The Multidisciplinary Project to Promote Story-Based Learning and Soft Skills: Integrating Biology, Technology, Engineering and Mathematics study

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Abstract

Story-based learning is the Engineering Science Classroom of King Mongkut's University of Technology Thonburi (ESC-KMUTT) curriculum promoting high school students to learn through "stories" by which all learning topics are interwoven and integrated. For applying knowledge, the multidisciplinary project called "Ecobox" was created by integrating ecosystem, computer programming, engineering drawing and mathematical modeling topics. Our previous research indicated that this project could enhance the student's soft skills. Therefore, the aim of this study is to find out how and why ecobox project could promote students' soft skills such as teamwork skills, problem solving skills, criticism and creativity. Data were collected form 45 questionnaires, 12 open-ended questions and model evaluation. The participants were 10th grade students form 3 classrooms (n=70). The result found that 12 groups of student in 3 classrooms accomplished to create ecobox models during one month. In term of teamwork skills, the most of students had found that working in ecobox team made them more respect and listen to friend's opinion (4.43±0.65) while mean value of team conflict was low (2.70±1.14). For problem solving, work as part of a team helped students to solve problem better (4.25±0.77). For criticism, working in team could increase the use of critical thinking (4.29±0.84). For creativity, ecobox project helped students to know how to use creativity when constructed ecobox model and increase the creative problem solving (4.06±0.80). The finding of this study could bring more understanding on nurturing students' soft skills using multidisciplinary project.

Keywords: multidisciplinary, story-based Learning, soft skills, ecobox

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Introduction

Ecobox project was created using concept of Project-based learning (PBL). PBL is a student-driven, teacher-facilitated approach to learning which students motivate their learning through inquiry. In addition, they learn through collaboration to research and create projects and employ 21st Century skills as they participate in projects (Bell, 2010). The 21st Century skills included creativity/innovation, critical thinking, problem solving, communication, and collaboration, etc. (Finegold & Notabartolo, 2010). The Ministry of Higher Education, Malaysia recently announced that the 7 soft skills are to be introduced to undergraduates of Institutes of Higher Learning in Malaysia. Those soft skills are communication skills, critical thinking and problem solving skills, team work, lifelong learning and information management skills, entrepreneurship skills, ethics, and professional moral and leadership skills (Shakir, 2009). For making more complex project, a multidisciplinary concept was also applied to ecobox. Many research found that a multidisciplinary project could enhance students' understanding and soft competencies. A multidisciplinary project called "Computer Integrated Manufacturing" was given to a required course in Mechanical Engineering at Temple University. The project integrated the design of electrical and mechanical component. The results indicated that 83% of the students discovered the project being a good implement to learn the knowledge and 96% of the students had the satisfaction of gaining hands-on experience when they was doing activities on the project (Jahanian & Matthews, 1999).

Story-based learning is the Engineering Science Classroom of King Mongkut's University of Technology Thonburi (ESC-KMUTT) curriculum promoting high school students to learn through "stories" by which all learning topics are interwoven and integrated. In the first semester, ESC-KMUTT students need to apply their knowledge to create the multidisciplinary project called "Ecobox" in subject ESC 415 The Relation. This project was designed by integrating ecosystem, computer programming, engineering drawing and mathematical modeling topics. Our previous research indicated that ecobox project could enhance the student's soft skills (Wongta et. al, 2015; Chomngam, et. al, 2017). Therefore, the aim of this study is to find out how and why ecobox project could promote students' soft skills such as teamwork skills, problem solving skills, criticism and creativity.

Methods

1. Participants

The participants were 10th grade students form 3 classrooms (n=70) of ESC-KMUTT. Each classroom consisted of 4 groups (5-6 students) therefore there were 12 groups in total. They were our new coming students who enrolled during 2017 academic year.The sample consisted of 38 male and 32 female students, at the age between 14-16 years old.

2. Multidisciplinary study

2.1 Ecosystem contents (Biology)

1) Lecture about ecosystem

A lecture about ecosystem's concept, structure and function was taught to our students for 3 hours. Topics are, for example, ecosystem definition, ecosystem types, food chain, food web, pyramid of energy and 10% laws which are basic knowledges for math modelling.

2) Laboratory of Mangrove forest

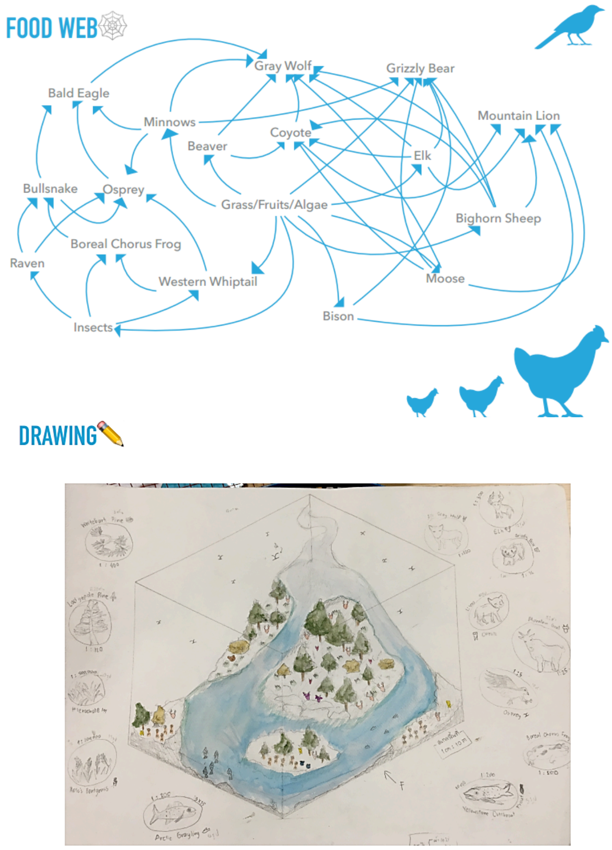
According to the Mangrove forest surrounded KMUTT Bangkhuntien campus, laboratory activity was design to promote the understanding of plant anatomy, animal and water inside Mangrove forest ecosystem for 3 hours.

3) Mangrove forest field trip

One day trip at Klongpittayalongkorn school was planned in order to introduce Mangrove forest ecosystem where students could learn through real experience.

2.2 Basic engineering drawing and design (Engineering)

Students learned how to use basic tools for engineering drawing, front-view, side-view, top-view, 3D isometric and oblique, and perspective drawing from subject called "ESC 417 Fundamentals of Engineering I". Many drafts were sent to teacher until the final draft of ecobox drawing was proved by teacher. Then, basic knowledge about drawing was applied to design terrarium inside 12×18×12 inches aquarium tank under different ecology conditions. Each group was randomly assigned for creating ecobox of an ecology type. There were 4 groups of land ecosystem, water and land ecosystem, water ecosystem and desert ecosystem.



Scale 1 cm. : 10 m.

Fig: 1 The example of Food web and drawing of Lower Falls in Yellow Stone National Park USA.

2.3 Mathematical models of population dynamics (Mathematics)

For this part of activities, we would like the students to learn the predictability of science in study about population dynamics. The students were experienced about how ecologists use mathematics, modeling, and computer simulations in their research works for investigating the relation between species in the ecosystem. The class for learning population dynamics was given in two hours. The first hour of instruction focuses on the definition of population growth and various parameters such as birth rate, death rate and others through the ecosystem models of exponential growth and logistic growth. The second hour was designed to practice students in simulating the model through the Excel program. For some students, this is a good time to start working on it seriously because they had not used it so much in the past. Hopefully, the skill of using Excel in data analysis and data visualization would be helpful for them in their future workings in school life. The activity in the class will be elaborated in the following.

Firstly, the students were persuaded to discuss what the population and population growth are. Then, we discussed about the parameters in the model of exponential growth through story telling approach. It is the story of Fibonacci's rabbit puzzle. This states that starting with the birth of one pair of rabbits in the first month and growing of that pair in the second month. Then this pair grows enough to give birth of another pair in the third month. The new pair needs to grow for one month and then give birth of another pair of rabbits, while the old pair do not need another month at all to give birth. So, the ecosystem has one pair of rabbits in the first and second months, then two pairs in the third month, and so on. With the given conditions of the puzzle, the instructor asked the students to think or calculate to find out how many rabbits exist in the ecosystem when the time passes for twelve months. Let students work on it for ten minutes. Then, the solution of the puzzle was shown with the discussion. In this step, many students could recognize the pattern of the Fibonacci sequence and its relation to the golden ratio. For students, it is the good moment to appreciate the magic of mathematics.

This set of number from the Fibonacci sequence was plotted in a graph on the blackboard. Students were made to realize the J-shape of the plot. After that, we related this with the growing of money savings due to the interest rate, which is analogous to the growth rate in the population. It was defined as the difference between the birth rate and death rate. It was time to introduce the model of exponential growth (J-shape) and logistic growth (S-shape). Next, let the students practice simulating these models using Euler methods and Excel. For example, the equation of the exponential growth could be written in the form

$$N(t+\Delta t) = N(t) + rN(t)\Delta t,$$

where $N(t)$ was the size of population at time t, r the growth rate, and Δt the size of time step. According to Euler method, this could be iterated to simulate for next step of time. This could be done by dragging down a line of the typed formula in table of the Excel program, and then the data was plotted to express the characteristics of the growth.

Similarly, students were taught in the second hour to learn how the model could represent the predator-prey relation between species. By designing the lessons, this model was used to link with what students had learned before about the pyramid of energy, food chain, and different kinds of the relations in ecosystem, etc. This should be one of reasons that the subject name of these activity is "The Relation." One of the best governing equation of the predator-prey relation could be the Lotka-Voltera equation. The set of equations describing population dynamics of two species, with $X(t)$ and $Y(t)$ are the sizes of population of species X and Y respectively, in the form of discrete mapping as

$$X(t+\Delta t) = X(t) + r_X X(t)\Delta t - h_{XY} X(t)Y(t)\Delta t,$$
$$Y(t+\Delta t) = Y(t) + e\left(h_{XY} X(t)Y(t)\Delta t\right) - d_Y Y(t)\Delta t,$$

where r_X is the growth rate of the species X, h_{XY} the death rate of X per each predator of species Y, e the efficiency of producing Y from turning each unit of species X killed from hunting, and d_Y the death rate of Y in the condition of no-hunting from other species. After learning this model and discussing each parameter, students practiced again to simulate the model using the Excel program and visualize the data. It took time for some students to practice this model in class. To ensure that all students able to simulate it, it was repeated in the task of simulating population dynamics of three species with this model. This was given as a homework. Apart from simulation, students had to give rational explanation of choosing the valid value of each parameters. With difficulties, some students had to be coached in using the program and adopting the concept of modeling. Interestingly, students could enjoy working on it when they could change the parameters and then the plotted graphs changed. In some ways, it looked like the animations.

As mentioned above, this activity would link to the main task of designing their own ecosystem. Therefore, students needed to choose the valid parameters for their designed Ecobox. It was the intersection between being an artist and a science researcher. The graphs were plotted using Excel to express the prediction of population growth of each species in time. Furthermore, integrating this with coding skills learned in another subject, the Python codes were launched to students. In our opinion, this exposition of using programming to data visualization was significant for them to realize about how to adapt many learned skills in their research works. However, what students needed to do was not to write the codes from nothing, but they just had to write the flow chart expressing their understandings of logical sequence of the codes. Furthermore, students used them with chosen values of parameters to data visualization. Finally, the plotted graphs were shown in the presentation and the discussions about the difference between using Excel and Python was given in the wrap-up by instructors.

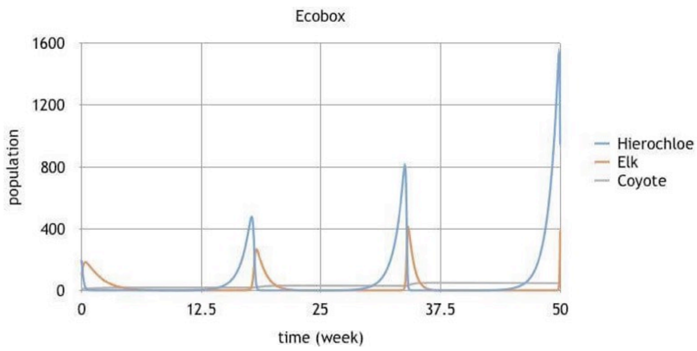


Fig: 2 The mathematical modelling of Lower Falls in Yellow Stone National Park USA showed the relationship between X= Hierochloe, Y= Elk, and Z= Coyote using excel program.

2.4 The implementation of read sensor value in Arduino (Technology)

This technology part was developed to create sensor for ecobox and apply the knowledge of basic programming. The user communicated with the PC and Arduino Board. Python programs were developed to create Lotka-Volterra equation for creating predator-prey graph.

A. Monitoring sensor reading

Sensor reading from Arduino: Arduino enables users to monitor various kinds of sensors such as thermometers, humidity, moisture, light and LCD display. The analog and digital pins on the Arduino board can all serve as general purpose input and output pins (GPIO).The ATmega328microcontroller embedded on the Arduino board contains the analog-to-digital converter (ADC), analog input signal to a number between 0 and 1023.The integer number is proportional to the amount of the voltage being applied to the analog input. Any sensor operating on 5 volts can be directly connected to the Arduino board. As a prototype for monitoring sensor readings with

Arduino, we had implemented a simple setup to connect the analog sensor to the Arduino board, and received the sensor readings from the PC.

Fig: 3 Monitoring sensor reading of Lower Falls in Yellow Stone National Park USA.

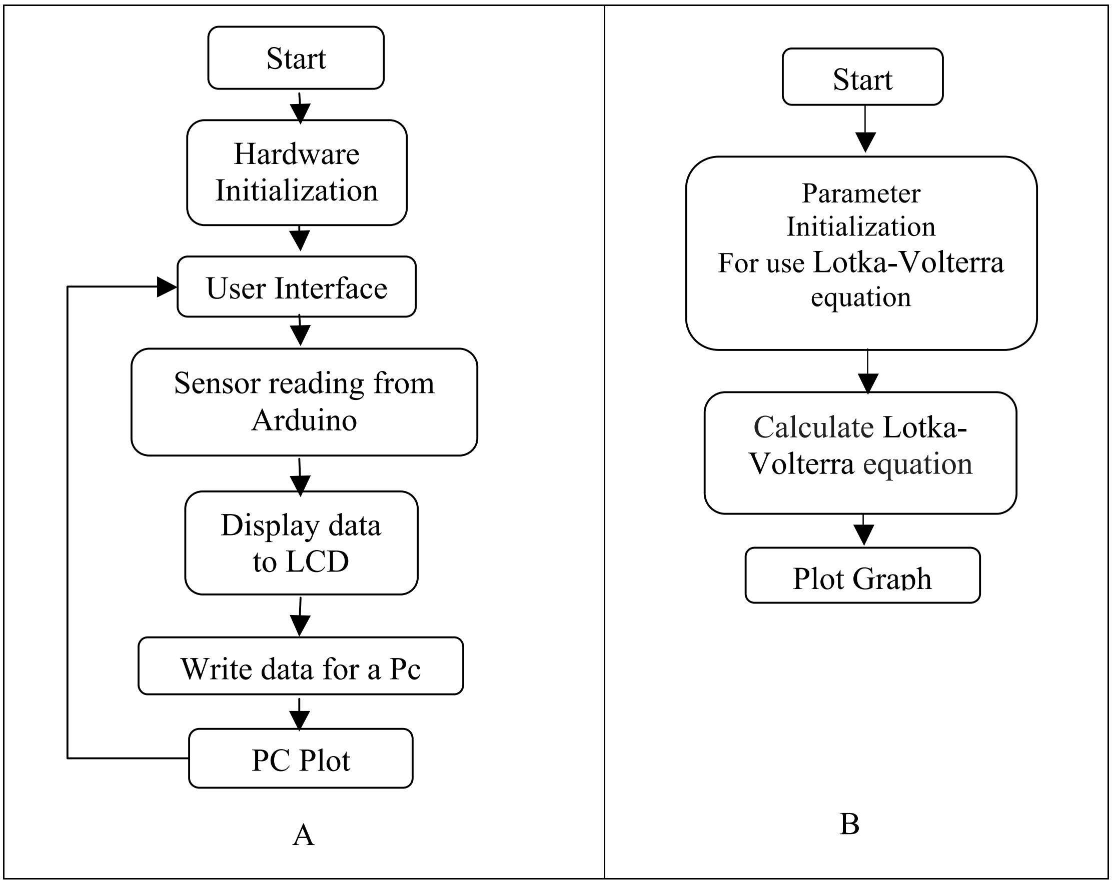


Fig: 4 The flow chart of read sensor value on the Arduino (A) and the flow chart of Lotka-Volterra equation on the Python programs (B).

B. The calculation of Lotka-Volterra equation using Python programs

Mathematical model in Microsoft Excel faced the problem when we used the plenty of time or compare many value of the step size for simulating the relationship between predator and prey. For over the limitation of excel program, Python programs were developed to create Lotka-Volterra equation to create predator-prey graph.

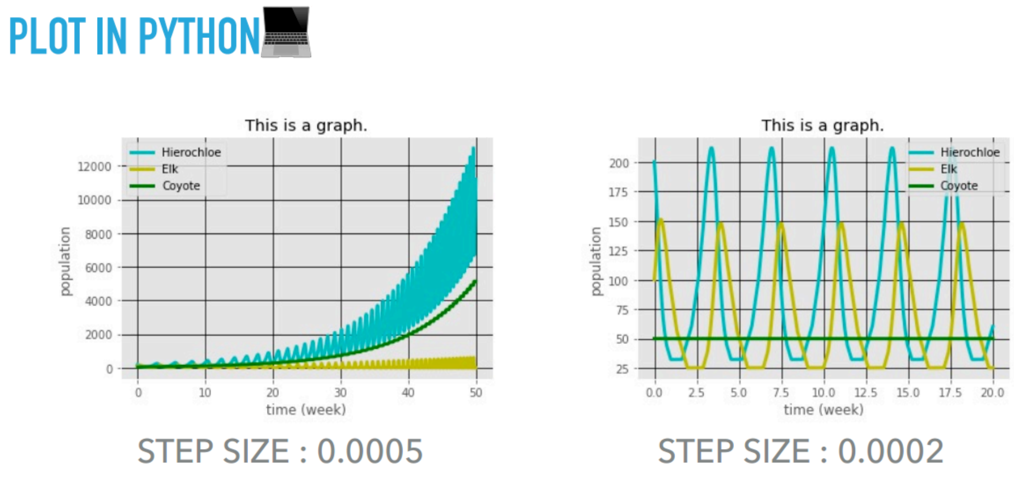


Fig: 5 The mathematical modelling of Lower Falls in Yellow Stone National Park USA showed the relationship between X= Hierochloe, Y= Elk, and Z= Coyote using Python programs with different step size.

The flow charts of sensor reading from Arduino and the calculation of Lotka-Volterra equation were shown in Fig.1A and 1B, respectively.

3. Learning process

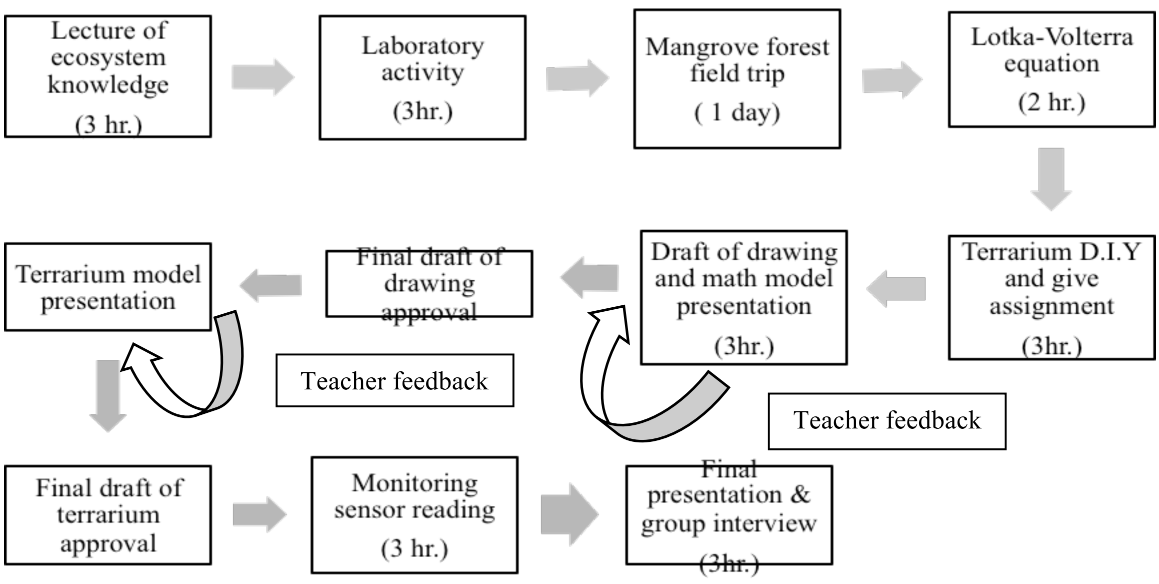


Fig: 6 Schematic diagram showing learning process of the Ecobox project.

4. Data collection and analysis

Data were collected form 45 questionnaires (Gibbs, 1994; Griffith University, 2011; Gallegos & Peeters, 2011), 12 open-ended questions (Gibbs, 1994; Griffith University, 2011; Gallegos & Peeters, 2011) and model evaluation.

Results and discussion

Model evaluations were divided into 2 parts. First, the teacher evaluation showed that Yellowstone National Park, Red sea and Fly geyser at Black Rock Desert had got 28, 27 and 24.5 point, respectively (Table: 1). Second, peer assessment form their friend showed that Yellowstone National Park, Red sea and Huai Kha Khaeng had got 34%, 16% and 10%, respectively (Table: 2). It seems like teacher and students evaluation quite agreed with each other.

Table: 1 Ecosystem location and teacher evaluation.

Group	Ecosystem type	Location	Ecosystem name	Teacher evaluation (Total 30)
1E	Land	15° 19' 59.988" N 98° 55' 0.012" E	Huai Kha Khaeng	22
2E	Water	7° 45’ -8° 15’ N 98° 15’ - 98° 40’ E	Andaman Phuket	21
3E	Land and water	44° 43’ 05”N 110° 29’ 46”W	Lower Falls in Yellow Stone National Park USA	24
4E	Desert	32° 39' 55.404" N 113° 6' 31.7736" E	Sonoran desert	20.5
Group	**Ecosystem type**	**Location**	**Ecosystem name**	**Teacher evaluation (Total 30)**
1S	Land	16° 52' 12" N 101° 47' 60" E	Phu Kradueng National Park	20
2S	Water	27°44’06.55” N 33°59’10.17” E	Red sea	27
3S	Land and water	16°11′59″N 99°12′07″E	Klong Lan National Park	24
4S	Desert	35°03’13.57”N 115°22’35.56”W	Mojave desert	22.5
1C	Land	44° 25' 25.2876" N 110° 35' 18.6576" W	Yellowstone National Park	28
2C	Water	35°16'14.0"N 120°53'52.5"W	Kelp Forest at Bluff Trail	21
3C	Land and water	14°22′55″N 101°25′54″E	Heo Prathun Waterfall at Khao Yai	23
4C	Desert	40° 51′34″N 119° 19′55″W	Fly geyser at Black Rock Desert	24.5

Table: 2 Peer assessment by voting from their friends.

Ranking	Room	Group	Percent of vote (%)	Room
1	C	Yellow stone National Park	34	C
2	S	Red sea	16	S

3	E	Huai Kha Khaeng	10	E

The results of self-evaluation questionnaire that related to students' soft skills showed the interesting information (Table 3). In term of teamwork skills, the most of students had found that working in ecobox team made them more respect and listen to friend's opinion (4.43±0.65) while mean value of team conflict was low (2.70±1.14). For problem solving, work as part of a team helped students to solve problem better (4.25±0.77). For criticism, working in team could increase the use of critical thinking (4.29±0.84). For creativity, ecobox project helped students to know how to use creativity when constructed ecobox model and increase the creative problem solving (4.06±0.80).

Table: 3 The results of self-evaluation questionnaire that related to students' soft skills.

Soft skills	Mean value	SD	Item
Teamwork	4.43	0.65	I had found that working in ecobox team made them more respect and listen to friend's opinion.
	2.70	1.14	There was team conflict.
Problem solving	4.25	0.77	Work as part of a team helped students to solve problem better.
Critical thinking	4.29	0.84	Working in team could increase the use of critical thinking.
Creative thinking	4.06	0.80	Ecobox project helped students to know how to use creativity when constructed ecobox model and increase the creative problem solving.

Conclusion

All ecobox teams could complete their work on time and some model showed high creativity and innovative such as Yellow Stone National Park which had lighting for expressing the volcano. The implementation of this project evaluated that ecobox learning process could help promote students to apply soft skills and knowledge for creating completely model. However, teacher feedback was a very important catalyst to encourage students' using their capabilities. The finding of this study could bring more understanding on nurturing students' soft skills using multidisciplinary project called "Ecobox".

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Appendix

Group	Ecosystem type	Ecosystem name	Photo
1E	Land	Huai Kha Khaeng	
2E	Water	Andaman Phuket	
3E	Land and water	Lower Falls in Yellow Stone National Park USA	
4E	Desert	Sonoran desert	

Group	Ecosystem type	Ecosystem name	Photo
1S	Land	Phu Kradueng National Park	
2S	Water	Red sea	
3S	Land and water	Klong Lan National Park	
4S	Desert	Mojave desert	

Grou p	Ecosyste m type	Ecosystem name	Photo
1C	Land	Yellowston e National Park	
2C	Water	Kelp Forest at Bluff Trail	
3C	Land and water	Heo Prathun Waterfall at Khao Yai	
4C	Desert	Fly geyser at Black Rock Desert