Students’ Applying STEM Knowledge in Learning on the STS-STEM Education Wave Learning Unit

Jiraporn Tupsai1*, Somsak Bunprom1, Janjira Saysang1 and Chokchai Yuenyong2
1Khon Kaen University (KKU) Demonstration School (Suksasart), Khon Kaen, Thailand
2Science Education Program, Faculty of Education, Khon Kaen University, Thailand

* Corresponding author’s email address: tjirap@kku.ac.th

Abstract. This study aims to explore Grade 11 activity of student on Science Technology Engineering Mathematics (STEM) with the integration of learning about wave based on Science Technology Society (STS) approach [8]. The participants were 50 students in Demonstration Secondary School, Khon Kaen University, Khon Kaen Province, Thailand. The methodology is in the respect of interpretive paradigm. The teaching and learning about wave through STS approach carried out over 5 weeks. The Wave unit through STS approach was developed based on framework that consists of five stages including (1) identification of social issues, (2) identification of potential solutions, (3) need for knowledge, (4) decision making, and (5) socialization stage. To start with, the question “How to change wave energy to electricity” was challenged in the class in order to improve students to find the problem of how to design wave energy to electricity from Clean Energy form force wave. Students were accepted to apply scientific and other knowledge to design of wave energy to electricity. Activity of students on STEM were collected during their learning by participant’ observation and students’ tasks. Them did on STEM were classified when they applied their knowledge for designing the wave energy to electricity. The findings indicated that students cooperatively work to solve the problem when applying knowledge about the content of Science and Mathematics and processing skill of Technology and Engineering. It showed activity that students held the integration of science, technology, engineering and mathematics to design their possible solutions in learning about wave energy to electricity. The paper also discusses implications for science teaching and learning through STS in Thailand.

1. Introduction
Researcher believe that if Physics is integrated into STEM education lessons, then students will become scientifically competent taught within well-designed. The STEM education lessons provide students opportunities to learn science in contexts that they understand and that can lead to cross-discipline connections to well skill. We plan many activities commonly found in technology classrooms have the potential to develop students’ scientific literacy [9] We also believe there are activity pass of important benefits to within instruction. When students define a technological design problem scenically they develop more cultured and understandings of those solutions. Finally, in this
era of high stakes responsibility, contributing to Physics instruction helps convince school and district administration that help should continue to be supported.

There, research conducted by our team suggests that, just because the physics is present in an activity. Our team has conducted research in science classrooms to teach science, technology, engineering, and mathematics (STEM) education—our focus has been on physics. We have found that in the design and setup of the lesson make a dishing in what students learn. In this article, we share our experiences in redesigning a lesson that uses Wave unit through STS approach in order to generate some general principles.

Knowledge in the 21st century has focused on globalization, information society, the expansion of the technology services industry, competition in the economy, and workforce needs to be creative. To compete in the future world, the government plan sets out to utilize STEM education in training future Thai citizen and Thai STEM workforce to compete in the ASEAN economic community (AEC). The plan outlines the goals, the processes and the participation from the governmental agencies, private enterprises and society as well as international and foreign agencies [3]. The communities are becoming more diverse socially, racially, ethnically, even politically. Changing technologies are disrupting traditional lifestyles and ways of doing business. Consequently, the individuals need to develop their understandings of the world. New technologies and new media are radically reshaping not only when, but how and why people learn. The boundaries of when, where, why, how and with whom people can and do engage in science learning experiences are increasingly blurring. Many research suggested that the 21st century science learning should provide integration of STEM content and pedagogy in ways that more accurately reflect learning as a lifelong process that occurs across settings situations. [2][3][4],[5], [6][10].

To provide for the future, the STEM education in school setting, therefore, becomes the key success. The literatures suggested some ideas related to the STEM curriculum design which required combining theories and practices in real situations, designing process, problem-solving ability and other aspects related to finding the possible solutions. STEM learning could be provided through context of, Science Technology and Society (STS) education [13].

Design-based learning, STEM activity requires students who could integrate and support creativity within activity. As creativity is considered to be an essential element of problem solving, critical thinking, science, and engineering design. The STEM education supports students to on tasks which are considered be ill-structured problem-solving tasks, which are complex, open ended, and more in line with real-world problems. Solving ill-structured tasks places a high level of cognitive demand on students [1] [6][8].

As the literature in this field [4], pondering the bipolarity of some cognitive dimensions is a suitable option in advancing toward a construct definition of creativity. Yuenyong [13] present some topics in order reach a better definition of creativity as a cognitive characteristic. For example, The teaching and learning about wave through STS approach carried out over 5 weeks. The Wave unit through STS approach was developed based on framework that consists of five stages including (1) identification of social issues, (2) identification of potential solutions, (3) need for knowledge, (4) decision making, and (5) socialization stage. To start with, the question “How to change wave energy to electricity” was challenged in the class in order to improve students to find the problem of how to design wave energy to electricity from Clean Energy form force wave. Students were accepted to apply scientific and other knowledge to design of wave energy to electricity [12].

This paper aimed to clarify the developing STEM education learning activities to enhance students’ creative thinking. The learning activities were developed for Grade 11 students who will study in the subject of Physics of Demonstration School, Khon Kaen University, Thailand.

2. Participants
Participants include 50 Grade 11 students who enrolled to study in the subject of Physics Demonstration School, Khon Kaen University, Thailand.
3. Methodology

The subject of Physics provided the learning activities to enhance students to design something to solve problems in the real world. The question “How to change wave energy to electricity” was challenged in the class in order to improve students to find the problem of how to design wave energy to electricity their creativity for an essential element of problem solving, critical thinking, science, and engineering design. Learning STEM education to develop the creativity of students. The intervention of STEM was provided for one 5 weeks as the below.

3.1. The Wave EPD-STS-STEM Education Learning Unit

The Intervention of wave EPD-STS-STEM education learning unit was designed based theoretical framework of Engineering Process Design and Yuenyong (2006) STS approach [13]. The ideas of learning activities, firstly, were provided regarding on five stages of Yuenyong (2006) STS approach [13]; then the ideas of the Engineering Design Process (EPD) was provided along each stage of STS approach.

3.2. Five stages of Yuenyong (2006) STS approach

In this research, participants developed the STS unit regarding Yuenyong(2006)’s STS approach. Teaching and learning are started from society realm and moved to attaining technology, science concepts and skills. In conclusion, students have chance to take action in society. Yuenyong (2006) [13] developed science unit through STS approach that involved of five stages including identification of social issues, identification of potential solutions, need for knowledge, decision-making, and socialization stage.

1. Identification of social issues stage. The issue of question asking student about wave phenomenon Tsunami occurred in Japan, Clip scenes, taken from the documentary called as "Japan Tsunami - How It Happened," sinami in Thailand on December 26, 2004, 10:00 am, occurred in the andaman sea. Issue form this clip, what do you think that this huge energy is caused by something? and What is the source of energy that can be devastated? " This video was projected to encourage students to identify some issues and then find imaginable solutions by applying knowledge, mainly knowledge about wave energy.

2. Identification of potential solutions stage. Students plan to solve the social problem related to wave energy, we used clip Kinetic Wave Power Station power station. It can harvest kinetic energy and turn it into electricity. We challenge them to see the benefits of wave energy. This stage supports students to concern with technological aspects for find the possible solutions. Technological aspects are skills to support student decision making. In the STS wave energy unit, students need to think of what, where, and how ideas also design, systems, volition of application scientific knowledge work for designing. The question for challenge “How can scientists bring the waves to electricity?” Students do brainstorm to list what knowledge could be applied and what they need to know in order to develop the possible solutions.

3. Need for knowledge stage. This stage involves developing scientific knowledge. Social questions and technological knowledge can create science content. Student explorer wave properties and composition of the wave tray simulation and creates concepts wave. These activities may provide chance to develop knowledge based for designing safety Electrical and Energy.

4. Decision-making stage. This stage with student involves in making a decision on how to use wave energy knowledge and technology. This aspect public rhetoric about Wave related technological and social issues. It’s becomes dominates would like to project and communicate wave energy. Teaching strategies may be used discussion among students’ group, and brainstorming to allow students designing the wave energy. On the process of students’ designing, they need to be enhanced to develop their possible solutions, select the best solution, and construct a prototype for Electrical and Energy.

5. Socialization stage. Students have to share their prototype for their best solution to project wave energy. They may exhibit their prototype in public and show new product in science project, or sharing...
in exhibition. The reflection or comments from public may allow students to communicate the solution, and also test and evaluate solution. Then, students need to be asked to write what they learn from those reflections which they may get some more ideas to redesign and completion decision. According to above activities of the STS wave unit, students probably learn science from social issues and then apply other knowledge on the way of their finding the best solution for the social issues.

3.3. **STEM Education and Engineering Design**

The pattern of the concept of engineering design and learning of Science, Technology and Mathematics is unique to STEM learning organization. As students attempt to learn, understand and practice skills in Science, Technology and Mathematics, they have an opportunity to apply the knowledge gained to design a product or a method to meet their daily life problem solving needs [7].

The Engineering Design Process (EDP) refers to organizing ideas to improve decision making in order to develop high quality solutions and/or products to problems. The main objectives EDP are 1) students become engineers, meaning that teachers need to listen to students, and 2) classroom environments need to change properly to enable learning through the EDP.

Specifically, skills and abilities associated with engineering design for high school student consist of nine stages according to including (1) identify need or problem, (2) research the need or problem, (3) develop possible solution(s), (4) select the best possible solution, (5) construct a prototype, (6) test and evaluate the solution(s), (7) communicate the solution(s), (8) redesign, (9) completion decision (see Figure 1) [3].

Frequently, the imaginative ideas emerged from overlooking the flaws, or a different approach may become apparent through work on the challenge. Throughout this process, students repetitively assess and challenge their ideas by repeating steps every now and then, even restarting from the beginning. [7],[12],[13].

![Figure 1. Engineering Design Process](image-url)
Table 1. Intervention of STEM education learning activities via STS.

| Week | Learning activities |
|------|---------------------|
| 1    | Course orientation was explained STS stage also, identification of social issues and identification of potential solutions stage and STEM stage identify need or problem, and research the need or problem. Researcher stimulates the student's interest by using a clip to show students about the wave and the phenomenon of the wave. Clip 1 is a wave phenomenon Tsunami occurred in Japan. Clip 2 is a clip from a documentary that describes natural phenomena using simulations the tsunami in Japan in 2011. And clip 3 is a tsunami that took place in Thailand. The news was born in Thailand on December 26, 2004 at 10:00 am in the Andaman Sea. We challenged student by video powered by Hashem Al-Ghaili Kinetic Wave Power Station. This power station can harvest kinetic wave energy and turn it into electricity (Correction: 10 m = 33 ft). |
| 2-3  | Students search the meaning of single of following word – science, technology, engineering, and mathematics. And, sharing their result of searching. Course orientation was explained STS stage also, need for knowledge stage and STEM stage. Students study waves form simulate the waves, creating the concept for some properties of waves because wave is abstracting to create understanding for students. |
| 4    | Working in group, students search for innovation which was designed for everyday life. And, each group of students, then, clarifies what aspects of STEM knowledge was applied for designed those innovations. Course orientation was explained STS stage also, Decision-making stage and STEM stage: select the best possible solution, construct a prototype, test and evaluate the solution, communicate the solution, redesign. |
| 5    | Course stop students present innovation which was designed final examination design wave energy to electricity from Clean Energy form force wave. Course orientation was explained STS stage also, Socialization stage and STEM stage: completion decision. |

4. Data Collection and Analysis

In this study, the STS electrical current unit for STEM learning has been taught by the first author for 16 periods in a month. The participant observation, students’ discussion and questions, worksheets, and unstructured interview were interpreted to examine what and how students applied their knowledge of science, and mathematics and others as well as their process of engineer process design to develop best solution as technology products.

Students’ ideas in applying these knowledge and processes were clarified in each stage of the STS electrical current unit. The dialogues and students’ tasks were also highlighted to represent the interpretation. Then, the interpretation was rechecked as peer debriefing in order to ensure the credibility since the interpretation could be subjective, varied from the particular researchers. The following the story of students on tasks of designing, making, and presenting their innovations will be clarified for representation of what and “How to change wave energy to electricity”.

4.1. Design activity Physics of wave motion using STS and STEM process

4.1.1. Improvement emphasis was explained STS stage also, identification of social issues and STEM stage identify need or problem. Researchers challenge the interest of students see the importance of wave power. Example: wave phenomenon Tsunami occurred in Japan. This is the country where this phenomenon occurs most, it is the most affected country by sea waves. The phenomenon was born in 2011. A clip from a camera with a personal view of the waves moving near themselves. And the waves can destroy the walls that scientists created to prevent tsunami destruction, but the walls are unprotected. The wave destroys building blocks from the water pressure, which can’t destroy 100%. And Clip scenes, taken from the documentary called as "Japan Tsunami - How It Happened," with focus on only a part with 3D-animated presentation of geological process causing Tsunami that swept Japan on March 11, 2011. That describes natural phenomena using simulations. The tsunami in Japan in 2011, the movement of the underwater crust is beginning in the tsunami. The enormous force of the
sea around sea as then energized see the phenomenon. They can saw wave composition move to the shore by simulate wave motion from deep water to shallow water. Notice the amplitude of the wave with the forward motion, the wavelength when it reaches the shore, and the impact on the building and car. And sinami in Thailand on December 26, 2004, 10:00 am, occurred in the andaman sea. A phenomenon was a damaging event the death of about 10000 people in the news was born in Thailand December 26, 2004 at 10:00 am.

\[\text{Figure 2.} \text{https://www.youtube.com/watch?v=UvYmZFPRzT4} \text{[22-7-2017].}\]

\[\text{Figure 3.} \text{https://www.youtube.com/watch?v=JFU9hqAN0t0} \text{[21-5-2017].}\]

\[\text{Figure 4.} \text{https://www.youtube.com/watch?v=cAsbmYRGvFk} \text{[22-7-2560].}\]
There clip reflected critical issues as perceived by students below.

Teacher: From the clip, what did the students notice?

Student 1: I saw the movement of wave moving and the boat was in the sea, and it was moving around.

Student 2: Sinami, there is enormous energy that destroys houses, which makes the house completely destroyed.

"Issue form this clip, what do you think that this huge energy is caused by something? and What is the source of energy that can be devastated? ".

Form clip help student saw phenomena of wave which allows students to see the energy of the waves from nature. The destruction can't protect in front of them to destroy and humanity. This occurrence was in the human hand, it is only to escape or accept the occurrence of nature.

4.1.2. Improvement emphasis was explained STS stage also, identification of social issues and and STEM stage identify need or problem. We used clip Kinetic Wave Power Station power station. It can harvest kinetic energy and turn it into electricity. We challenge them to see the benefits of wave energy.

![Kinetic Wave Power Station](https://web.facebook.com/ScienceNaturePage/videos/818130261652567/?pnref=story [21-5-2017])

They learned energy of wave by observe wave to related to various fields. Which is punishable and useful in life, they analysed why tsunamis are so powerful in their destruction and what the characteristics of the waves are. How can scientists bring the waves to electricity? Answer of student interpretive clip was solved situation to finding data, example in below.

Student 1: See the difference that one clip creates huge damage and another human clip can bring energy from the waves.

Student 2: Seeing the concept and ability of scientists who can take the dam from the dam to create a benefit to humans.

Also, the challenge clip and stimulate student interest about wave. The part of the wave with wave components and wave properties Influence on humans. So, from the clip on the wave will notice the wave motion and the power of waves. Where energy is hugely tries to find energy to replace it? If students are engineers from this VOD study, students can design power generation. What's around the students? They could to emphasis explained social issues and identify need or problem for thinking in next station.

4.1.3. Improvement emphasis was explained STS stage also, need for knowledge stage and STEM stage develop possible solution. Student explorer wave properties and composition of the wave tray simulation and creates concepts wave. They studied properties of waves to create understanding to a conceptual element of wave. They studied two main types of waves: mechanical and electromagnetic.
Mechanical waves propagate through a physical matter, whose substance is being deformed. Restoring forces then reverse the deformation. For example, sound waves propagate via air molecules colliding with their neighbours.

Figure 6. https://phet.colorado.edu/sims/wave-on-a-string/wave-on-a-string_th.html [21-5-2017]

Figure 7. https://phet.colorado.edu/th/simulation/radio-waves [21-5-2017]

A standing wave, also known as a stationary wave, is a wave that remains in a constant position. This phenomenon can occur because the medium is moving.

Figure 8. https://web.facebook.com/ScienceNaturePage/videos/818130261652567/?pnref=story [21-5-2017]
Student studied waves that encounter each other combine through superposition to create a new wave called an interference pattern. Important interference patterns occur for waves that are in phase.

Figure 9. [Video Link]

The diffraction occurs whenever propagating waves encounter such changes, its effects are generally most pronounced for waves whose wavelength is roughly comparable to the dimensions of the diffracting object or slit.

Figure 10. [Video Link]

Figure 11. [Video Link]
The diffraction occurs whenever propagating waves encounter such changes, its effects are generally most pronounced for waves whose wavelength is roughly comparable to the dimensions of the diffracting object or slit.

![Figure 12](https://phet.colorado.edu/th/simulation/legacy/wave-interference [21-5-2017])

![Figure 13](https://phet.colorado.edu/th/simulation/legacy/wave-interference [21-5-2017])

We had question enhancing understanding of student about simulation wave.

Teacher: What does wave occurs?
Student 1: Wave had a wave power station, the waves arriving because the water in the chamber to rise and fall, which means that air is forced in and out of the hole in the top of the chamber.

Teacher: How was wave move?
Student 2: Wave can move energy forward to around but wave make water rise and fall in chamber.

Teacher: What were character of wave?
Student3: Wave have 4 specifics basic: Reflection, Diffraction, Refraction, and Interference. And the action of the waves moves the device, pumping hydraulic fluid to a shore station to drive a generator in my project. Because wave water was transverse wave so were contrast force and moving to diverge.

Teacher: How were they wanted to solve problem wave energy to use to people?
Student could inquiry content wave form activity and simulation about character of wave: Reflection, Diffraction, Refraction, and Interference. They were finding as ocean waves are caused by the wind as it blows across the sea. Waves are a powerful source of energy. Once they've thinking built a wave power station, the energy is free, needs no fuel and produces no waste or pollution. More ideas about how to extract energy from waves are being proposed all the time.
4.1.4. Improvement emphasis was explained STS stage also, Decision-making stage and STEM stage develop possible solution, select the best possible solution, construct a prototype, test and evaluate the solutions, communicate the solutions, redesign. The ability of student to think of decision making in plan for develop possible solution. They could select best possible for construct project wave power. Then, they would to test project evaluate and communicate the solutions with friend, if it projects not possible, they could be redesign new project. They studied force of wave simulation and activity, they were decision-making develop possible their ideas, generate and construct prototypes, and balance competing constraints and criteria in order to create an optimal solution and communicate their work to stakeholders. The fundamental goals for providing students with opportunities to engage in engineering design in class physics. Research had cognitive goals include improving students’ problem-solving abilities; system thinking abilities; and understanding of science, technology, and mathematics concepts, while the affective goals include generating interest in engineering and enhancing self-efficacy to solve engineering problems. Research would to create experiences that allow students to draw connections to real engineering projects such that students are motivated to engage in the design problem for reasons other than evaluation. We can also make real world explicit about design wave force and energy to electric. Example student design in below:

![Figure 14. Student design wave force and energy to electric.](image)

Models and modeling are widely used in engineering education. Engineers construct models that are based on physical laws and mathematical descriptions, but these models are simplifications of the world around us. For example, an engineer might construct a model of wave force and energy to electric. The model can provide the student who is designing bridge trusses useful guidance on the types of structures that will be most efficient in their design. As students engage in an authentic engineering design task in engineering design may shift, allowing them to embrace the opportunity to learn why something does not work well and to redesign it for optimal functionality. students may engage in iterative engineering design, not because it is what their teacher requires, but because they are invested in the design process and motivated to solve the problem. Moreover, students engaged in the search for solutions to design challenges recognize the need to collaborate and communicate effectively with each other learn to contribute systematically to the design process. Having opportunities to engage in processes that afford such tinkering may also help students expand their repertoire of resources situated within the context of classroom-based of The Wave EPD-STSS-STEM Education Learning Unit[1][2][5]).

4.1.5. Improvement emphasis was explained STS stage also; Socialization stage and STEM stage develop completion decision. Students were designing recycling devices, they developed more creative ideas in contexts relation of content physics. They were that solved ill-structured problems those who had initially encountered failure in attempting to solve ill-structured problems outperformed their counterparts who had initially confronted and solved well-structured problems [8]. Researcher would
employ different levels of scaffolding throughout an engineering design process depending on
students’ experiences with open-ended problems, strengths in content areas, and the degree of support
they require to overcome obstacles. Accordingly, we can deliberately design learning experiences that
activation and differentiation of prior knowledge in relation to the targeted concepts. They could to
discussion around specific features or unexpected occurrences organization, assembly, and synthesis
of the critical conceptual features into the target concepts; and reflection throughout the iterative
design process. Because there is no single correct way to design and implement an engineering design
experience, we would vary levels of complexity, dimensions of the problem, or applications. we would
choose to introduce students to engineering through well-structured problems, providing explicit
criteria. Constructing a prototype is usually viewed as a “hands-on” activity. The term, hands-on,
implies an active learning process. Product life cycle management also poses a range of choices, such
as the need to provide for efficient disposal or recycling. Example student design in below:

![Figure 15. Model wave force and energy to electric.](image)

Students have encouraged on theme’s judgment, even when that judgment is based on the teacher’s
own informed understanding of the design requirements. They were come to see their positive
evaluations as the primary goal in and of itself. An alternative situation in which students are able to
assess and evaluate their designs according to the requirements of the design problem may help the
students to become better design decision makers. Having the requirements drive the students’ own
assessments and evaluations helps to monitor progress in the middle steps of the design process and
determine conditions that will meet the given requirements. The engineering design process must be
iterative so that the quality or the functionality of the design can be improved. In order to bring some
sense of closure to the engineering design process. When documentation has been completed and
edited, and the design team has made oral and written presentations describing the final design
solution and demonstrating the prototype to our or stakeholders[6][8].

5. Conclusion
This product is not simply the result of passing a set of predefined tests, but is based on whether or not
students believe they have sufficiently optimized their product to the selected constraints. In this step,
students make a decision that they have sufficiently met the design requirements and are ready to
implement their prototype as a final product. These facets of understanding provide a framework when
identifying the desired results of instruction or specific learning outcomes. Within the context of engineering design challenges, these outcomes include systems thinking, the engineering design process. An important consideration in assessing student learning outcomes in the engineering design challenge paradigm is the use of multiple, layered assessment strategies that provide a holistic picture of student learning. Engineering design challenges that target several domains of learning in a complex environment typically require multiple strategies for collecting evidence.

In research to start with, the question “How to change wave energy to electricity” was challenged in the class in order to improve students to find the problem of how to design wave energy to electricity from Clean Energy form force wave. Students were accepted to apply scientific and other knowledge to design of wave energy to electricity. Activity of students on STEM were collected during their learning by participant’ observation and students’ tasks. Them did on STEM were classified when they applied their knowledge for designing the wave energy to electricity. This study uses of inquiry for 5 stages STEM education including step (1) set long term and short-term goals of fundamental STEM education concept, (2) know how they are spending their time generating creative thinking from prototype, (3) arrange typical tasks according to priorities revised ideas, (4) engineering ability Distinguish between ‘urgent’ and ‘important’ tasks recognize the need to schedule blocks of time monitor and evaluate their time usage , and (5) presentation and discussion Apply these skills to typical student time demands. The use of inquiry for STEM education support students to structure the problems to get start designing and making their innovations or products. This research indicated that a design-based STEM education activity could enhance students to creatively design products. Clarifying and focusing questions on students’ designing and products make students’ thoughts more explicit on originality and elaboration creative thinking. Sharing of applying knowledge and designing on their products could enhance students’ fluency and flexibility creative thinking. This study may have implications for providing of design-based The Wave EPD-STS-STEM learning activities. Project management in ways that can be implemented in the Physics subject setting.

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