The effect of SSI overlap STEM Education on Secondary Students’ Socio-scientific decision making

Srirup Sirirunam
Secondary school science teacher at Phadungnaree school, Mahasarakham, Thailand
Email: crutongtang@gmail.com

Radka Bednarova
Secondary school English teacher at Phadungnaree school, Mahasarakham, Thailand
Email: bednarova.r@gmail.com

Prasart Nuangchalermb
Mahasarakham University, Thailand
Prasart.n@msu.ac.th

Abstract. The purpose of this study is to investigate the secondary students’ decision making process when global socio-scientific issue (SSI) is applied to STEM-based learning. SSI overlap STEM framework adapted from the literature was designed to help students to take a responsible informed decision when considering global environmental issue as a part of their classroom activity. Thirty one students participated in the pre- and post-socio-scientific decision-making test. Data was also collected through class observation. Both quantitative and qualitative data were gathered and analysed; content analysis of qualitative data collected from student’s reasoning helped to explain the initial quantitative findings. Based on the qualitative analysis, the results revealed that the students’ abilities benefited from the SSI overlap STEM framework implementation. The results showed that there were considerable changes in the students’ decision making before and after the activity. It also indicated that the SSI overlap STEM framework designed for this study was effective and could be used in science classes.

1. Introduction
The advancement of science, technology, and the proposition concerning the 21st century skills have great influence on educational paradigm changes. Education on all levels nowadays puts emphases on so-called higher thinking skills, such as critical thinking, problem solving, decision making and creativity, as well as developing students’ social skills and communication, and use of technology as a tool for inquiry [12]. Integration of all these as well as the ability to learn, both in the classroom and in a real life, became the primary trend in education in order to make learning meaningful to students. Only that way, students will recognize the value of their studies and will be able to apply their knowledge in their everyday lives.

The study of science is essential to our lives. Furthermore, the advancement of science generates rapid changes in society. Learners these days need to be equipped with the ability to think rationally and to make decisions based on data obtained by information technology. They also need to be aware of global affairs and a global citizenship based upon the 21st century skills. The reformation of study of science is, therefore, necessary for improvement of scientific literacy [14] which includes such topics as, understanding of Nature of Science, appropriate application of scientific concepts, and implementation of scientific process in solving problems and making decisions.
Our understanding of science, as well as its practical application, could be divided into two parts, non-normative (e.g. gathering data, observation, prediction, scientific method and process) and normative (e.g. describing courses of action, choosing to create selected products, decision about what ought to be done). Both elements are closely connected. Recognising the importance of their mutual contribution to the understanding of the Nature of Science is, therefore, vital for formulating and implementing policies when teaching science. However, there seem to be trends in promoting non-normative to normative elements when practising science [19].

A prime example was illustrated in the examination of the Next Generation Science Standards (NRC 2012) by [19] who points out disintegrated views that allow those who practice science, or make decisions about the use of science in everyday life, to abandon their sense of responsibility by making science awkwardly independent on what is happening in the world [19].

There have been efforts to create guidelines (NRC 2011, BOSE at NAS 2012) that would improve current situation; however, they somehow fail to provide complex answers. The document compiled by the National Research Council (NRC 2011), for example, offers variety of generalised suggestions on improving the STEM learning experience while, unfortunately, the school settings remain separated from the cultural context thus failing to connect to the life environment of the students [19]. Both STS (science-technology-society) and STEM education have thus so far failed to pay enough attention to socio-scientific and sociocultural perspectives that play central role in forming one’s sense of scientific identity which is necessary for developing moral responsibility [19],[13].

The issue thus remains. The students still depend on the teacher in regard to what to know and how to think, and / or the studied problems lack the connection to the students’ interests and beliefs.

1.1 STEM Education
The educational acronym “STEM” represents a multidisciplinary educational perspective that combines Science, Technology, Engineering and Mathematics. It is widely used and is directed at those involved in education focusing on improving how STEM education is developed and delivered. Even though STEM education should incorporate all four disciplines, it often focuses on science and mathematics only. In these, students engage in group activities, laboratory and field studies, and projects, as they are expected to develop cognitive skills, such as adaptability, complex communication, non-routine problem solving, self-management, and systems thinking, in order to enhance their competitiveness in the modern world. However, there has been considerable lack of promoting technical knowledge and engineering. Using technologies and understanding of how things work is the real concept of STEM education and it has great economic importance [2].

To improve this situation, teachers involved in STEM education need to learn more about the STEM areas, and need to start showing the students how these are connected. To begin this transformation, teachers must become STEM thinkers who can demonstrate how STEM is involved in most areas of the students’ lives [5].

Content knowledge of the subjects is essentially important for students to be able to express their intrinsic opinion on any STEM-related topic in a meaningful way which brings them to further inquiries, discussions, and evidence-based reasoning. The ability to put scientific issues in context, as well as real understanding of the context, demands the exercise of prudence, morality and character. It is the lack of these that elucidates the deficit thinking in STEM-based initiatives [2].

1.2 SSI and decision making
Socio-scientific issues (SSI) are a product of knowledge and technology discussed and criticised by public in regard of its relevance to the society. These include problems concerning health, general living conditions, limited energy supplies, economic growth etc. in contrast to environmental conservation [13]. Socio-scientific issues are applied to stimulate the interest in argument-based learning and in discussion based on scientific knowledge and data [11]. At present, the management of knowledge derived from issues concerning science and society is regarded important when studying
science making learners realize that their learning is connected to their lives. Taking into account the context of socially responsible science, teaching should encourage the students to base their decisions on moral reasoning and on a wide scope of scientific literacy.

A current reformation of the study of science tends to support the scientific advancement towards establishing morality and ethics in a scientific dimension, instead of teaching solely science-based content. The use of socio-scientific issues responds to these scientific needs [16].

The use of scientific knowledge before applying it onto situations within social and moral context stimulates learners to find the truth while opening their minds to the opinions of others. They learn to negotiate carefully and systematically while using reasoning [17]. As a result of that, a meaningful way of learning is created for students.

Even though great variety of work has been done on socio-scientific issues, further investigation at a classroom level is still required. There is a need for identifying evidence-based pedagogic practices which could improve students’ decision-making abilities. Using issue-based approach, the students would be guided towards making an informed decision. The focus here would be on enhancing their understanding of the concept and scientific inquiry, attitudes and values, and their ability to use rational arguments [8]. The SSI movement also seeks to engage students in decision-making regarding current social issues with moral implications embedded in scientific contexts [18].

To help students to look at the studied issue from different perspectives, taking into account relevant scientific knowledge, reasoning, and values concerning the possible outcome, a decision-making framework has been created [10]. However, even though most of the students, when making decision, do look at the issue from various perspectives, these are in the end considered unequally, relying more on ethical values. This is particularly true for controversial SSI, such as stem-cell research [4]. In addition to that, results by Walpuski et al. suggest that decision-making and argumentation are highly dependent on how frequently students are given the chance to argue in their science classes.

SSI is becoming part of the science curricula as an important way of achieving scientific literacy among secondary school students (e.g., Hong Kong Curriculum Development Council, 2007; National Research Council [NRC], 1996, [9]. For example, Lee and Grace. Zeidler (2016) considers biodiversity conservation an important socio-scientific issue that is often thought of as a prerequisite to sustainable living and development. The foundation for citizens’ understanding of conservation issues could be laid down in formal school education.

1.3 SSI overlap STEM framework
It has been mentioned above that STEM-related research and programs restrict their views only on science, technology, engineering and mathematics, mostly paying attention to crosscutting connections among those four areas. That however, leaves gab where particular scientific issue should be put into context of cultural and life experiences of ordinary students. Zeidler (2016) in his study uses a term “STEM silos” to describe this situation.

He offers a model (“STEAM”) which comprises of STEM disciplines supported by the Arts. The Arts here are represented by disciplines, such as sociology, psychology, history, fine arts, philosophy and education, and serve as a means of sociocultural contextualization.

He supports the idea that only when bringing down the rigorous boundaries of discipline-specific silos of STEM education, proper integration of science and socio-cultural context is possible using sociology, psychology, fine arts, etc. to contextualize the knowledge in a way personally meaningful to students.

Zeidler (2016) also points out that to take responsible informed decision we need to have both, the knowledge as well as the ethical responsibility and the ability to use evidence-based reasoning. The concept of dividing science into normative and non-normative components is thus unrealistic if not dangerous. Only accepting moral responsibility makes us scientifically literate and ready to participate in a larger global society.
“While literacy may not require a moral compass, scientific literacy, in the sense [he advocates], does.” [19].

Teaching science in Thailand is not yet satisfactory. What is taught in schools remains virtually irrelevant to the reality failing to stimulate learners’ interests and to connect the studied subjects with the students’ daily lives. The little emphasis on knowledge and testing leaves the students poorly equipped with effective thinking skills, such as problem solving and decision making, when entering the labour market. This is especially true when dealing with socio-scientific issues.

According to the latest testing under the Programme for International Student Assessment (PISA), it was found out that the mean of scores earned by Thai students was below the international average. The results are even more alarming as the scores dropped notably in comparison to the previous years’ evaluations. The reason for this is that the students are not familiar with tests consisting of analytical features which use reasoning as part of the decision-making process.

The aim of this study is to investigate decision making process in a class of secondary students when global socio-scientific issue is applied to STEM-based learning. The following questions were asked:

1. Does implementing the SSI overlap STEM framework help 13- to 14-year-old secondary students to make an informed socio-scientific decision?
2. What are the characteristics of the SSI overlap STEM framework that they use to make an informed decision?

2. Methodology

The study was conducted in an intact class of 31 secondary students aged between 13 and 14 years and it examined the decision making process that the students use to make decisions about a socio-scientific issue under the guidance of the SSI overlap STEM framework. The decision making process here includes perspectives that the students took into consideration as well as the way how they reached the various options and evaluated the significance of contextual concepts and values.

2.1. Presentation of the socio-scientific issue.

At the beginning of a lesson, the students are introduced with some basic facts about carbon dioxide and greenhouse effect, a real life socio-scientific issue which was presented to the students in a form of a short video clip. In the video atmospheric scientists demonstrate their experiences and evidence of the greenhouse effect and climate change, including global warming, obtained through their research.

Global warming is considered to be a consequence of expending greenhouse effect which is caused by gases such as carbon dioxide, methane and nitrous oxide that block heat from escaping from the atmosphere. Carbon dioxide (CO$_2$), as a minor but very important component of the atmosphere, is released through natural processes such as respiration and volcano eruptions. However, over the last century, human activities, that include deforestation and fossil fuels burning, have increased the concentration of CO$_2$ in the atmosphere by more than a third.

We decided to use global warming as a chosen topic presented to students, because it is of particular importance in the contemporary world due to its great impact on the global environment.

2.2. Data Collection Techniques and Analysis Methods

The development of the students’ socio-scientific decision making abilities was tracked by analyzing data collected through class observation. For the analysis, both quantitative and qualitative data was used; content analysis of qualitative data collected during students’ discussions helped to explain the initial quantitative results. The results of the socio-scientific decision making pre-test and post-test were compared.
2.3. SSI overlap STEM framework

At the beginning of a lesson the students were divided into six groups and were asked to suggest socio-scientific issue and their solution to it. This was treated as a pre-test with socio-scientific decision making reasoning test. Then the chosen topic, global warming, was presented to the class.

After being presented with the topic, the students then engaged in a decision-making exercise through group discussion guided by the SSI overlap STEM framework. This was designed drawing on works by Lee (2014) and Billiar et al (2014) who developed six-key-stage practice which is depicted in Figure 1.

Figure 1 : SSI overlap STEM framework used in this study

Stage one - Identifying problems- serves to encourage students to identify questions and problems within broader socio-cultural context of a larger global society. Students practice proposing questions such as: “How can we reduce CO2 in the atmosphere?” or “How can we stop or at least slow down rising sea level?” These are the type of questions that can be given to secondary students to enhance their ability to make decisions about environmental conservation.

Since reasoning and argument are essential to finding the best solution to a problem, in stage two – Generating information from multiple perspectives – the students are encouraged to explore as many perspectives as possible through brainstorming. Practicing this should prevent them from focusing excessively on preconceived beliefs and not exploring other options. It also helps the students to understand the scientific evidence and to compile and evaluate all the evidence they have at hand [7].

In stage three – Developing possible solutions – students are asked to present at least two options of a possible solution; that way they keep their minds open to a plausible solution. Later they engage in a discourse about advantages and disadvantages of each of their options. Among others,
they need to consider the ethical aspects of their solutions and these must be discussed in a way relevant to the issue. The aim of this exercise is for students to enhance their critical thinking.

In stage four – *Creating a model solution / product* - students design a model product or a solution to the particular issue. During the process they are developing their problem-solving skills when applying scientific knowledge to a question or a technological problem, identifying mathematical components of the issue, and using reasoning to link evidence to an explanation. Students are required to work individually along with taking part in group activities.

In stage five – *Testing and evaluating solution / product* - students test and evaluate the model prototype or model solution they created. Students need to consider its effectivity, and balance competing criteria of required functions, technical viability, safety, costs and aesthetics, and keeping with legal requirements. There is not a simple answer but rather a range of more or less satisfactory solutions of which the optimal choice depends on how well the proposed solution meets the set criteria and restrictions.

In stage six – *Making an informed decision* – the students are asked to debate about specifications they would use to choose from their options. Each group needs to present their ideas both verbally and in writing using tables, graphs, drawings and their model. During extended discussion with peers, they are asked to consider the main pros and cons of their principal arguments, including the ethical aspects. They need to revisit their criteria ensuring that they considered every option. The groups then take turns to present their results, including decisions and justifications, to the whole class.

Following the presentation, students in each group were asked to discuss and reflect on their group’s decision, drawing on the decisions and arguments of the other groups.

Each group was required to record the results of their discussion at each stage on their worksheet and to analyze the data collected in the test of their proposed solution or a model.

After the groups had arrived at their mutual decisions, individual students in each group were asked whether they agreed with the decision of their group. If they did, then the collective decision was recorded as the member’s decision. If not, then the student was asked to present his/her own decision as well as to supply justification for his/her point of view. This gave us the opportunity to compare various solutions and determine which one of them met the specific design criteria and which design solved the problem best when considering given restrictions. In stage six this was treated as the post-socio-scientific decision making test.

During the lessons, students’ feedback on the socio-scientific decision making process was collected.

3. Results

3.1 Parties affected by the issue as suggested by students

Table 1 shows the range of groups affected by the issue as identified by the students; these are listed in descending order of frequency. It also shows a number of groups of students that listed each particular party when considering the impact of global warming. The most frequently cited group was the ‘environmentalists’. The fact the students mentioned ‘humans/people’ implied that the students are concerned with the future of humanity. Some group also mentioned the global ecosystem. Even more surprisingly one of the groups identified an ‘atmosphere’ as a party affected by the global warming reflecting on the role that the atmosphere plays in the analyzed issue. Taking these perspectives together, the students seemed to be thinking quite extensively about different views of a sufficiently wide range of affected parties.
Table 1: Parties affected as perceived by students

| Parties affected            | No of groups of students who listed particular party (N= 6) | Point of observation (as predicted by the students) |
|-----------------------------|-------------------------------------------------------------|-----------------------------------------------------|
| Environmentalists           | 5                                                           | Concerned with deforestation, biomass burning, using fossil fuels and cement production. People should become more environmentally aware. |
| Ecosystem                   | 4                                                           | The ecosystems are changing dramatically as global temperature rises. |
| Plants                      | 4                                                           | Plants use CO\(_2\) and water to produce sugars which are then used to build more complex compounds. During this process oxygen is produced as a by-product. |
| Coal and fossil fuels       | 3                                                           | Most of the CO\(_2\) that comes from human activities is released while burning coal and other fossil fuels. People should increase use of alternative sources of energy. |
| Public/government           | 3                                                           | Set policies for economic development and environmental conservation. They also design laws to make sure that people and businesses comply with the legislation. |
| Scientist                   | 3                                                           | Human activities have caused CO\(_2\) to increase above levels not seen in hundreds of thousands of years. |
| Cell                        | 2                                                           | CO\(_2\) is an end product of cellular respiration in organisms that metabolise sugars, fats and amino acids while obtaining energy. |
| Food                        | 2                                                           | CO\(_2\) is added to drinking water and carbonated beverages including beer and sparkling wine to add effervescence. The frozen form of CO\(_2\), known as dry ice, is used as a refrigerant |
| Humans / people             | 2                                                           | Humans live more comfortably since the beginning of the industrial revolution. However, the impact of their activities on the environment is massive. |
| Atmosphere / oceans         | 1                                                           | CO\(_2\) released from the burning of fossil fuels remains in the air and is not absorbed by the vegetation and the ocean |

3.2. Knowledge and information researched by the students
Table 2 shows the types of information and knowledge that the students researched in order to provide more in depth arguments during a discussion with their peers that eventually led to resolving the problem. The type of information such as chemical and physical properties, carbon footprint and CO\(_2\) emissions, sought out by the students, reflects their views and opinions on the issue in question and it could serve as background and contextual information for further discussion of possible strategies. Another type of information, such as that on photosynthesis and cellular respiration, reflects the will of some of the students to find solution to the issue.
Table 2: Types scientific and social oriented evidence, requirement and constraints thought to be useful by the students

| Information / knowledge | Chemical and physical properties | Greenhouse gas | Photosynthesis | Carbon fixation | Fossil fuels | Human activities | Earth’s atmosphere | CO₂ emissions | Carbon footprint | Cellular respiration | Electricity |
|-------------------------|---------------------------------|----------------|----------------|----------------|-------------|-----------------|-------------------|---------------|----------------|---------------------|-------------|
| No. of responses        |                                 |                |                |                |             |                 |                   |               |                |                     |             |

### 3.3 Models designed by the students

Table 3 shows examples of models designed by the students according to the set criteria using respective arguments, counterarguments, and ethical considerations. These options can be categorized into four main types of action as shown in the following table. Various ways how to reduce CO₂ level in the atmosphere were suggested by the students, among others using less-electricity, RRR – reduce, reuse, recycle, growing more plants and reduce the use of fossil fuels thus reducing CO₂ emissions; these are described in the following table.

Table 3: Examples of the possible solutions with arguments, counterarguments and any ethical considering as put forward by the students

| Option /Solution | Argument | Counterargument | Ethical considering | Evaluating model/revise |
|------------------|----------|-----------------|---------------------|------------------------|
| Model 1: Action: Using as little electricity as possible | Human-powered amplifier (3) | -Humans should use less energy | -Future benefits of reducing use of electricity | -Original model worked, however, it was not very efficient |
|                  |          | -Campaign for reducing the use of electric power. | -Cleaner environment | -Modifying materials |
|                  |          | -Humans live comfortably while using electric-powered machines | | -Change in size |
| Model 2: Action: Implementing RRR – reduce, reuse and recycle | Reduce, reuse and recycle things on daily basis (4) | -Reduce the consumption of non-recyclable materials (plastic) | -Save usage of natural resources | -Make the multi-purpose shelf model stronger. |
|                  |          | -Educate about separating waste | -Not always possible –some materials in too small pieces. | -Adapt future board shoes can be use in actual |
|                  |          |                               | -Recycling certain kinds of plastic may spread toxins | |
|                  |          |                               | -Preserving the environment | |
|                  |          |                               | -Help to lower greenhouse gas emissions | |
Model 3: Action: Breaking down the CO₂ or turning it into another substance

| Option/Solution | Argument | Counterargument | Ethical considering | Evaluating model/revise |
|-----------------|----------|-----------------|---------------------|-------------------------|
| **Growing plants** | Grow plants and trees to transform CO₂ into food and air | The problem is not solved completely people will continue with “unhealthy” habits / activities. | People can live comfortably on Earth. | -Follow up plant Growth -Prove pot plant can be decomposed. |
| (5) | | | -Taking care of the atmosphere should come first. | |

Model 4: Action: Reducing the use of fossil fuels and CO₂ emissions

| Option/Solution | Argument | Counterargument | Ethical considering | Evaluating model/revise |
|-----------------|----------|-----------------|---------------------|-------------------------|
| **Eco car model** | -The public would get to know more about using of fossil fuels solution. -Save energy and money. | -Governments focus on economic development -Biodiesel gives about 10 percent less energy than diesel. | -Preserving the environment -People should focus on using alternative energy sources | -To make it efficient optimal use of lightweight materials is necessary. -Reducing air resistance |
| (3) | | | | |

3.4 Criteria used to choose between the options

Table 4 states the main criteria chosen by the six groups of students. From the list presented in Table 4, the students chose explicit criteria that they used to make their decision. Groups 1 to 5 emphasized that their decision should be environmentally sound. On the contrary, group 6 was mostly concerned with saving money. This approach was consistent with the ethical arguments the students used to justify their final decision.

Table 4: Criteria adopted by the students that they used to make their final decision.

| Group | Criteria for choosing between the option/solution |
|-------|--------------------------------------------------|
| 1     | -Practical and effective way of reducing CO₂     |
| 2     | -Taking care of the atmosphere                    |
| 3     | -General environmental awareness                  |
| 4     | -Use alternative sources of energy / use less fossil fuels |
| 5     | -CO₂ decomposition                                |
| 6     | -Saving money                                     |

Table 5 shows a more detailed comparison of the results. The action most often cited in the pre-test, at 38.7%, was ‘reducing use of fossil fuels’ (the Eco-car model); the second most often cited action was ‘using less electricity’, at 22.6%.

However, after implementing the SSI overlap STEM framework the students’ most favorite action became ‘breaking down the CO₂’ action which is represented by the growing plants model (41.9%). The second most cited action was again the ‘using less electricity’ action (25.8%).
Table 5: Frequencies of each type of action used in decision making process, comparing pre-test and post-test results

| Type of action                        | Pre-test (N=31) | Post-test (N=31) |
|---------------------------------------|-----------------|------------------|
|                                       | No. of Students | percentage      | No. of Students | percentage      |
| Model type 1:                         |                 |                  |                 |                  |
| The less-electric machine             | 5               | 22.6%            | 8               | 25.8%            |
| Model type 2:                         |                 |                  |                 |                  |
| The reduce reuse and recycle          | 6               | 19.4%            | 6               | 19.4%            |
| Model type 3:                         |                 |                  |                 |                  |
| Growing plant                         | 5               | 16.1%            | 13              | 41.9%            |
| Model type 4:                         |                 |                  |                 |                  |
| The Eco cars model                    | 12              | 38.7%            | 4               | 12.9%            |

3.5 Students’ progress in reasoning

The audiotaped record of the group discussion captured nuances of the students’ reasoning throughout the decision-making process. The following exchange is an example of the students engaging in argumentation and reasoning, which led them to become aware of the fact that any option is bound to have advantages and disadvantages as well as ethical aspects that need to be taken into consideration. They learned to debate about specifications they would use to choose from their suggested options, and eventually managed to evaluate the model prototype or model solution they had created.

Transcript 1 shows a sample exchange that the students use reasoning before arriving at a conclusion that is supported by their interaction with their peers.

Transcript 1:

S1: Using too much of fossil fuels is a big problem that leads to increasing CO$_2$ level.
S2: Although we use fossil fuels much, it makes it easier and more comfortable for us to go around.
S3: Everybody should be environmentally aware.
S4: Now that I know more about CO$_2$, I feel that I can create a possible solution to solve the problem.
S5: Finding more information about CO$_2$ makes it easier for me to design a solution.
S6: There are various options for us.
S2: Even though we proved that the model solution can decrease CO$_2$, I think it will work better if we adjust it.
S3: Solving the problem with a group of peers makes it easier than when working on my own.
S4: Global warming wouldn’t be such a big problem if everybody “chipped in”.
S3: Our group used criteria that helped us to decide with environmental awareness on our minds.
S4: Growing plants is the best solution if we want to reduce CO$_2$ effectively.
At the end of the lesson, the students communicated their decisions to the rest of the class. Their decision was to growing plants and their reason for it was that trees and other plants transform carbon dioxide into sugars (food) and air. Considering the specific criteria before making their final decision, this seemed to be practical and effective way of reducing CO₂.

4. Discussion

As we know from previous studies, the students are better motivated to learn new information from problems presented to them within broader socio-cultural context rather than from textbooks. These too often explain concepts without the contextual background information. This is especially true when students are given the chance to apply their newly acquired knowledge to solve problems based on the SSI overlap STEM framework, as occurred in this study. The discussion of socio-scientific issues in case studies like ours provides the students with social context for learning scientific concepts as well as developing their decision making skills to handle environmental issues. Although the chosen topic, global warming, is not covered in the secondary earth-system science curriculum, it helps to illustrate a number of key concepts, such as the importance of the environmental relationships in keeping the ecosystems in balance, that the students need to learn at this level.

In this study, the students were provided with the information about CO₂, and how to reduce its level. It could be argued that this information might have influenced the students’ attitude towards the way how to resolve the issue. The analysis, however, show that while using the prescribed framework as a guideline for their decision making process, the students were able to better identify and understand problems within broader socio-scientific context. They were encouraged to explore number of perspectives through brainstorming suggesting number of views on parties affected by the issue in question. The knowledge acquired through studying various resources was also an important aspect that helped the students to develop conceptual understanding of the effect of CO₂ and global warming on the environment, the studied issue, and to detect any misconceptions about the said issue. Both the perspectives and the knowledge acquired by the students contributed to their ability to better formulate broader range of suggestions and possible solutions while considering their advantages and disadvantages as well as their ethical aspects. The most important part of this exercise was peer discussion. At the beginning of the exercise it was not easy for the students to specify their thoughts, especially regarding the ethical aspects, but their argumentation and reasoning improved significantly after applying the SSI overlap STEM framework. The arguments which were recorded during the post-test and which provided justification for the students’ decisions also proved that the students managed to acquire the scientific knowledge necessary for making better informed decision. It may be useful to turn this classroom activity into a project-based task in which students search for information relevant to the issue by themselves. This independent kind of learning has the added value of developing students’ inquiry skills, mainly searching for and evaluating information, and capacity to clarify their understanding of the impact of CO₂ thus assuming greater ownership of their learning.

The findings of this study have several implications for the teachers too. Firstly, it is the need of developing their pedagogical content knowledge which will necessarily lead to improving students’ decision making skills in the context of environmental education. The inclusion of the SSI overlap STEM framework in the earth system science curriculum means that students would be expected to consider wider perspectives in tackling the earth-system science issues in addition to applying scientific knowledge. Teachers would thus need to readjust their roles and lead the students to study environmental issues, with the aim of developing both the scientific knowledge of students as well as a wide range of other skills, including reasoning, argumentation, and decision making. Lee and Grace (2010) in their work proposed students’ reasoning processes in making decisions about an authentic, local socio-scientific issue: bat conservation. After evaluating their results they found out that there were substantial changes in students’ decisions taken before and after the activity. That indicates changes in students’ values moving from anthropocentric to wide-ranging perspectives which emphasize both pragmatic as well as biocentric values. That however poses conservational dilemma.
on students in which they need to choose between human needs and their impact on the world. On one hand, this encourages students to reflect on the main impacts of human actions in regard to global warming and how this influence, if left unnoticed, could affect other organisms, which might, in turn, affect humans in the long run. On the other hand, students need to consider the price that humans might need to pay for preserving wildlife and natural habitats. There are numerous studies on local as well as global level illustrating this conservation dilemma which could be used for classroom discussion activities. This could help the students to develop their abilities to make informed decisions and to further their understanding of the earth-system science concepts and values behind earth-system science.

5. Acknowledgement

We would like to thank for Director of Phadungnaree School and the Promotion of Teaching Science and Technology (IPST) Thailand

6. References

[1] Billiar, K., Hubelbank, J., Oliva, T., and Camesano, T. Teaching STEM by design. *Advance in Engineering Education,* 2014, (1), pp. 1-21.

[2] Bybee, R. M., “The case for STEM Education Challenges and Opportunities,” National Science Teachers Association (NSTA), 2013, Virginia.

[3] Grace, M. “Developing high quality decision-making discussions about biological conservation in a normal classroom setting,” *International Journal of Science Education,* 2009, vol.31, no.4, pp. 551-570.

[4] Halverson, K. L. and Siegel, M. A. and Freyermuth S. K. “Lenses for Framing Decisions: Undergraduates’ decisionmaking about stem cell research,”*International Journal of Science Education.* 2009, vol.31, no.9, pp. 1249–1268.

[5] John, S., “An Introduction to STEM Education Best Practices and lesson design#3, /ASTEP Training Suite,” Academy for science Mathematics and Technology Education Professionals(ASTEP), IPST, 2018, Bangkok. pp. 1-21.

[6] Kortland, K. “An STS case study about students’ decision making on the waste issue,”*Science Education,* 1996, vol 80, pp. 673-689.

[7] Kuhn, D. *Education for thinking.* Cambridge, Massachusetts : Harvard University Press, 2005.

[8] Lee, Y. C., “Developing decision-making skills for socio-scientific issues,”*Journal of Biological Science Education,* 2007, vol.41, no.4, pp. 170-177.

[9] Lee, Y. C., Students’ Reasoning and Decision Making About a Socioscientific Issue : A Cross-Context Comparison : Published online 9 August 2012 in Wiley Online Library <http://wileyonlinelibrary.com> 2012.

[10] Lee, Y. C., and Grace, M. “Students’ reasoning processes in making decision about an authentic, local socio-scientific issue: bat conservation,” *EducationResearch,* 2010, vol.44, no.4, pp. 156-165.

[11] Nuangchalerm, P. “Engaging students to Perceive Nature of Science through socio scientific issues-based Instruction,”*European Journal of Social Science,* 2010, vol.13, no.1, pp.34-37.

[12] Siriputchatchai, P., “STEM Education and 21st Century Skills Development,” *Executive Journal,* 2013, vol.33, no.2, pp. 49-55.

[13] Sadler, T. D., and Zeidler, D. L. “Patterns of informal reasoning in the context of socioscientific decision making,”*Journal of Research in Science Teaching,* 2005, vol.42, no.1, pp.112-138.

[14] Sadler, T. D., and Zeidler, D. L. 2004. “Student conceptualizations of the nature of science in response to socioscientific issue,”*International Journal of Science Education,* 2004, vol.26, no.4, pp. 387-409.
[15] Walpuski, M., Tepner, O., Sumfleth, E., Dollny, S., Hostenbachs, J., Pollende, T. “Multiple perspectives on students’ scientific communication and reasoning in chemistry education,” *Acta Didactica Norge Conference Vision Teaching*, 2012, vol. 6, no. 1, University Duisburg-Essen.

[16] Yu, Y. *Adults' Decision-making about the Electronic Waste Issue: The Role of the Nature of Science Conceptualizations and Moral Concerns in Socio-scientific Decision-making.* Dissertation, Ph.D. (Art and Science). Columbia: Graduate School, 2010, Columbia University.

[17] Zeidler, D. and B. Nichols. “Socio scientific Issues Theory and Practice,” *Journal of Elementary Science Education*, 2009, vol. 21, no. 2, pp. 49-58.

[18] Zeidler, D. L., Sadler, T. D., Applebaum, S. and Callahan, B. E. “Advancing reflective judgment through socio scientific issues,” *Journal of Research in Science Teaching*, 2009, vol. 46, no. 1, pp. 74-101.

[19] Zeidler, D. L., “STEM education: A deficit framework for the twenty first century? A sociocultural socio scientific response,” *Culture Study of Science Education*, 2016, vol. 11, pp. 11–26.