of the concepts of simple machines applied in their designs. Moreover, most of them strongly agreed that the activity was suitable for them and could help improve their creativity and teamwork skills. These findings demonstrate the potential of using a LEGO™-based activity to teach science during extra-curricular hours and in formal classrooms. More studies are necessary to strengthen the findings.

STEM education is a pedagogical approach that integrates science, technology, engineering, and mathematics into a learning experience that provides opportunity for students to apply what they have learned to solve real-world problems (IPST, 2014a). While the name suggests exclusiveness in the four disciplines, the implementation of STEM education activities or projects can also be integrated with other subjects or principles such as arts, social studies, ethics and moral education. Students with experiences in STEM activities are not only expected to gain better understanding and more interest in the STEM subjects, but also be equipped with skills of the 21st century workforce such as problem-solving, critical thinking, creativity and collaboration (IPST, 2014a; Partnership of 21st Century Skills, 2008). In the long term, STEM education is envisioned to help develop STEM literate citizens and high-performance STEM workforces that would enable Thailand to enhance its global competitiveness and escape the middle-income trap (Chulavatnatol, 2014).

Since the introduction of STEM education into the Thai education arena in 2013, several workshops, seminars and projects related to STEM education have been conducted and promoted. There have also been some ongoing efforts made by Thai educators to develop and implement STEM activities in classrooms such as the STEM Project at Rajinibon School (Sirisak, 2015) that merged the school's existing programs with a STEM education approach to create more rigorous, engineering-oriented and project-based activities for students from kindergarten to secondary level; the STEM Education Activity Manual (IPST, 2014b), which provided Thai K-12 teachers with worksheets and teacher guides of 14 exemplary STEM education activities designed and tested by IPST staff; and "Learning About Global Warming Through STEM Education" (Thananuwong, 2013), which is an article that describes research-based STEM education activities related to global warming and thermal energy transfer for the middle school level. Some investigations by Thai researchers, teachers and graduate students have also been done to study the effectiveness of STEM

education, such as the work of Saengpromsri, Nuangchalerm and Chantiratikul (2015), Ektragoon (2014) and Intalapaporn, Patphol, Wongyai and Pumsa-ard (2015).

This article describes a STEM activity "Designing for Flood Crisis", which integrates the science of simple machines and an engineering design process using LEGO™ materials as learning tools. Preliminary findings from our evaluations of students' performance and understanding of the concepts are presented. Students' opinions about the activity were also evaluated and are discussed in this article.

LEGO™ Materials as Learning Tools

Since STEM education has been introduced to the Thai education arena, the majority of STEM activities developed by Thai science educators involve the use of everyday materials. Some of the main reasons are that they are low cost, simple to use and locally available. The use of LEGO™ materials as learning tools might be considered unnecessary, expensive and suspicious of being a target of marketing schemes. However, LEGO™ materials have several advantages over everyday materials. First, LEGO™ bricks and pieces can be assembled into a variety of shapes without requiring cutting or assembly tools (e.g., cutter, scissors, tape, or glue), which could consume significant amounts of time and cause injuries. Second, while most low-cost everyday materials are fragile, the fastening mechanism of LEGO™ bricks and pieces provides a fairly stable constructed model, which can be easily deconstructed or modified to make a design change. The modification process could well enhance students' learning of engineering design. Third, while most everyday materials have to be disposed after activities have been completed, the high-cost LEGO™ materials are reusable and can last for many years. Investing in LEGO™ sets that will be used for multiple years could therefore be considered a cost-effective decision. Fourth, with colorful and firm structure, the LEGO™ finished models can be easily moved and exhibited in a presentation. Fifth, activities using LEGO™ materials could easily be extended to activities that involve programming and information and communication technology (ICT) since they are designed to be compatible with microprocessors and electronic sensor probes. Finally, LEGO™-based activities were reported to enhance students' conceptual understanding in science, improve higher-ordered thinking, develop abilities to work collaboratively, and increase positive attitudes towards learning (Marulcu & Barnett, 2013; The LEGO™ group, 2015). Therefore, with several positive impacts on teaching and learning as described above, LEGO™ materials are promising tools for Thai students.

STEM Holiday Project

STEM Holiday was a project initiated by the Institute for the Promotion of Teaching Science and Technology (IPST) in 2014 to develop STEM activities for Thai students from primary and secondary school levels to participate during weekends or holidays. It is one of several private-public-partnership projects on STEM education directed by the IPST. The activity "Designing for Flood Crisis" is one of the LEGO™-based STEM activities developed for the STEM Holiday project. It aims to teach the concepts of simple machines, which, in Thailand, are normally introduced in an elective science curriculum at the lower-secondary (middle school) level and in the physics curriculum at the upper-secondary (high school) level.

Engineering Design Process

The STEM activity "Designing for Flood Crisis" employed the engineering design process as defined by the Department of Design and Technology, IPST. The definition is adopted from the International Technology and Engineering Educators Association (ITEEA) (2000, 2002, 2007). A diagram depicting the five cyclical steps of the process is shown in Diagram 1.

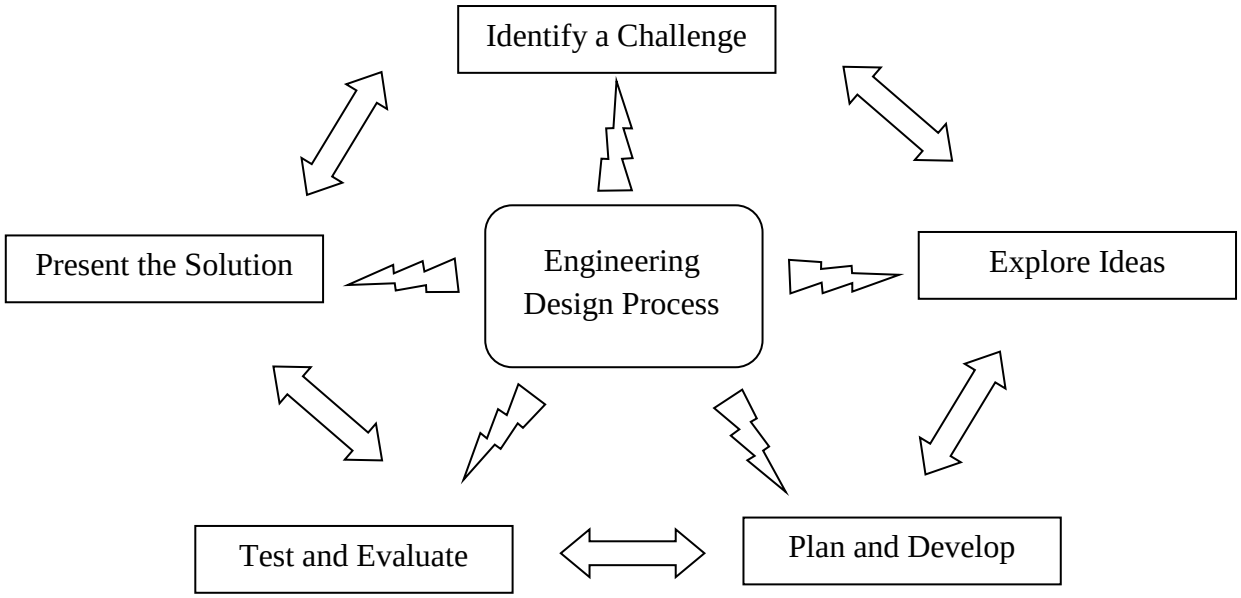

Diagram 1. Engineering Design Process

Teaching science through the engineering design process has potential in improving students' learning and achievement in science (National Research Council, 2009) and helps students connect the ideas from science to real-world problems, which involve people working together to come up with multiple solutions (Atman et al. 2007, 2008). Therefore, including the engineering design process in the teaching of K-12 science shows promises in helping students develop some important 21st century skills such as problem-solving, creativity, collaboration and communication.

Methodology

We piloted the activity with twenty Thai 9th Graders who came to participate for three hours in one Saturday morning. Students were first divided into groups of four or five and they were encouraged to work collaboratively. The procedure that the students undertook is described below.

Identify a Challenge

The students were first asked to discuss causes and effects of natural disasters they have learned from news, movies, or other resources. Then, they were asked to identify the types of natural disasters occurring in Thailand and ranked them according to frequency. The majority of students agreed that flooding was the most frequently occurring natural disaster in Thailand. They also came to a consensus that flooding takes place in many regions of Thailand during the rainy season every year, which causes severe damage to lives and property.

After the discussion, each group of the students was challenged to create a model of a vehicle, equipment, or machine that could be used to protect lives or property during the times of flood crises. Their work had to meet the following four criteria: First, the model must have at least one function that could be demonstrated; Second, the principles of simple machines must be applied in the design and development of their model; Third, a set of LEGO™ Simple and Power Machines was the only available materials for each group to construct a model; Fourth, the design, testing, modification and construction of the model must be complete and ready to present within two hours.

Explore Ideas

Because there were only three hours for the whole activity, the students were lectured on the principles of some simple machines: wheel and axle, pulley, lever, and gear. The lecture, including some discussions, took about 15 minutes. Handouts containing information about all types of simple machines were then distributed to every student as a resource for more detailed reading. A LEGO™ Simple and Power Machines manual was also provided to each group as a guide on how to assemble the LEGO™ bricks and pieces.

Figure 1 illustrates a model of a tower crane depicted in the LEGO™ Simple and Power Machines manual. The model was used as an example of "a Saver," a machine that, in a flood situation, can lift heavy objects to a higher position or from underwater to the ground level.

Figure 1. A model of a tower crane.

Figure 2 illustrates a model of a pontoon which was used as an example of a structure or equipment that could help save lives and property during a flood crisis.

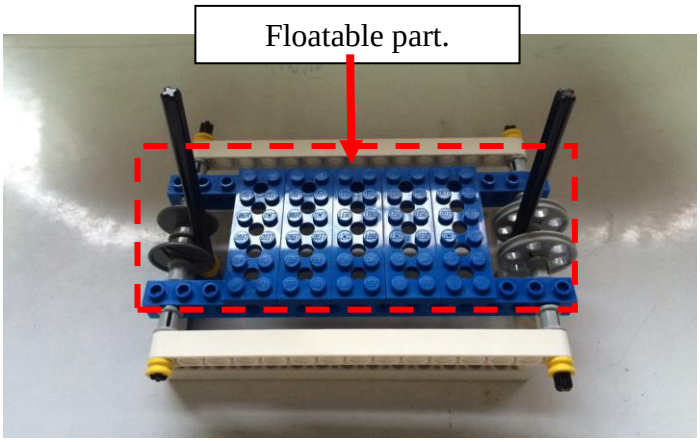

Figure 2. A model of a pontoon.

Plan and Develop

After exploring ideas, the students were asked to discuss within their groups in order to come up with designs of LEGO™ models that could meet all of the criteria. Then, each group had to draw a sketch of their design in a blank space on a worksheet (See Figure 3) and they also had to think of a name for their model. Before the students could start to construct their LEGO™ models, each group had to explain the purpose(s) and function(s) of their model to the instructor who would decide whether to approve their model for construction.

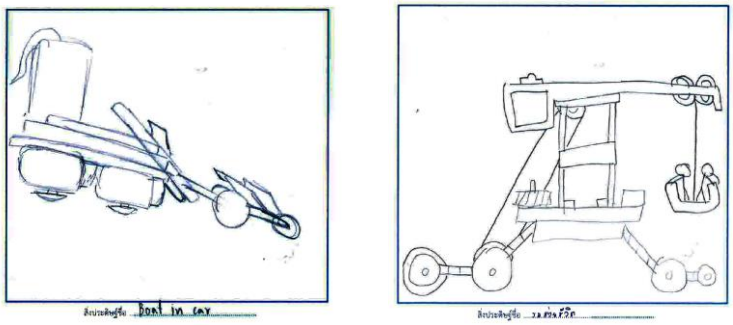

Figure 3. Examples of the students' designs.

During the construction, we had a staff member from a LEGO™ distributor, who was highly experienced in facilitating LEGO™ materials construction, provide guidance and support to the students. With such help, most groups were able finish their models within the given time limit. Nevertheless, groups that were not able to construct their models as described in their designs were allowed to modify their designs or come up with new designs and to seek new approval. In such cases, we found that students were able to construct their second LEGO™ model faster than their first one.

One example of a LEGO™ model constructed by the students is shown in Figure 4. This model was named "A Rescue Car." Its tower-like body, as described by the students, had some advantages over other vehicles: it could run in highly flooded areas without being submerged in water and it could lift people or property up from flood water to put in a dry place high above the ground. In the process of developing this model, the students applied the concept of wheel and axle to the design and construction of the vehicle's wheels and applied the concept of pulley to the design and construction of the lifting system. Even though the model was similar to a Saver, an example we discussed in the step of exploring ideas, students' creativity was shown in making modification of the lower part. The similarity to a given example was expected because there were only three hours for the whole activity. More innovative designs by the students would require more time for explorations of different ideas and more familiarity with using the LEGO™ materials. Teaching the series of activities may help reinforce students' creativity.

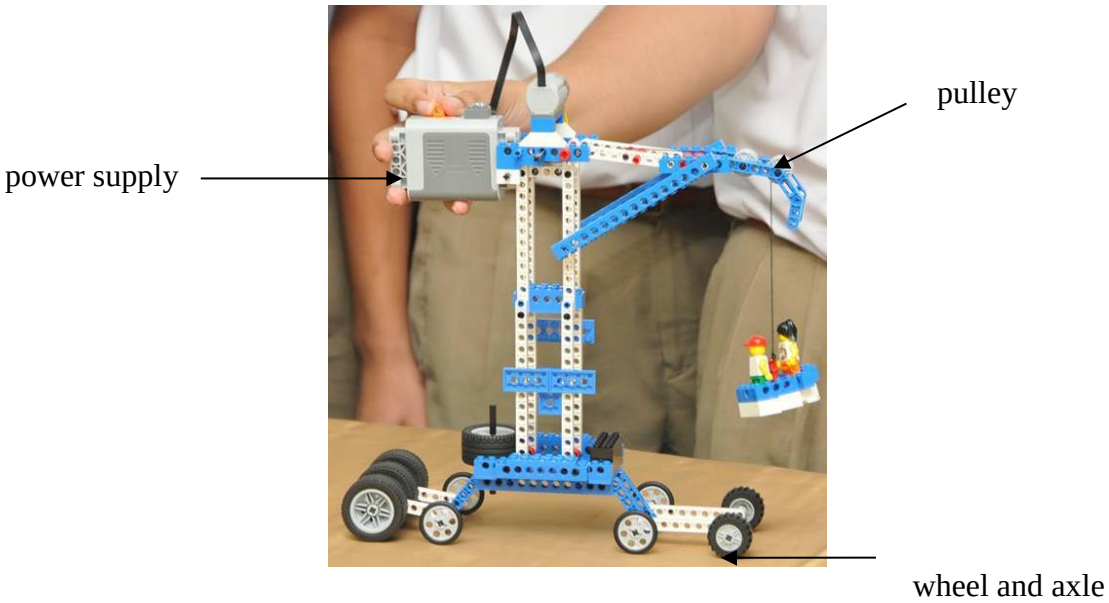

Figure 4. A Model Rescue Car.

Test and Evaluate

In this step, each group took some times to test the function(s) of their models and assess whether they should make a design change. For example, a group that constructed "An Amphibious Car" model ran a test to determine whether their model could run on the floor and on water. The group that built "A Rescue Car" model ran a test to determine whether their vehicle could run well on the floor and could lift some submerged objects from a water bucket to place on a table. If the models did not work as described in their designs, the students were required to modify their designs and then ask for new approvals before they could do another round of constructing, testing and evaluating.

Present the Solution

All groups had to present their work and demonstrate how their models could help save lives and property in the time of flood crisis. The presentation was required to include the followings topics:

- The function(s) of the model (e.g., rescue people, lift or drag objects, asylum, etc.).
- Explanation of the principles of simple machines applied in developing the model.
- Discussion of the possibility of making a real vehicle, equipment or machine, including types of materials and budgets.

Data Collection and Analysis

During the activity, the instructor evaluated the students' performance and understanding of the simple machines by observing their discussions, interactions with group members and presentations. Worksheets collected at the end of the activity were also used as a source of evidence for the evaluation. The evaluations were scored using the rubrics we developed, as shown in Table 1 and Table 2.

Table 1. Rubric for performance evaluation

Description/Score	3	2	1
Planning	Evidence of students' planning is present. Approval of construction or modification from an instructor is shown.	Only evidence of students' planning is present.	No evidence of students' planning.
Construction and Application of Knowledge	Construction of a LEGO™ model is completed. Application of the knowledge of simple machines can be observed.	Construction of a LEGO™ model is completed but application of knowledge of simple machines is neglected.	Construction of a LEGO™ model is not completed or the model is not relevant to the flood situation.
Creativity	The model is outstanding and obviously different from others.	The model is not outstanding or is little different from others.	The model is the same one as in the LEGO™ Simple Machines manual.

Table 2. Rubric for presentation evaluation

Description/Score	3	2	1
Content	Principles of science, engineering, technology and mathematics are correct and clearly communicated.	Principles of science, engineering, technology and mathematics are partially incorrect and/or not clearly communicated.	Principles of science, engineering, technology and mathematics are mostly or totally incorrect and/or not clearly communicated.
Skills	Presentation is engaging and well organized.	Presentation is either engaging or well organized.	Presentation is neither engaging nor well organized.

Questionnaires were handed out to every student after the end of the activity. The question items in the questionnaires asked for students' opinions about the activity and about their improvement in creativity and teamwork skills. There was also one open-ended question that asked the students to give any comments or suggestions about the activity. The answers to all questions, except the open-ended question, were scored using Likert scales where 5 = strongly agree, 4 = agree, 3 = neutral, 2 = disagree and 1 = strongly disagree. The data were analyzed using descriptive statistics. For all the written responses to the open-ended question, we analyzed them for similarity and put them into groups; then we counted the number of similar opinions in each group.

Results and Discussions

Results from the direct observations are shown in Table 3. From the results shown, we can infer that most of the students could complete their LEGO™ models within the given time. Their explanations on the principles of simple machines given during their presentations indicated that they had good understanding of the concepts. Moreover, each design of their LEGO™ models for fighting flood crisis showed evidence of their creativity.

The results from the questionnaires are shown in Table 4. All items have mean scores ranging from 4.70 to 5.00. These can be interpreted as the students' strong agreement on all of the questionnaire items. In other words, most of the students strongly agreed that the activity was suitable for them and the length of time was appropriate. They also strongly agreed that they could learn the concepts, develop their creativity, develop their skill in applying what they have learned to a new situation and their teamwork skills, while also having fun.

Table 3. The means and standard deviations (SD) of the scores of each item in performance evaluation and presentation evaluation

Description	Mean ± SD
Performance	
1. Planning	3.00 ± 0.00
2. Construction and Application of Knowledge	2.80 ± 0.44
3. Creativity	3.00 ± 0.00
Presentation	
1. Content	3.00 ± 0.00
2. Skills	2.80 ± 0.44

Table 4. The means and standard deviations (SD) of the scores of each item in the questionnaires

Description	Mean ± SD
1. Your opinions regarding following aspects of the activity	
1.1 The activity is appropriate.	4.95 ± 0.22
1.2 The time for this activity is appropriate for you in planning, constructing the model, and presentation**.**	4.95 ± 0.22
2. Your achievements	
2.1 Knowledge	4.70 ± 0.47
2.2 Creativity	5.00 ± 0.00
2.3 Application of knowledge to everyday life	4.75 ± 0.44
2.4 Teamwork	4.85 ± 0.36
2.5 Fun and entertainment	5.00 ± 0.00
3. Your satisfaction overall	5.00 ± 0.00

The percentages of similar responses to an open-ended question are shown in Table 5. As shown in the table, half of the students thought the activity was interesting, challenging and fun. About one-third of them wanted their teachers to have similar LEGO™-based activities in their classrooms; and about one-fifth commented that the available materials were too specific such that it limited the imagination of their designs. Some students suggested that the activity should allow the combination of both LEGO™ materials and everyday materials; so that the activity would be more fun, more challenging and open to more ideas.

Table 5. The percentages of similar responses to an open-ended question

No.	Description	% of total responses
1	The activity was interesting, challenging and fun.	50
2	More LEGO™-based activities were requested.	33
3	Available materials were too specific such that they limit the imagination of the designs.	17
Total		100

From many positive results, we can infer that a LEGO™-based STEM activity could be promising prospects for extra-curricular as well as formal classroom activities in Thai secondary schools. However, for teachers who would like to implement a similar approach in their classrooms, there are two aspects to be considered: First, while this STEM Holiday

activity had students learn about simple machines through lecture and reading, the teachers could have students learn the concepts through inquiry and hands-on activity the days or week before, which would provide more enduring understanding on the concepts; Second, to substitute the help that students received from a highly experienced LEGO™ distributor's staff, the teachers may attend some workshops about how to use LEGO™ materials in a classroom so that they can become good LEGO™ instructors themselves.

Conclusions and Implications

A STEM activity utilizing a set of LEGO™ Simple and Power Machines was developed for Thai secondary school students under a STEM Holiday project initiated by IPST. The activity offers opportunities for students to apply the knowledge of simple machines and the engineering design process to design and create models that could help protect lives or property during a flood crisis. The activity was piloted with twenty 9th grade students. The students' performance and understanding of the concepts were evaluated from direct observations of students' discussions, presentations, LEGO™ models and worksheets. Responses from questionnaires were used as evidence to evaluate the students' opinions about the activity. Based on our data analysis, we found that most of the students could put the engineering design process into action to solve the real-world problem. In addition, most of them found the activity interesting, challenging and fun, while some students would prefer combining LEGO™ materials with everyday materials. They also strongly agreed that it helps them improve their creativity and teamwork skills. With such positive outcomes, we can infer that similar LEGO™-based STEM activities are promising prospects for extra-curricular and formal classroom activity in Thai secondary school. Investigations of the learning outcomes, performance and feedbacks of more number of students who are from different types of schools and grade levels are necessary to reinforce our findings and implication.

Dr. Sonthi Phonchaiya *is a specialist (Chemistry) at the Institute for the Promotion of Teaching Science and Technology. As a STEM Education Core Trainer, he works collaboratively with academic staff from National STEM Education Center and university professors under Engineering is Elementary (EIE) project. He develops activities, undertakes teacher training and supervises researchers and graduate students on STEM Education.*

Raksapol Thananuwong *is a senior academic staff member at the Institute for the Promotion of Teaching Science and Technology. His work focuses on K-12 physics and STEM education. He is passionate about igniting curiosity in science, especially in physics, and improving Thai students' critical thinking skills and creativity.*

References

Atman, C., Adams, R., Cardella, M., Turns, J., Mosborg, S., & Saleem, J. (2007). Engineering-design processes: A comparison of students and expert practitioners. *Journal of Engineering Education, 96*(4), 359–379.

Atman, C., Kilgore, D., & McKenna, A. (2008). Characterizing design learning: A mixed-methods study of engineering-designers' use of language. *Journal of Engineering Education, 97*(3), 309–326.

Chulavatnatol, M. (2014, October). *Science Technology Engineering and Mathematics (STEM) for Regional Growth and Integration*. Presentation conducted at SEAMEO Congress, Bangkok, Thailand.

Ektragoon, N. (2014). *A study of learning achievement and problem solving ability in science of 6th grade students taught by STEM Education Approach.* Retrieved from http://swis.act.ac.th/

Intalapaporn, J. , Patphol, M., Wongyai, W., & Pumsa-ard, S. (2015). The study guidelines for learning management of the STEM Education for elementary students. *Veridian E-Journal, Silpakorn University*, *8*, 62-74.

International Technology and Engineering Educators Education Association (ITEEA) (2000/2002/2007). *Standards for technological literacy: Content for the study of technology*. Reston, VA: Author Retrieved from https://goo.gl/P0b4Cd

Marulcu, I., & Barnett, M. (2013). Fifth graders' learning about simple machines through engineering design-based instruction using LEGO materials. *Research in Science Education, 43*, 1825-1850.

National Research Council (2009). *Engineering in K-12 Education: Understanding the Status and Improving the Prospects*. Washington, DC: The National Academies Press. doi:10.17226/12635

Partnership for 21st Century Skills (2008). *21st Century Skills, Education & Competitiveness.* Retrieved from: http://goo.gl/U9ZnLM

Saengpromsri, P., Nuangchalerm, P., & Chantiratikul, P. (2015). Comparisons of learning achievement, integrated science process skills and attitude towards chemistry learning for Matthayomsueksa 5 students between STEM education and conventional methods. *Journal of Education, Mahasarakham University*, *9*, 401-418.

Sirisak, P. (2015, October). *STEM Project*. Presentation conducted at EDUCA 2015, Bangkok, Thailand.

Thananuwong, R. (2013). Learning about global warming through STEM education. *IPST Magazine, 41,* 15-20.

The Institute for the Promotion of Teaching Science and Technology (2014a). *Introduction to STEM Education*. Retrieved from http://goo.gl/6albtA

The Institute for the Promotion of Teaching Science and Technology (2014b). *STEM Education Activity Manual*. Retrieved from http://goo.gl/Sv79oJ

The LEGO group (2015). *LEGO education*. Retrieved from https://education.lego.com/en-us

Vasquez, J. A., Sneider, C., & Comer, M. (2013). *STEM lessen essentials: Integrating science technology engineering and mathematics*. Portsmouth, NH: Heinemann.