



Research Article

Enhancing Grade 12 Students' Critical Thinking and Problem-Solving Ability in Learning of the STS Genetics and DNA Technology Unit

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This study reported grade 12 students' critical thinking and problem-solving ability in learning and innovation skills in genetics and DNA technology unit through science technology society (STS) approach. The participants were 43 grade 12 students in Maung, Khon Kaen, Thailand. The STS unit has been taught by the researcher for 3 weeks. The Genetics and DNA Technology unit were provided learning activities through STS approach in framework of Yuenyong (2006) based on 5 stages. These included (1) identification of social issues, (2) identification of potential solutions, (3) need for knowledge (4) decision-making, and (5) socialization stage. Students' critical thinking and problem-solving ability was collected during their learning by participant observation, students' discussion and questions, worksheets, students' behavior, and students' performance. The findings revealed that the Genetics and DNA technology unit on the STS approach are promoted students' critical thinking and problem-solving ability. Not only indicated that the solution rose from the problem that lead to solving through critical thinking and problem-solving but also could be mentioned that students developed their ability of critical thinking and problem-solving while they learned STS of Genetically Modified Organisms (GMOs) issue. These finding would be a good practices for teaching biology through STS approach for those who may take further applications for science teaching and learning.

Keywords:

Critical thinking and problem-solving, STS, genetics and DNA technology

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Introduction

World Economic Forum (2015) surveyed and analyzed labor market needs and technology trends in major corporations around the world, found that the results of the study have defined the 21st-Century skills into 3 categories includes: foundational literacies, competencies, and character qualities. These skills does not end, which calls 'lifelong learning'. Moreover, the skills most valued in today's complex globalized and rapidly changing world. The process used to build these skills cannot be derived from traditional classroom processes. Especially, competencies or learning and innovation skills (4Cs) which students can address outside the classroom. There are the basic skills that people in 21st century must learn that allow them to become innovative in what they do. The skills will focus on developing a quality of life for changing world of work in some critical skills. It would be mentioned that learning and innovation skills will determine the preparation of students to work that will be more complex in today's world. So, this is the necessary skills for developing students' thinking both inside and outside the classroom. (Songsaen et al., 2014)

The grounds of learning and innovation skills were promoted by science and technology. Innovation arises from the knowledge of science and technology to contribute to social development. Moreover, science and technology provided students to become innovator (National Science Foundation, 2012). In Thailand, Developing students' technological capability is another aspect of scientific literacy that supported students to create innovation. Klahan and Yuenyong (2012) reported *An Analysis of Grade 12 Students' Technological Capability in Learning about Electromagnetics through Science Technology and Society Approach (STS approach)*. The study found that students supported by model forming on technological process that were designed various innovation models based on electromagnetic wave knowledge such as weapons or metal scanners, radio program, cartoon book, brochure of studying electronics, remote control for home devices, solar cell toy car, and radio program in their house. These innovation models showed that students analyzed the process of technological problem-solving by developing the concept of their pathway. Moreover, there are many influences on the way students carry out a technological task including cognitive, practical and affective influences. The influence on that process could be interpreted from the applying scientific and other knowledge and skills during students constructing the innovation model. It can be seen that students' learning and innovation skills were assisted by science and technology.

Learning and innovation skills composed of 4 critical skills recognized as those develop students who are prepared for more complex life and work environments in the 21st century, and those who are not. A focus on creativity, critical thinking, communication, and collaboration that is essential to prepare students for the future. These skills described by World Economic Forum (2015) that are students approach

complex challenges. For example, Creativity is the ability to imagine and devise innovative new ways of addressing problems, answering questions or expressing meaning through the application, synthesis or repurposing of knowledge. Critical thinking is the ability to identify, analyze and evaluate situations, ideas and information in order to formulate responses to problems. Communication and Collaboration involve working in coordination with others to convey information or tackle problems. Learning and innovation skills are essential to the 21st-century workforce, where students be able to critically evaluate and convey knowledge. These students' thinking skills could be addressed by scientific knowledge that related to science, technology, and society issue. Chantaranima and Yuenyong (2014) also reported on The Outcomes of Teaching and Learning About Sound Based on Science Technology and Society (STS) Approach. The study revealed that students made the decision by created the innovation models based on Sound unit such as mobile phone, Bluetooth, guitar, walky-talky, and models from their imagination, not related to sound transmission on the earth such as the ear rings, watches, pendants, dental braces, and dragonfly robot. Some groups designed their helping equipment to have multifunctional ability beside from sound sending such as flash lighting to send signal for their position, abilities to watch films and listen to music, and receiving news from the earth. This innovation raised from the problem that lead to solving or decision making of students.

The literature suggested many possible activities could promote students' thinking through science, technology, and society that lead to various innovation (Anantasook, 2011; Aryowong, 2011; Pornsena, 2012; Boonprasert et al., 2018). Therefore, the researcher believed that the students thinking should develop on science classroom is critical thinking and problem-solving ability that involved with social issues in the present. The researcher follows the framework of P21 Partnership for 21st-century learning (2015) of critical thinking and problem-solving ability that composed of 4 elements:

1. Reason Effectively

- Use various types of reasoning (inductive, deductive, etc.) as appropriate to the situation.

2. Use Systems Thinking

- Analyze how parts of a whole interact with each other to produce overall outcomes in complex systems.

3. Make Judgments and Decisions

- Effectively analyze and evaluate evidence, arguments, claims and beliefs.
- Analyze and evaluate major alternative points of view.
- Synthesize and make connections between information and arguments.
- Interpret information and draw conclusions based on the best analysis.
- Reflect critically on learning experiences and processes.

4. Solve Problems

- Solve different kinds of non-familiar problems in both conventional and innovative ways.
- Identify and ask significant questions that clarify various points of view and lead to better solutions.

According to the literature of learning activities for biology in order to develop students to learn biology in science, technology, and society (Aryowong, 2011; Pornsena, 2012). The authors were suggested how to provide design learning activities to improve learning and innovation skills. The 4 elements of critical thinking and problem-solving will be taken into account for biology learning by self-directed learning and teamwork.

Teaching science in the classroom today and for the future should encourage students to control their thinking process to be effective. Students thinking skills could be addressed as a way of enhancing students' critical thinking and problem-solving ability. Student have a chance to develop their thinking skills related to STS issue (Yuenyong and Narjaikaew, 2009; Mokpa, 2010; Chaina, 2010; Yuenyong, 2013; Prawvichien et al., 2018). Introducing students to learn science regarding the integrated concept of science, technology, and society (STS) which is learned scientific knowledge by choosing the best solution to solve the problem. Yuenyong et al. (2006) stated that the teaching of science, technology and society (STS) not only enhances the understanding of the content but also help them develop their thinking skills. Likewise, Chantaranim and Yuenyong (2014) also reported that STS approach could support students to gain their capability of analytical thinking such as thinking for classifying, compare and contrast, reasoning, interpreting, collecting data and decision making. Moreover, Seatha et al. (2016) studied Students' View on STEM in Learning about Circular Motion through STS Approach. They found that the STS circular motion could enhance students to find the solutions for the social issues. Therefore, the researcher has an objective to develop critical thinking and problem-solving ability on genetic and DNA technology unit. Especially, "GMOs" issue by using scientific, technological and social instructional model of Yuenyong (2006) to provide the improved mean of scientific instructional development particularly biology for the future.

Method

This study was a qualitative study focusing on paradigm in interpreting to search for explaining and evaluating grade 12 students' approach or behaviour of critical thinking and problem-solving ability, during the first semester of 2018 school year, The Modindaeng Demonstration School of Khon Kaen University. The study would emphasize on the importance of the students' critical thinking and problem-solving behavior, expression during participating in learning activities, discussing, presenting

performance as well as reflecting's learning in their worksheet for reflecting their attitude and motivation toward science studying. Data were analyzed, interpreted, and concluded.

Participants

The participants were 43 grade 12 students in The Modindaeng Demonstration School of Khon Kaen University, Khon Kaen, Thailand. Demographic features of the participants are given in Table 1.

Table 1.

Demographic features of the Students participating in the Study

Variable	Demographic feature	f	%
Gender	Female	13	30,2
	Male	30	69,8
School	The Modindaeng Demonstration School of Khon Kaen University	43	100
Grade	12th grade	43	100

Intervention

The goal of this study is to acquire students develop their critical thinking and problem-solving ability by considers the relationship between science, technology and society. Consequently, the researcher was design learning activities through STS approach of Yuenyong (2006) that promote the critical thinking and problem-solving ability in learning and innovation skills on GMOs issue. The STS GMOs were organized the regarding on the Table 2. Finally, students will create innovation or some ideas on the right solution that showed different perspectives.

Table 2.

Overview of the STS Genetic and DNA technology Unit

Stages	Learning activities
	<ol style="list-style-type: none"> 1. Teacher asks the questions to engage the student to realize about food issues. 2. After that students see news "Let's start to know what GMOs is "that showing the effect of GMOs in Khon Kaen province.

Identification of social issues stage



(Source: Rakkaset Nungruethail)

	<p>Questions for students:</p> <ol style="list-style-type: none"> 1. If GMOs are approved by the government to plant in Thailand. What's your opinion? 2. If students are involved in the GMO problems, how do students solve the problem?
Identification of potential solutions stage	<p>- Students will need to identification of potential solution on identification of social issues stage from the question.</p> <p>- Students on each group brainstorm to review prior knowledge: "What knowledge can be used to solving the problem?"</p> <p>Moreover, Students create an unknown knowledge question and further research.</p>
Need for knowledge stage	<p>The researcher use The 5Es Instructional Model on this stage.</p> <p>Engagement:</p> <p>- Students watch video about GMOs on human's life.</p> <p>Exploration:</p> <p>- Teacher show the news "The effects of GMOs on agriculture in Thailand"</p> <p>- Students brainstorm to answer the question on worksheet.</p> <p>Explanation:</p> <p>-Teacher and student discussion to summarize "Should GMO products continue to be used?"</p> <p>Elaboration:</p> <p>-Teachers present pictures on Power point and explain more GMOs.</p> <p>Evaluation:</p> <p>- Teachers use the evaluation tools to be used either interview, observation or checklist etc. To evaluate the topic taught based on the learning objectives set at the beginning of the lesson.</p>
Decision-making stage	<p>Each group works together to use critical thinking and problem-solving ability on GMOs. From Need for knowledge stage to create possible solution. Moreover, they work together again to make decision for select the best possible solution of group. Next, hand on design on worksheets.</p>
Socialization stage	<p>Each group presents "The best possible solution". By record it is a Video File or post poster on Facebook. This performance will open for comments and ideas. Comments and ideas will be revise and develop again to completion.</p>

Data Collection

For this study, the researcher follows the framework of P21 Partnership for 21st-century learning (2015) of critical thinking and problem solving ability in learning and innovation skills to design the lesson plans through STS instructional model that composed of 4 elements. The STS Genetic and DNA technology unit has been taught by the researcher for 3 weeks. The participant observation, students' discussion and questions, worksheets, students' behaviour, and students' performance were interpreted to examine what and how students applied knowledge of science to develop best solution as technology products. Students' ideas about application of these knowledge and processes will be clarified in each stage of the STS Genetic and DNA technology unit. The

dialogues, students' tasks, and others will be highlighted to represent the interpretation. Then, the interpretation will be rechecked as peer debriefing in order to show the credibility which the interpretation would depend on the particular researcher and each researcher.

Data Analysis

- Data analysis from worksheets

Students' critical thinking and problem-solving ability in learning and innovation skills will be interpreted from students' discussion and questions where they provided on the worksheet 1 – 4. The worksheet 1 aimed to provide students to conscious about GMOs that is the social issue. The worksheet 2 aimed to investigate their data about GMOs. The worksheet 3 aimed to provide students need more information before discussion and decision. The worksheet 4 aimed to provide students to present their idea that lead to the possible solution. The Table 3 - 5 showed that what students were asked by the worksheet 1 – 4 and their answers regarding on the elements of critical thinking and problem-solving ability in 21st-century, respectively.

Table 3.

Data analysing of students' discussion and questions and worksheet 1

The elements of critical thinking and problem-solving ability in 21st century	Questions for students	Example answer
Reason Effectively		
- Use various types of reasoning (inductive, deductive, etc.) as appropriate to the situation.	- How should we do if the world runs out of food?	- We should cooperate the food resources. The producer.
	- If one day the food is runs out of the world. What happen?	- All organisms cannot live.
Use Systems Thinking		
- Analyze how parts of a whole interact with each other to produce overall outcomes in complex systems.	- What did you get on the news and what happen?	- Students can analyze and evaluate the situation from the news.
Make Judgments and Decisions		
- Effectively analyze and evaluate evidence, arguments, claims and beliefs.	- How do you feel about this news?	- Depend on students' attitudes.
- Analyze and evaluate major alternative points of view.	- Why do students need to know about this news?	- To be a person who have a self-awareness on society, technology and environment.
- Synthesize and make connections between information and arguments.	- How does this news effect to students?	- Effect to anxiety on food.

<ul style="list-style-type: none"> - Interpret information and draw conclusions based on the best analysis. 	<ul style="list-style-type: none"> - Who is involved in this situation? 	<ul style="list-style-type: none"> - Producers, Consumers, and Government.
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<ul style="list-style-type: none"> - Reflect critically on learning experiences and processes. 	<ul style="list-style-type: none"> - What is the problem of this situation? 	<ul style="list-style-type: none"> - Depend on students' attitudes.
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Solve Problems

- Solve different kinds of non-familiar problems in both conventional and innovative ways.
- Identify and ask significant questions that clarify various points of view and lead to better solutions.

Reason Effectively

<ul style="list-style-type: none"> - Use various types of reasoning (inductive, deductive, etc.) as appropriate to the situation. 	<ul style="list-style-type: none"> - If GMOs are approved by the government to plants in Thailand. What's your opinion? 	<ul style="list-style-type: none"> - The government should be emphasized the importance of the process, and control the tight production.
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Use Systems Thinking

<ul style="list-style-type: none"> - Analyze how parts of a whole interact with each other to produce overall outcomes in complex systems. 	<ul style="list-style-type: none"> - How does GMOs effect to students? - What do students know about GMOs, now? 	<ul style="list-style-type: none"> - Students aware on the consumption. - Depend on students' attitudes.
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Make Judgments and Decisions

<ul style="list-style-type: none"> - Effectively analyze and evaluate evidence, arguments, claims and beliefs. 	<ul style="list-style-type: none"> - What do student need to know more? 	<ul style="list-style-type: none"> - The effect of GMOs on living organisms in long term, economics/the process of GMOs.
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<ul style="list-style-type: none"> - Analyze and evaluate major alternative points of view. 	<ul style="list-style-type: none"> - What is the advantages and disadvantages on students viewpoint, now? 	<ul style="list-style-type: none"> - The GMOs can improve plant species. / The GMOs give an effect to health.
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<ul style="list-style-type: none"> - Synthesize and make connections between information and arguments. 	<ul style="list-style-type: none"> - What is the advantages and disadvantages on students viewpoint, now? 	<ul style="list-style-type: none"> - The GMOs can improve plant species. / The GMOs give an effect to health.
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<ul style="list-style-type: none"> - Interpret information and draw conclusions based on the best analysis. 	<ul style="list-style-type: none"> - What is the advantages and disadvantages on students viewpoint, now? 	<ul style="list-style-type: none"> - The GMOs can improve plant species. / The GMOs give an effect to health.
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<ul style="list-style-type: none"> - Reflect critically on learning experiences and processes. 	<ul style="list-style-type: none"> - What is the advantages and disadvantages on students viewpoint, now? 	<ul style="list-style-type: none"> - The GMOs can improve plant species. / The GMOs give an effect to health.
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Solve Problems

- Solve different kinds of non-familiar problems in both conventional and innovative ways.
- Identify and ask significant questions that clarify various points of view and lead to better solutions.

Table 4.*Data analysing of students' worksheet 3*

The elements of critical thinking and problem-solving ability in 21st century	Questions for students	Example answer
Reason Effectively - Use various types of reasoning (inductive, deductive, etc.) as appropriate to the situation.	- What is GMOs, explain?	- An organism whose genetic makeup has been modified in a laboratory using genetic engineering.
Use Systems Thinking - Analyze how parts of a whole interact with each other to produce overall outcomes in complex systems.	- Benefits and risks of GMOs to organisms?	- GMOs have benefits including the increased nutritional value in foods./ humans may get the toxicity from GMOs.
Make Judgments and Decisions	- The role of GMOs in Thailand?	- Improve the organism that get a problem such as disease in plants.
- Effectively analyze and evaluate evidence, arguments, claims and beliefs.	- Future plans of GMOs in Thailand?	- Expanding the trade opportunities by improving yields of exporting.
- Analyze and evaluate major alternative points of view.	- What is the process of making GMOs?	- Identify a trait of interest, Isolate the genetic trait of interest, Insert the desired genetic trait into a new genome, Growing the GMO
- Synthesize and make connections between information and arguments.		
- Interpret information and draw conclusions based on the best analysis.		
- Reflect critically on learning experiences and processes.	- Why do people have to concerns about GMOs?	- They concern the long-term health effects that are yet unknown.
	- What products are GMOs?	- Corn, soy, cotton, and papaya.
Solve Problems		
- Solve different kinds of non-familiar problems in both conventional and innovative ways.	- How to control the production of GMOs in Thailand?	- The products with GMO components have to labels that should provide information to consumers.
- Identify and ask significant questions that clarify various points of view and lead to better solutions.	- How could people find out more the information about GMOs?	- Internet, Researchers, and Journal.

Table 5.*Data analysing of students' worksheet 4*

The elements of critical thinking and problem-solving ability in 21st century	Questions for students	Example answer
Reason Effectively - Use various types of reasoning (inductive, deductive, etc.) as appropriate to the situation.		
Use Systems Thinking - Analyze how parts of a whole interact with each other to produce overall outcomes in complex systems.		
Make Judgments and Decisions - Effectively analyze and evaluate evidence, arguments, claims and beliefs.		
- Analyze and evaluate major alternative points of view.	- Should GMO products continue to be used, why?	- Should or Should not. Depend on students' attitudes.
- Synthesize and make connections between information and arguments.		
- Interpret information and draw conclusions based on the best analysis.		
- Reflect critically on learning experiences and processes.		
Solve Problems - Solve different kinds of non-familiar problems in both conventional and innovative ways.	- What is the method or solution that our group chooses, why?	- Students may choose the solutions just follow the decision of group such as: Planting Organic plants for sale, Label their plants, and making campaign for other people to realize on GMOs.
- Identify and ask significant questions that clarify various points of view and lead to better solutions.		

Data Analysis

- Data analysis from students’ behavior

This information will be collected by researcher assistance. The researcher explained and expanded the elements of critical thinking and problem-solving in learning and innovation skills of 21st century to the researcher assistance. The example of researcher assistance data collection and analysis about students’ behavior on critical thinking and problem-solving ability could be examined in the Table 6.

Table 6.

Data analysing from researcher assistance

The elements of critical thinking and problem-solving ability in 21 st century	Students’ behaviour		Explanations
	Found	Not found	
<p>Reason Effectively</p> <p>- Use various types of reasoning (inductive, deductive, etc.) as appropriate to the situation.</p>	...✓....	- Students gave a variety of reasons for GMO on questions “How do you feel about this news?”
<p>Use Systems Thinking</p> <p>- Analyze how parts of a whole interact with each other to produce overall outcomes in complex systems.</p>	...✓....	- Students analyzed GMOs useful and useless to themselves.
<p>Make Judgments and Decisions</p> <p>- Effectively analyze and evaluate evidence, arguments, claims and beliefs.</p>	...✓....	- Students analyzed the arguments and claims on the news by brainstorm in their group.
<p>- Analyze and evaluate major alternative points of view.</p>	...✓....	- Students on each group compared their opinion and gave their reason about GMOs issue between them.
<p>- Synthesize and make connections between information and arguments</p>	...✓....	- Students shared their opinion and exchanged the information between groups for discussion.
<p>- Interpret information and draw conclusions based on the best analysis.</p>	...✓....	- When students got more information about GMOs, they analyzed for finding the conclusion of group.

- Reflect critically on learning experiences and processes.	...✓....	- Students showed their viewpoint of GMOs on prior knowledge.
<u>Solve Problems</u>			
- Solve different kinds of non-familiar problems in both conventional and innovative ways.	...✓....	- After students consult on GMOs issue, They can present how process are that use for solving such as: Planting Organic plants for sale, Label their plants, and making campaign for other people to realize on GMOs.
- Identify and ask significant questions that clarify various points of view and lead to better solutions.	...✓....	- Students determine some question to find a conclusion of GMOs issue. Such as: Can government determine clear rules of GMOs?

Results

The results revealed that the learning activity about genetic and DNA technology unit through science, technology, and society (STS) of Yuenyong (2006) approach promoted students’ critical thinking and problem-solving ability in learning and innovation skills followed the framework of P21 Partnership for 21st century learning (2015) including: reasoning effectively, using systems thinking, making judgments and decisions, and solving problems. The students' critical thinking and problem-solving ability was interpreted from students’ worksheet 1-4 and students’ performance are as follows:

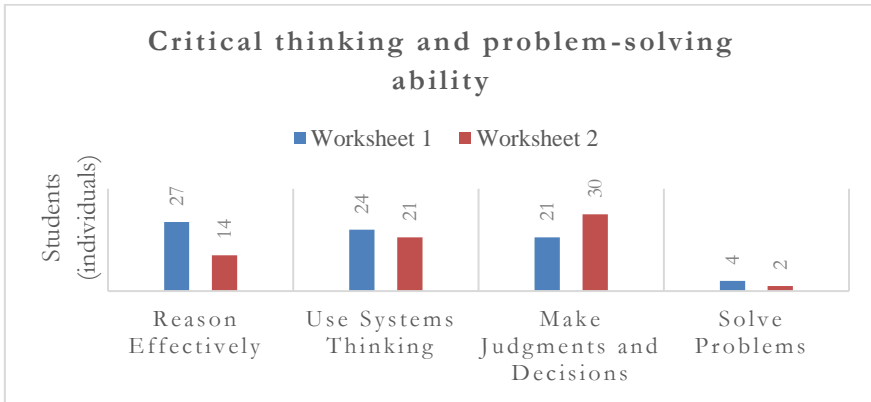
The Critical Thinking and Problem-Solving Ability from Students’ Worksheet 1-4

The finding of this stage divided into 2 parts because the worksheet 1-2, students were do individual worksheet. For the worksheet 3-4, researcher group students into 8 groups for brainstorm activity. Consequently, the data form worksheets were interpreted on graph 1-2 as follows:

Table 7.

The Critical Thinking and Problem-Solving Ability from Students’ Worksheet 1-2

The 4 elements (individuals)	Worksheet 1	Worksheet 2
Reason Effectively	27	14
Use Systems Thinking	24	21
Make Judgments and Decisions	21	30
Solve Problems	4	2

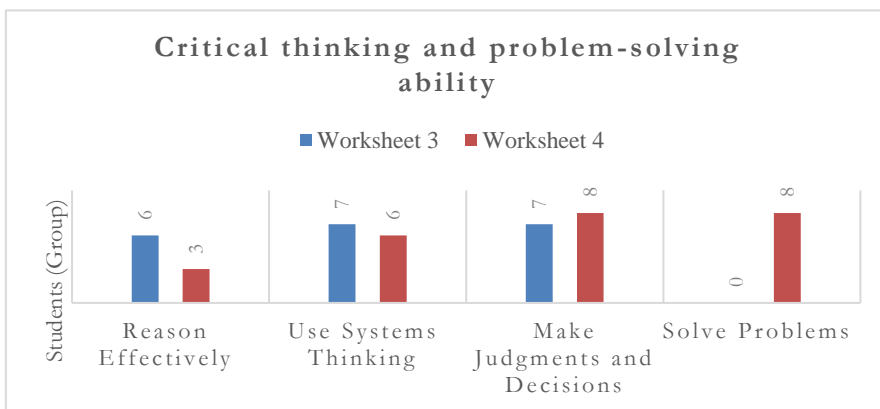


This graph showed the data about the 4 elements which interpret from worksheet 1 and 2. The result of worksheet 1 found that the number of students' reason effectively is 27, used systems thinking is 24, make judgment and decisions is 21, and solve problem is 4, respectively. It can be seen that the worksheet 1 on identification of social issues stage can enhance students' critical thinking and problem-solving ability. In addition to the worksheet 2 on identification of potential solutions stage also showed that the number of students that occur the 4 elements of critical thinking and problem-solving ability are 14 21 30 and 2, respectively.

Table 8.

The Critical Thinking and Problem-Solving Ability from Students' Worksheet 3-4

The 4 elements (group)	Worksheet 3	Worksheet 4
Reason Effectively	6	3
Use Systems Thinking	7	6
Make Judgments and Decisions	7	8
Solve Problems	0	8



This graph display the data about the 4 elements which interpret from worksheet 3 and 4. The worksheet 3 on need for knowledge stage found that the group of students' reason effectively is 6. The students' used systems thinking is 7. The students 'make judgment and decisions is 7. The student's solve problem is 0, respectively. It mentioned that students' solve problem did not occur because this worksheet was design to provide students to focus on finding more information that lead to using in the worksheet 4. In the worksheet 4 connected both stages of STS are decision-making stage and socialization stage. The result found that most student' groups illustrated the 4 elements of critical thinking and problem-solving ability as 3 6 8 and 8, respectively. It concluded that the worksheet 1-4 supported students' critical thinking and problem-solving ability.

The critical thinking and problem-solving ability from students' performance

The students created performances on their group by model or ideas on GMOs issue. The students' performances were analyzed by using significant features including (1) reasoning effectively (2) using systems thinking (3) making judgments and decisions, and (4) solving problems. Data analysis found that students exhibited various kinds of model or idea depending on their interests as showed in figure 1 to 8. These include (1) posters; (2) slide online on Facebook, and (3) short story. Moreover, the first process of students' performance composed of introduction about GMOs issue on their group views. The second are illustrated problem or issue that they concern. Next, showing the models or ideas to solve the problem which decided about GMOs issue that get through the ability of critical thinking and problem-solving in learning and innovation skills.

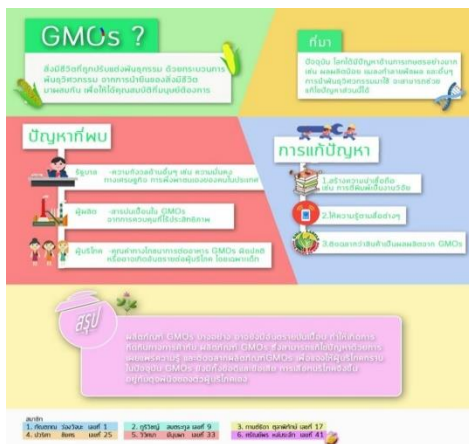


Figure 1.
The Poster from Group 1

The performance of group 1 showed that they concerned about the GMOs' products which lead to barriers to trade. They chose poster to represent the problem that found from people who



Figure 2.
The Poster from Group 2

The performance of group 2 display about creating clarity for consumers by label on GMO products. They used poster to offer the data for the people to know why we have to label on GMO products.

involved and offered the way to solved GMOs' problem by inform the advantage and disadvantage to other people for decision.



Figure 3. The Short Story from Group 3

The performance of group 3 demonstrated that they used the short story to link between GMOs to the consumers as well as gave the reason why we have to concern about the GMOs' products.

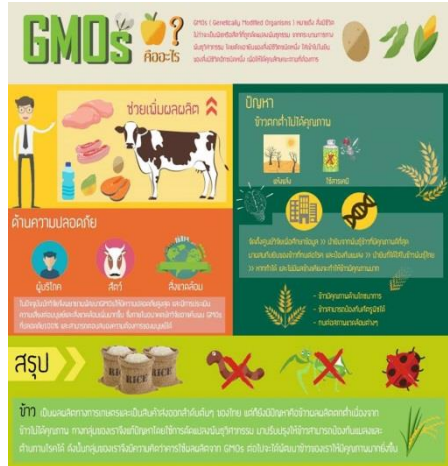


Figure 4. The Poster from Group 4

The performance of group 4 presented about the effect of GMOs on poster. They mention to the process of GMOs for breed improvement and the way to take GMOs to develop economic plants.

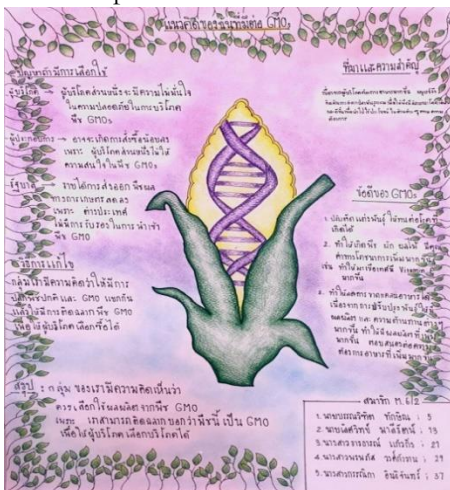


Figure 5. The Poster from Group 5

The performance of group 1 showed poster about the various point of views



Figure 6. The Slide Presentation Online from Group 6

The performance of group 6 is slide presentation online that display about why we do not choose GMOs such as the risk to consumers and environment from GMOs. They supported that creating campaign by label on GMO products and campaign to spread the

from who involved with GMO’ problems and the right advantage of GMOs.

information to people for decision on sale.



Figure 7.
The Short Story from Group 7

The performance of group 7 demonstrated that they used the short story to show their opinion on GMOs issue. Moreover, they choose their decision by planting organic plants by themselves.



Figure 8.
The Poster from Group 8

The performance of group 8 presented about the effect of GMOs on poster. They mention to the way that their chose is avoided GMOs products by planting organic plants.

Table 9.
Students’ Critical Thinking and Problem-solving Ability from the Performances

Group	Reason effectively	Use Systems Thinking	Make Judgments and Decisions	Solve Problems
1	- Students gave the reasons about economic security, GMOs’ contamination on environment and harmful to consumers.	- They proposed that the agricultural problems in Thailand has low products value, and facing with insects.	- Students’ thinking is support against GMO products that be harmful to a barrier in trade.	- This group made a campaign that present about awareness on GMOs for gaining knowledge to other people and suggested that label GMOs products to consumers by poster.
2	- Students	- They analyzed	- Students’	- This group

	provided reasons that GMOs make resistance disease in plants and added nutritional value to plants.	the enforcement of GMOs laws is not concise in crops that make people concerned on GMO plants.	thinking is supported the consumers for deciding to buy GMOs products.	offered by poster to promote a campaign to label on GMOs for make a choices for consumers.
3	- Students gave the reasons that GMOs have the resistance to pests and the residues in plants.	- They aware to GMOs will make an effect to evolution of some species such as plants extinction.	- Students' thinking is showing or separating between the GMOs products and normal products to consumers.	- This group make the short story for present to other people on their social that involved with the label on GMOs products and normal products.
4	- Students provided the reasons that GMOs got decreased chemicals residue on plants and animals, and reduce the revenue of chemical industries.	- They suggested that GMOs increase the productivity to manufacturer such as milk quantity, vitamin in crops, and muscle in some animals.	- Students' thinking is support to using genetic engineering to improve the products to response basic human needs.	- This group support the genetic engineering to develop agricultural industry by gaining knowledge to other people by poster about the advantages of GMOs.
5	- Students looked that the consumers are not confident about GMOs safety and the government does not support importing of GMOs.	- They proposed that should increase productivity and reduce the demand of foods.	- Students' thinking is separated the planting between GMO plants and normal plants to avoid plants breeding.	- This group offered that creating brand for GMO products to make a choice for consumers. They chose the best solution is persuade another by posting poster on their Facebook.
6	- Students gave the reasons that GMOs have a financial loss of producers and the nutrition is not enough as a natural food. Moreover, they concerned that	- They looked that the enforcement of GMO laws is not concise in some crops which effects to fruits and vegetables that cannot withstand the environment.	- Students' thinking is against the importing GMO products in the country.	- This group promoted a campaign for producers to recognize the disadvantages of GMOs on environment broadcast the knowledge to

	gene flow will happen in plants that lead to mutation in organisms.			citizen by slide online.
7	- Students looked that GMOs able to have self-resistance to pests and reduce insecticide. Moreover, GMOs have a resistant to changing weather and chemical residue in plants.	- They analyzed that the creating new plant varieties such as strawberry prolong their growing season that effect to basic human needs.	- Students' thinking is avoid eating GMO plants and support the way to eat normal plants by planted organic plants.	- This group promoted planting organic plants by themselves. So, they make a short story about a boy who want more information that lead to choosing for eating. The proposed is invite people for eating healthy foods.
8	- Students concerned that consumers will get chemical residue in plants.	- They looked that it will increase high-quality output and farmers' income but it may effect to health in the long-term.	- They support to avoid eating GMO plants.	- This group present their solution by poster which support a campaign for eating healthy foods by planting organic plants.

These performance from 8 groups in biology class, it can be seen that students were made the decision to find out the right solution on their group base on the 4 elements of critical thinking and problem-solving in learning and innovation skills in table 7. The first element is the process to give the appropriate reasons on GMOs situation, researcher think that students link between the risen GMOs and the effect of GMOs to another life from students' explanation. The second element is the process of thinking to link between many factors about GMOs that happened and the course in the overall. So, researcher suggested that students analysed each part of whole of GMOs that have an interactive. Next, the third element revealed that students had judgments to GMOs on their information from brainstorming activity as well as they had an analysed the arguments, comments and other point of views such as government, consumers, and producer. The researcher think that this element lead to the decision critically by students' consideration. The last element found that when they decided on GMOs issue based on their judgment. They choose the right solution by their consider that

possible in the real life such as planting organic plants, label their plants, and making campaign for other people to realize more about GMOs.

Conclusion

The results of this study show that learning biology by science, technology, and society of Yuenyong (2006) enhanced high school students' critical thinking and problem-solving ability in learning and innovation skills which follows the framework of P21 Partnership for 21st century skills (2009). The elements of critical thinking and problem-solving ability consist of reasoning effectively, using systems thinking, making judgments and decisions, and solving problems.

After students were learning activities to develop critical thinking and problem-solving ability according to science, technology, and society of Yuenyong (2006) on genetics and DNA technology. The completion of each worksheets and students' performance of 8 groups have been found that learning activities according to concept of science, technology and society of Yuenyong (2006) is science-oriented subjects that are student-centered. Moreover, enabling the students aware that science and technology are all around them, saw the value of science that affects in life, and can be used and applied knowledge that is useful for oneself and society. Aryowong (2011) reported that using STS approach to teach genetics and DNA technology was promoted students identified the issues of genetics and DNA technology in society and used the media to find answers to critical, used the scientific knowledge to create a reasonable explanation, and they were interested in science, supported for the resources and the environment. The interventions of learning management based on this science, technology and society concept has encouraged the students to develop critical thinking and problem-solving ability all 4 elements. In this regard, students gave the effective reasons on social issues and linked the various factors to the overall of effect which is the protest against GMOs before making judgments by analyzing, comparing, comparing to their conclusions that lead to proposing solutions to problems or asking questions to critical thinking and problem-solving. They reasoned about the relationship between them and GMOs. They linked different factors relate to GMOs and gave examples. After that analyzing, evaluating, comparing the information that has been traced to find that GMOs are very close to them and use their judgment and decision to summarize how their viewpoints on GMOs issues. Then, they proposed guidelines or solutions for co-existence with GMOs which reflect critical thinking and problem-solving. Moreover, they gave the effective reasoning from a variety of roles including consumers, producers, and governments on issues that need to be decided. In addition, learners can connect various factors that affect each other until the overall results. After that created the students' performances through the process of using judgment and decision making. Leading to the presentation of the students' performances to the public about their viewpoint of using those solutions along with proposing the ways to find the right solution and the real possibility.

These results are similar to the findings reported by Mokpha (2010), Chaina (2010), Tonsinon (2010), Sonsanam (2010), and Thipruetree (2012) reported that

learning activities through science, technology and society approach enhanced students to promote both of critical thinking and problem-solving ability. Students give their opinions to the activities of this subject were interested and the content about GMOs is consistent with the problems on local people were facing. In addition, they recognized that scientific knowledge is basic information useful to design many ways to solving the problems for social and better quality of life. It indicated that students also applied these results to their experience. Moreover, it could be mentioned that students could develop their ability of critical thinking and problem-solving while they learning STS of GMO issue.

Moreover, after teaching these intervention the researcher was finding the good practices of adaptive instruction for enhanced critical thinking and problem-solving ability in another biology classroom were 1) Using empirical data to guide the classroom discussion, 2) Group activities allow students to exchange their ideas, 3) Providing opportunities for students to design solutions to solve problems or create creative working together, and 4) designing worksheets to be suitable for learning activities for enhance critical thinking and problem-solving ability.

This study involved enhancing students' critical thinking and problem-solving and motivation of learning biology. Some difficulties of STS genetic and DNA technology teaching and learning had high classification of thinking, participation and responsibility of students, and appropriate teachers' roles. These finding would be a good practices for teaching biology through STS approach to who may take further applications for science teaching and learning.

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