Development and implementation of the science-technology-society learning unit to enhance grade 10 student's scientific argumentation

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Abstract

This case study aimed to enhance students' scientific argumentation through the Science-Technology-Society (STS) approach. There were two phases in this study: a) Exploring the current situation of grade 10 students' scientific argumentation in real classrooms, and b) Developing and implementing the STS learning unit to enhance students' scientific argumentation. In the first phase, the researchers observed two science classrooms located in urban and rural areas. The scientific argumentation-related interactions in those classrooms were analyzed by using the Toulmin's Argument Pattern (TAP) framework. The findings revealed that the students in observed classrooms could provide some claims; but they lacked an ability to link their claims with appropriate evidence and warrants. The researchers utilized the data from the first phase to develop one learning unit based on the STS approach for enhancing grade 10 students' scientific argumentation. The learning unit developed consisted of six lesson plans in the Work and Energy topic that covered seven teaching hours. The learning units was implemented in one grade 10 science classroom with 20 students in Khon Kaen province, Thailand. The STS learning unit could help the participating students generate better reasonable claims. However, some claims were not properly generated from the relevant evidences and lacked warrants with appropriate supporting theories. The implications for further development of STS learning unit to enhance students' scientific argumentation are also discussed.

Keywords: Scientific argumentation, Science-Technology-Society approach, learning unit, grade 10 student, Thailand

Introduction

The National Education Act B.E. 2542 (Office of the National Education Commission, 1999) and Amendments (Second National Education Act B.E. 2545) (Office of the National Education Commission, 2002) emphasize the student-centered learning processes where learners are regarded as being the most important. Thus, the teaching and learning process shall aim at enabling learners to develop themselves at their own pace and to develop their full potential. Educational institutions and agencies shall provide training in thinking process, management, how to face various situations and application of knowledge for obviating and solving problems. The ultimate goal of education aims at developing Thai citizen to cope with the economic, social and political growth of the countries in the ASEAN region.

Even though the Ministry of Education has emphasized the student-centered teaching and learning process in Thailand since 1999, in many classrooms this process still focuses on teacher-centered learning and teaching students to acquire good scores in school exams and, ultimately, the Ordinary National Education Test (ONET). In science learning, many students focus their learning on memorization of contents rather than practicing an ability to critically think, logically analyze and systematically solve real problems. Also, there are a few connections between students' learning scientific knowledge and its application in their daily lives. This situation is harmful for the growth of Thailand because these youths will grow to become the quality Thai citizens in the near future (Office of the Education Council, 2011).

The new science curriculum emphasized science teaching and learning based on scientific inquiry that emphasizes learners construct knowledge themselves through scientific inquiry process. One important process of scientific inquiry is scientific argumentation (Berland & Reiser, 2009). There is a relationship between the scientific argumentation skill and scientific understanding. In the science classroom, learners must utilize their scientific knowledge and cognitive processes to generate scientific argumentation and participate in social process to communicate their arguments and exchange and defend them with their classmates. Thus, promoting scientific argumentation through scientific inquiry classrooms is important in helping learners reach learning objectives in science (Sampson, Grooms, & Walker, 2009).

The current science education movement needs students to attain good argumentative skills because there are various social-related scientific issues and conflicts which are being argued about. This means that students are expected to be able to consider reliable evidence before forming an opinion or making a decision. In addition, students should be able to communicate their arguments with their peers who may agree or disagree with them. In the argumentative process, students express their efforots, seeking for reliable evidence to confirm and convince opposing students to agree with them (Toulmin, 2003).

The Science-Technology-Society (STS) is one constructivist teaching approach that can help students develop their ability to make arguments and defend their arguments by raising appropriate reliable data sources. The degree of reliability of a data source can improve the effectiveness of decision-making process. The skills to search for reliable data and create relevant arguments would enable students to comfortably participate in social discussion and allow them accept and display their social responsibility (Driver, Newton, & Osborne, 2000). When students learn how to create scientific arguments and develop the rationale for such arguments, they will be able to integrate their scientific understanding with the real problem. In argumentation, students must be able to develop a sensible reason to support their argument until reaching quality argumentation that greatly helps them solve issues or conflicts (Lin & Mintzes, 2010).

From the literature review, there was two gaps in the literature of scientific argumentation, especially in the educational context of Thailand. First, there is no study on the current situation of students' scientific argumentation in grade 10 science classrooms in Thailand. From this, the literature suggests that the STS teaching approach has its potential to help students develop their scientific argumentation. Thus, the second gap is there is no study related to the utilization of the STS approach in enhancing grade 10 students' scientific argumentation. These are two big gaps in the literature about STS approach and scientific argumentation that this study will to contribute to.

Research Questions

Therefore, the research questions of this study are:

a. What is the current situation of students' scientific argumentation in grade 10 science classrooms?
b. What are desirable characteristics of the STS learning unit in the Work and Energy topic for enhancing grade 10 students' scientific argumentation?
c. What is the impact of the STS learning unit on Work and Energy on enhancement of grade 10 students' scientific argumentation?

Research Objectives

The objectives of this study are

a. to explore the current situation of scientific argumentation-related interactions in grade 10 science classrooms; and
b. to study the impacts of developed STS learning unit on work and energy on grade 10 students' scientific argumentation.

Literature Review

This section presents the review of literature related to the national science education reform in Thailand, STS approach, scientific argumentation and enhancement of scientific argumentation through an STS approach.

National science education reform

The second wave of the national science education reform in Thailand had been started since the announcement of Constitution of the Kingdom of Thailand (B.E. 2540) in 1999. Then, in 2001, the Thailand government announced the National Education Act B.E. 2542 that led to the proclamation of the new national curriculum: the Basic Education Curriculum B.E. 2544 (Ministry of Education, 2001). In this new national curriculum, the learning subjects were divvied into eight learning areas: science was included as one of them. The learning area of science aims to enable learners to link scientific knowledge with processes, acquire essential skills for investigation, build knowledge through investigative processes, seek knowledge and solve various problems. Learners are allowed to participate in all stages of learning, with activities organized through diverse practical work suitable to their levels. There were eight learning strands in the new national science curriculum: Living Things and Processes of Life; Life and the Environment; Substances and Properties of Substances; Forces and Motion; Energy; Change Process of the Earth; Astronomy and Space; and Nature of Science and Technology. There were two brand new learning strands in this new science curriculum, the Change Process of the Earth and Nature of Science and Technology.

STS approach

The STS approach emphasizes students as being the most important which is different from the traditional teaching method in the sense that the STS approach integrates science, technology and society. Learning science occurs in the technological and social context and then applied to society. In the STS classroom, students will feel that their learning is more meaningful because it is closely related to their lives as well as benefiting to their society (Yuenyong, 2006). The STS approach encourages students to be more interested in science learning and to regard science as a valuable method of learning inquiry. It also helps students realize that science and technology are things around them (Protjanatanti, 2001). In sum, the STS approach starts from bringing societal and environmental issues and requires students to develop and apply their technological and scientific knowledge and skill to solve the issues raised. In the end, the students can plan their actions for sustaining their society (Aikenhead & Ryan, 1992).

According to Yuenyong (2006), the STS approach has five stages: Identification of social issues, Identification of potential solutions, Need for knowledge, Decision-making and Socialization. In the Identification of Social Issues stage, a teacher encourages students to ask questions about the societal and environmental issues raised. The issues should be interesting and current controversial issues in society. The students must be aware of the social problems due to appreciation of science and technology and their involvement in solving the issues. Then, the students move to the Identification of Potential Solutions stage. They will plan to seek answers to the issues or problems raised. The students are required to review their existing knowledge and seek more knowledge for finding the potential solution of the problems raised. In the Need for Knowledge stage, students are required to discover more knowledge or database to solve societal and science-related issues. The strategies in this stage include reading and reflection based upon the teacher's documents assigned or the documents students searched for. The appropriate knowledge will lead the students to make good selection decisions for the issue raised. Then, students move to the Decision-making stage. They are required to analyze knowledge from the third stage and synthesize the potential or possible solutions for the issues raised. Then, the students have to make decisions for solving the problems. Finally, in the Socialization stage, students need to act as a citizen who take part in society. They are required to present their potential or possible solutions for the issues or problems.

Scientific argumentation

Scientific argumentation is a part of communicative skills that is important in learning science, since science is based on reasonableness. Scientific argumentation is a process or action where a student expresses idea or provides a rationale with supporting evidence persuade others of the correctness of an opinion. Stephen Toulmin (1958) stated scientific argumentation is a rebuttal (Toulmin's Argumentation Pattern: TAP) that consists of Ground (Evidence), Claim, Warrant, Rebuttals (Counter argument), Backing (Supportive argument) and Qualifiers. Ground (Evidence) means that the student can use facts or evidence to prove his/her argument. The facts or evidence involved in the student argument aim to support the student claim. Claim means that the student thinking of the argument. It is the student's most general statement in the disputation. It is also the student's common principle or affirmation made after student brainstorm in group. Warrant means that the student has the argument consisting of a title versus the claim with supporting data and has warranties or backings having no rebuttals. Warrant is a reason (e.g. rule, principle, etc.) that is proposed to justify the connections between the data and the knowledge claim, or conclusion. Rebuttals (Counter Argument) specify the conditions when the claim will not be true. Rebuttals express counter arguments or statements indicating circumstances when the general argument does not hold true. Backing (Supportive Argument) is the basic assumptions that are usually considered to be commonly agreed on. Backing provides justification for particular warranties. Arguments do not necessarily prove the main point being argued but aims to prove that the warrants are true. Finally, Qualifiers specify the conditions under which the claim can be taken as true. Qualifiers represent the limitations of the claim (Toulmin, 2003).

Enhancement of scientific argumentation through STS approach

There are several constructivist teaching strategies having the potential to promote students' scientific argumentation; one of these is the Science-Technology-Society (STS) approach. The STS approach is appropriate in promoting student scientific argumentation (Lin & Mintzes, 2010). because it starts from the controversial issue or question raised by students. Students are aware of the issues raised and apply their scientific understanding and skills to seek the best information for solving problems or responding to the issues.

The STS approach encourages students as individuals or a group to discover the ways for solving the real controversial issues or problems occurring in society. The students then present their proposed solutions to the class and scientific argumentation then is conducted to identify the best possible solutions for those controversial issues or problems. In this case, teaching science by emphasizing argumentation helps students understand the targeted concept. During argumentation, students are required to utilize their scientific knowledge to explain and support their arguments (Erduran, Simon, & Osborne, 2004). The STS approach can promote students' development of scientific knowledge from social process since the nature of scientific knowledge is developed from social process. When students debate various social-related scientific issues in the STS activity, they have chance to strengthen their scientific knowledge. Also, after argumentation, they have chance to make more reliable and appropriate decisions (Ziman, 1978). Individual students' argumentative skills are different due to the difference of their prior knowledge and experience regarding the issue raised. As an individual grows older, their argumentative skills can be developed through facing various situations (Kuhn, 1993).

One problem of science education in Thailand is that science teaching and learning still focus on student test or exam scores rather than their ability to construct knowledge by themselves. Also, students lack an ability to make scientific argumentation that can affect their construction of scientific understanding. In particular to the Northeastern region, there is a lack of studies aimed at exploring the current situation of grade 10 students' scientific argumentation in real science classrooms. In addition, there is a lack of study related to the utilization of the STS approach to enhance grade 10 students' scientific argumentation in the Thailand science education context.

Methodology

This study employs a case study (Sturman, 1997) as research methodology to holistically study the complex phenomenon of students' scientific argumentation bounded in the science classrooms in the Northeastern region of Thailand. There were two phases in this study: a) Exploring current situation of grade 10 students' scientific argumentation in real classrooms, and b) Developing and Implementing the STS learning unit on the Work and Energy topic to enhance grade 10 students' scientific argumentation. The topic of work and energy was selected as the content and context of STS approach in this study because there are several socio-scientific issues and problems explicitly included in this topic and they are valuable enough for students to make arguments on them such as the issues about safety of children in playground and alternative choices of generating electricity. The STS learning unit on work and energy is consisted of two sub-units. The contents of first sub-unit covers the Work and Energy theorem, Kinetic energy (Ek), and potential energy (Ep) and took seven hours of teaching. The second sub-unit covers the conservation of energy and took 6 hours of teaching.

Data collection

In the first phase, the researchers spent four months in observing two voluntary science classrooms located in urban and rural areas in Khon Kaen province, Thailand. The teaching and learning in those two science classrooms were videotaped and audiotaped. Also, the researchers collected related teaching and learning documents such as student worksheets and products.

In the second phase, the researchers developed the STS learning unit on the Work and Energy topic to enhance grade 10 students' scientific argumentation. Then, the learning unit was implemented with one grade 10 science classroom with 20 students in Khon Kaen province, Thailand. The participating students aged about 16 to 17 years old and there were 13 males and 7 females. The first author of this paper herself taught the STS learning unit on Work and Energy to the participating students. In addition, there were two persons involved in this phase. One person was a science teacher who graduated in a bachelor degree in Physics and was an owner of the class.

Another person was a research assistant who graduated in a master degree in Science Education to help cross-check the data from classroom observation. The researchers also collected data from informal interview with students and collection of related documents.

Data analysis

The researchers transcribed verbatim all videotapes and audiotapes. Then, the scientific argumentation-related interactions in the classrooms were coded by employing the Toulmin's Argument Pattern (TAP) framework (2003).

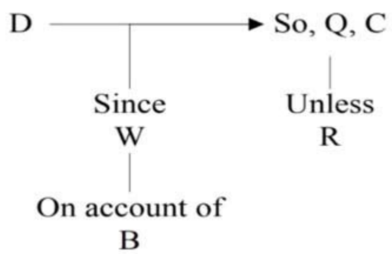


Figure 1. *TAP analytical framework*

Figure 1 shows the TAP analytical framework. Claim (C) is a viewpoint student would like to express and aims to persuade others to agree with. Warrant (W) establishes a cognitive interaction between the claim and the grounds. Therefore, W demands an implication to the underlying meaning that sheds light on the claim thanks to the grounds. The warrant's responsibility as a link is achieved by the Qualifiers (Q), which, in contrast, states the degree of strength or probability that the claim is true, indicating how sure the argument is. The next element is Rebuttals (R), counter-arguments or statements depicting situations where the argument fails to prove itself. A list of limitations and exceptions could be embedded in the R. Backing (B) further justifying the W with evidence arguing for the reasoning of the W. The types of scientific argumentation can be classified into four types according to its complexity and how elaborate the evidence or grounds are, how compatible they are with examples given as justification and the appearance of any rebuttals to counter-arguments.

Table 1. Types of scientific argumentation

Type of scientific argumentation	Code	Description
1	AC	A simple claim without justification or grounds versus another claim or counterclaim.
2	AG+	One or more claim with simple justification or grounds (comprising data, warrant, and/or qualifier and backing) but no rebuttal.
3	AG++	One or more claim with more detailed justification or grounds (comprising data, warrant, and/or qualifier and backing) but no rebuttal.
4A	AG+R	One or more claim with justification or grounds and with a rebuttal that addresses a weakness of the opposing argument and/or provides further support for one's earlier argument.
4B	AG+RS	One or more claim with justification or grounds and with a self-rebuttal that considers the limitation or weakness of one's own argument.

Source: Chin and Osborne (2010)

The numbers in the codes of scientific argumentation are not hierarchical levels. Rather, the numerical order indicates the degree of complexity; Type 1 is the most rudimentary, while Type 4 is more advanced. On the other hand, in some cases, the complexity is less prominent between Type 3 and Type 4 as Type 3 may embody better established justifications with more extensive grounds than Type 4, whereas Type 4 may contain a very basic justification, but include rebuttal.

Results and Discussion

This section illustrates the findings and their discussion according to the research phase.

Phase 1 Exploration of current situation of students' scientific argumentation in real classrooms

This section presents the current situation of students' scientific argumentation in two different school contexts, i.e. one urban and one rural, in Khon Kaen province, the Northeastern region of Thailand. The results were presented through six argumentation situations: Data, Claim, Warrants, Qualifiers, Rebuttals and Backing.

Component of students' scientific argumentation: Data

Urban classroom context

The school urban students could provide pieces of data in their arguments but such data was incorrect such as in the case of Law of Conservation of Energy.

T	:	Regarding the law of the conservation of energy, this is the question: Consider the objects at the highest of vertical plane. The objects drop in the positions X, Y and Z, then compare the kinetic energy of object at each position.
G2	:	I Think the object at point Y has zero kinetic energy because its velocity is zero.
T	:	Other groups, do you agree with Group 2?
G4	:	We agree considering the velocity of the object is continually decreasing until it will be zero at the highest position.
G2 S7	:	I think when the object dropped, its velocity will be increasing until it has velocity at considered point.
G2 S8	:	I think the velocity of object at point X is higher than at point Z and velocity at point Y is zero. Do you agree with me?
G2 S9	:	Yeah. I agree with her.

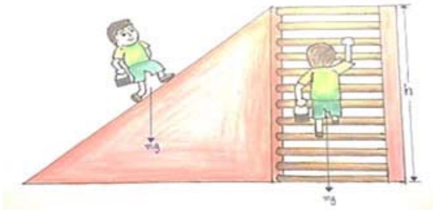
Note T = Teacher, G = Group, S = Student; a number represents a code of the participant

The urban school students used the data that the teacher had written on the board. Some students drew a picture to present the data of their arguments. In the Force and Work topic, it was found that the urban school students prepared themselves in advance from the work given by the teacher. The teacher motivated students to participate and concentrate in learning activities by using a score as a reward. Thus, students were motivated to attend the class for their high scores. This situation was common in the urban schools in Thailand.

Rural classroom context

The students in rural school context could generate their arguments by using the data and conclusion from the group in addressing the problem posed by the teacher. Some students had a counter-argument with peers. The teacher in rural school was more likely to provide knowledge to students rather than to require students to study by themselves. The classroom environment tended to be quiet and students were not daring enough to comment or express their arguments with peers in class. Therefore, the teacher tried to encourage students to discuss and listen to students and see how students applied learned knowledge in answering the questions posed.

T : Mr. Red carries basket A and Mr. Black carries basket B; both baskets have equal size and weight. Then, Red climbs a stair vertically and Black climb an inclined stair until reach the same height. Which basket has more energy?



S : …(Silence)…

T : Who can explain that for me? Please.

G2 S3 : I think basket A has more energy than basket B because of basket A move farther than basket B.

G4 : (Discussion in group before answering) I disagree with Group 2 because energy that both baskets' potential energy is equal to Ep= mgh. So, both baskets have the same energy. Both baskets have the same weight and height and g is a constant, so both baskets have equal energy; EpA= EpB. But we are not sure and afraid to answer the teacher.

T : Hey! Who can explain to me? How do you think? Can be right or wrong, never mind.

S : …(Silence)…

T : If no group answers my question, I will choose a random group to answer…Group 4 please.

Component of students' scientific argumentation: Claims

Urban classroom context

The urban school students were not dare to raise their arguments because they did not want to comment on their peers' arguments and they were fear of making a mistake. Students agreed with a conclusion that a majority of students believed to be correct. Therefore, most students act as a listener rather than a claim maker. However, some student frequently presented several claims and counter-claims through the brainstorming activity. Students also presented their claims and compare them with the existing data and facts. The teacher compared claims presented by each group and came up with the conclusion.

T	:	A bungee jumper jumped from the released point, could you please describe energy of the bungee jumper at the points X (before jumping), Y (when a bungee cord is not straight) and Z (when the bungee cord is straight).
G3 S12	:	(Discussion in group) I think the bungee jumper has the highest gravitational potential energy at point A.
G3 S13	:	(Discussion in group) I think so. And what about point B?
G3 S14	:	(Discussion in group) Hmm…at point B, gravitational potential energy of the bungee jumper is decreased, while his kinetic energy is increased. Who did agree with me?
G3 S15	:	(Discussion in group) I agree. It should be. What about point C?
G3 S16	:	(Discussion in group) I think there is the elastic potential energy of the bungee cord and gravitational potential energy of the jumper. Everyone agrees?
G3	:	We think at point A, there is only gravitational potential energy of the jumper. Then, at point B, gravitational potential energy of the jumper is decreased, while his kinetic energy is increased. Finally, at point C, there are the elastic potential energy of the bungee cord and gravitational potential energy of the jumper.

Rural classroom context

The students in the rural school context could make the arguments from their discussion and brainstorming. However, students waited for other groups' arguments and waited for encouragement from the teacher. The teacher often said "How do you know that?" or "Do you have any comments?" to encourage students to generate their scientific argumentation. Students often presented claims by using the supporting data from scientific process, facts and evidence to support their comments. Often, students also referred to their everyday experience.

T	:	OK. I will start from the review of concept of power. This problem reviews your understanding of power. Can you try to solve this problem?

G3 S31 : I think the first path is easiest because the less steep, the less power.

G3 S32 : I am not sure. I am afraid to answer that.

T : How do you know?

G3 : I think because the less steep, the less power.

G5 : We think that the second path has the same work that was changed from gravitational potential energy.

G2 : We support Group 5 because $\Delta Ep = mgh$.

T : Anyone want to add comment on it? Do not be silent! You can comment.

S : …(Silence)…

G1 : We agree with Group 2. We think mg is weight of a tourist and h is height of the waterfall.

T : Group 4 What do you think?

G4 : …(Silence)…

G4 S34 : Max! You are the smartest. You should answer the teacher.

G4 S35 : Wait a minute. Let me look in the textbook.

G4 : OK. I have a question to ask Group 3 How do you know the less steep, the less power?

T : Aha! Group 3 could you please explain to Group 4. How do you know and why do you know that?

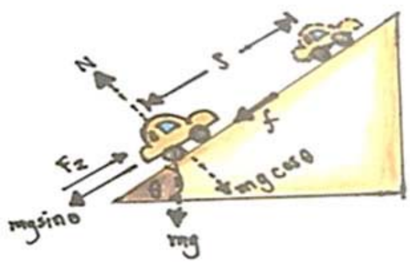
Component of students' scientific argumentation: Warrants

Urban classroom context

When the students in urban school context presented their claims or discussions, they often presented evidence and employed reliable data for supporting the claim. When students claimed something; it consisted of reasoning, assumptions and sources of comment. Some students raised their warrants for their claims or listened to the comments from other groups.

G4 : We support Group 1: the car B has more work than car A or FB > FA.

G4 S2 : A student warrants the claims by drawing this figure



Rural classroom context

It was found that the students in the rural school used evidence for reasoning their arguments. They did brainstorming of the topic and constructed an argument by using data in a physics textbook. However, such warrants did not contain any rebuttals.

G3 S24 : The object at point A has maximum gravitational potential energy and zero kinetic energy.

G3 S25 : At point B, the object's gravitational potential energy is decreased, while kinetic energy is increased. The bungee cord has elastic potential energy and gravitational potential energy, while the jumper has potential energy.

G3 S26 : At point C, the bungee cord has elastic potential energy and gravitational potential energy, while the jumper has no kinetic energy.

T : Who would like to comment on these statements?

S : …(Silence)…

G4 : We agree with Group 3 but we need more information about why the kinetic energy of the bungee jumper at point C is zero.

Component of students' scientific argumentation: Qualifiers

Urban and rural classroom contexts

There was no evidence that the students from in both urban and rural school contexts presented any qualifier of their argument. It seemed that the students may not have been aware of providing qualifier to make better argument in physics classrooms.

Component of students' scientific argumentation: Rebuttals

Urban classroom context

The students in urban school context rarely made rebuttals to their argument. The poor students normally relied on their more expert peers and did not make any rebuttal. The students were afraid to comment on arguments made by others because they were fear their rebuttal went wrong.

T	:	I would like to review your understanding about Power. Could you try to solve this problem?
G1	:	We think the first path is easier than the second path because it uses less power. The steep is less.
T	:	Anything else.
S	:	…(Silence)…
G2	:	The second path has the same work from the change of gravitational potential energy, but the use of time is different.
G1 S35	:	OK. I use this relationship; P = W/ t. When W in both cases are equal, so P1 is more than P2 because t1 is more than t2.
T	:	Anyone think differently than this?
G5 S36	:	That's can't be right! I think both paths use the same power because they have the same gravitational potential energy. Anyone agree with me?

Rural classroom context

In the rural school context, it was found that sometime students displayed the extension of argumentation with more than one rebuttal. In this case, scientific argumentation contained a series of claims or counterclaims with data, warrants or backings. Although scientific argumentation has a claim with a clear rebuttal, the rural students tended to wait for the teacher to stimulate discussion rather than encourage themselves to answer the question.

T : Please show us your idea. Answer it! Don' fear of being wrong.

G1 : Potential energy of an object is ranged from point Y to point Z and then to point X.

G4 : We disagree. At point X, the object has the highest kinetic energy, then point Y and Z.

T : Anyone think differently?

G5 : We think the object has the same kinetic energy at all points because there is no external force acting on the object.

G2 : …(Silence)…

Component of students' scientific argumentation: Backings

Urban classroom context

It was found that the urban school students could generate scientific argumentations with a series of claims with data, warrants and backing that were obtained from physics theories. Even though they had reliable reference to support their comment, they tended to support their friends or wait for other groups' comments more rather than give their comments.

G2 : The baskets A and B have equal energy because they were at the same height.

T : Anyone else think differently?

S : …(Silence)…

G3 : We agree with Group 2. Potential energy (Ep = mgh) of basket A is equal to basket B because h (height) and m (mass) are equal.

T : What about other groups? Do you think differently?

S : …(Silence)…

T : It's OK to answer wrong.

G1 : We agree with Group 2 and 3 because energy of the baskets A and B were caused by height or potential energy (Ep).

G4 : So, equal height and weight lead to equal energy; EpA = EpB.

Rural classroom context

The students in the rural school context rarely used reasons to support the discussion of arguments. The students tended to agree and support the warrants made by the head of group rather than make comments by themselves. The students were often shy and afraid to raise any argument or comment to the classroom. Most students waited for the teacher to motivate and encourage discussion and argument because they realized that the teacher would give them the correct conclusions at the end. To cope with this, the teacher randomly selected the students who were not brave enough to make comments.

T : How do you think?

S : …(Silence)…

T : If no one answers my question, I will pick you at random. OK. Group 4 please answer me.

G4 : We disagree with Group 2 because the energy of basket is potential energy and due to Ep = mgh, so EpA = EpB

T : Anyone think differently or the same?

S : …(Silence)…

Comparison between urban and rural school students' scientific argumentation

The students in urban and rural school contexts presented several claims based on various issues raised by the teachers in science classrooms. The common pattern of scientific argumentation for both groups consisted of data (D) and warrants (W). The students rarely presented rebuttals (R) and backing (B) in their scientific argumentation. Interestingly, the more experienced or knowledgeable students showed their ability to generate more complex scientific argumentation including both rebuttals and backing. The students, in particular in the rural school context, tended to rely for scientific argumentation on their more knowledgeable and experienced peers. A majority of students also waited for the teachers to encourage the scientific discussion.

At present, the national science curriculum of Thailand mandates science teachers to employ scientific inquiry in their classrooms and encourage their learners to learn by constructing knowledge by themselves through scientific inquiry process. Regarding this, Berland and Reiser (2009) propose scientific argumentaion as one core element of students' scientific inquiry. Sampson, Grooms and Walker (2009) also shows that there is a relationship between the scientific argumentation skill and scientific understanding. Learners must utilize their scientific knowledge and cognitive process to generate scientific argumentation and participate in social process to share and defend their arguments with their classmates. This study shows that an undestanding about and skill of argumentation are demanded for students in developing their scientific understanding throgh scientific inquiry and there is a need to develop scientific argumentation skill in the grade 10 students in both urban and rural school contexts (Aufschnaiter, Erduran, Osborne, & Shirley, 2008). Students may be able to conduct scientific inquiry to seek for their scientific knowledge, but they lack an ability to generate appropriate and quality scientific argumentation (Berland & Reiser, 2009).

The current movement of science education in the international contexts needs science learners to attain good argumentative skills because there are lots of controversial social-related scientific issues and conflicts to make arguments on them. This means that students are expected to be able to consider reliable evidence before making an opinion or making a decision. In addition, students should be able to communicate their arguments with their peers who may agree or disagree with them. In argumentative process, students express their efforts in seeking for reliable evidence to confirm and make other side students agree with them (Toulmin, 2003). However, Thailand, at present, still faces the problem relating to a lack of promotion of argumentation in science classrooms that is similar to the international contexts. This study shows that science classroom culture in Thailand does not support student face-to-face argumentation. Students fear to debate their arguments with their peers and teachers. The teacher should create a more appropriate classroom environment in encouraging students explicitly to participate in more scientific argumentation-related interactions in science classrooms. In addition, students should be persuaded to feel more comfortable in debating with their peers and teacher about their scientific arguments. The teacher should also help guide students in what are the characteristics of, and how to generate, good scientific argumentations (Newton, Driver, & Osborne, 1999).

To adjust the science classroom environment to become appropriate for promoting students' scientific argumentation, the STS approach may be one choice (Boulter & Gilbert, 1995; Dawson & Venville, 2010; Yuenyong, 2006). The STS approach generally raises interesting controversial societal issues related to students' daily lives that are effective in promoting student discussion and debate until they are able to generate related scientific argumentation (Yuenyong, 2006). The STS-related learning activities and curriculum materials should be created as an example for science teachers who are interested in utilizing the STS approach in developing students' scientific argumentation their science classrooms.

Phase 2 Impacts of the STS learning unit on students' scientific argumentation

The STS learning unit for enhancing students' scientific argumentation

The researchers employed the STS framework based on Yuenyong's (2006) in designing the STS learning unit in the Work and Energy topic for grade 10 students. The STS learning unit was consisted of six lesson plans for seven teaching hours. The main controversial societal issue for the STS learning unit was building safe playground for children. This issue may motivate students to begin to learn science in the realm of society through the utilization of relevant technology. The lesson plans in the STS learning unit are illustrated in Table 2.

Table 2. Lesson plans of the STS learning unit on Work and Energy topic

Lesson plan	STS activities	Hour
1	1. Identification of the social issues stage • The teacher asks: What about the playground in your community, do you think is it safe? • Students watch three videoclips: Silent disasters from the playground (source: https://www.youtube.com/watch?v=55x4l-xZ9X8), Challenging the death swing (source: https://www.tvpoolonline.com/content /226004) The most dangerous slippery boards (source: https://www.youtube.com/watch?v=ZSjG6V9yKJo) 2. Identification of potential solutions stage • Students develop possible solutions from their ideas and share with the classroom • Students identify knowledge they need	1
2	3. Need for knowledge stage • Students do experiment on Potential and Kinetic Energy • Students work in group about "How to play safely with some playing equipment in playground"	1
3-4	3. Need for knowledge stage (continued) • Students investigate energy including both potential and kinetic energy	2
5	4. Decision making stage • Students list possible choices to make decisions about how to develop and design playing equipment in playground • Students attend brainstorming for reaching arguments about fun and safe playing equipment • Students make decision to agree or disagree with other arguments	2
6	5. Socialization stage • Students present works about fun and safe playing equipment to the classroom • Students evaluate playing equipment designed by each group to decide whether or not they will buy it	1

	• Divide students into two groups (buy and not buy) and require them to debate	

Examining impact of the STS learning unit in enhancing students' scientific argumentation

The students' scientific argumentations were examined through their actions and discourse in the STS classroom. The quality of students' scientific argumentations in each step of STS approach was presented.

Step 1: Identification of the social issues

Students engaged in the societal and technological issues about playground that stimulated students to present their argumentation. They could provide some claims about the dangerous playground.

T : Do you think the playground things are safe for playing?

S5 : Yes, they are. They have handles.

S6 : They are dangerous sometimes. My friend's head was injured because they fell down off a slide.

S9 : I think that the see saw is probably dangerous because it has no belt. If the player falls down, he or she will be hurt.

S10 : No, it is not dangerous, if we do not move up too high.

Students mentioned various basic types of claim related to the danger versus safety of the playground. These claims could be categorized into three types: fact, judgment or value and policy claims. The playground issue allowed students to raise the fact claims to argue about the safety of the playground. They raised empirical evidences about the danger of the playground such as injury of head, legs or hands. It seemed that the judgment claims, which involved opinions, attitudes, and the subjective safety of playground, were provided when they mentioned some subjective issues of careless and other ways of playing in playground. Another basic type of claims is policy claims that involved advocating designing a safe playground and providing play instruction. Their claims mentioned what things should be considered for designing a safe playground such as raw materials used and height and slope of a slide. It revealed that the Identification of social issue stage in the STS learning unit could engage students to develop some argumentation. However, a majority of their scientific argumentation was simple claim without justification or grounds versus another claim or counterclaim. Most students provided claims about fact or evidence of dangerous of playground which had no warrant and qualifier. Also, there were few claims with simple justification or grounds (AG+). This indicates that students could provide some warrant to support their claims about organizing the safe playground. These students' warrants could be constructed meaning for concepts of work and energy. It revealed few rebuttals on argumentation (AG+R), for example, when students provided a reason as supporting and counter argument to the danger of the swing. It indicated that students could provide some rebuttals to further support their earlier argument about a safe playground. Another rebuttal could be interpreted when students provided reason to oppose the argument of providing water to protect children when they stopped at the bottom of the slide. However, these students' rebuttals on argumentation addressed the weakness of the opposing argument and providing further support for their earlier argument (AG+R).

Step 2: Identification of the potential solution

Learning activities were provided to support students in clarifying the plausibility of finding possible solutions for the playground issue. Students listed various playground things for their description of design: swing, slide, see-saw, spring board and pull-up workout. They described an overview of designing a playground for children to play with fun and safety. These allowed students to provide scientific argumentation in designing a safe playground during drawing and presenting their tasks.

> S1: The slider is too steep. People may hurt their stomach because they moved too fast.
> S2: So, we should change the slope of slider.
> S3: Your drawing need to present something to safe people when they slide down till reach the ground.
> S4: We could put sand at the base of slider.
> S5: How did you design your slider based on a safety?
> S1: By providing some instruction or teaching adult to take care of the children when they are playing on it.

Students mentioned various basic types of claims related to a list of possible solutions for safe playground and design description. These claims could be categorized into fact and policy claims. The identification of potential solution stage allowed students to describe designing of the possible solution related to fact and experiences such as water and sand. The policy claims were also often provided when they tried to argue about advocating a design of a safe playground and providing instruction about playing.

It revealed that the Identification of potential solution stage helped students develop some scientific argumentations. However, the quality of argumentation indicated that there was a majority of simple claims and some claims with grounds. Most of them provided claims about fact or experiences to describe the designing of a safe playground without warrant and qualifier (AC). Also, there were few claims with simple justification or grounds (AG+). Students could provide some warrant supporting their claims about material for designing a safe playground. It seemed that they tried to describe their thinking based on the sense of impulse in order to support the reason for using materials. It revealed few rebuttals on argumentation (AG+R), for example, when students provided reason as supporting and counter argument to the danger of the swing. This indicated that students' scientific argumentation on the plausibility of designing a safe playground engage students to become aware of what they need for scientific knowledge. These could be grounded (warrants, backing, qualifier) for argumentation on the plausibility of the design of a safe playground.

Step 3: Need for knowledge

Learning activities were provided to support students to develop scientific concepts as reasonable explanations for the safe playground. Experiments, exercises and simulations were provided to help students to construct the meaning of energy formation, velocity, work and so on. The scientific inquiry learning activities allowed students to develop argumentation.

> T: How do you know the experimental car has kinetic energy?
> S2: The car is moving.
> T: How much kinetic energy is there?
> S3: It is two points.
> S4: No, it doesn't. The two points are not energy. They are distance.
> S3: We need to calculate kinetic energy
> S2: No, we have to calculate the velocity. It will tell us how much the kinetic energy is from the formula: $E_k = \frac{1}{2} mv^2$

Scientific inquiry interactions between teacher and students seemed to enhance students development of scientific argumentation. Teacher tried to ask students questions to help students to construct the meaning of force in the moving cart; where the force comes from, how to measure the velocity and how energy could be explained. Then, students could provide evidences to support the claims about the kinetic energy of the cart. This indicates that teacher's questioning support students' claims with simple justification or grounds (AG+). It could be interpreted that students provided quality argumentation because of evidence or data from experiments which provided grounds for claims about work and energy. The physics exercises were also provided in order to allow students to make sense of physics concepts. For example, the exercise of the roller coaster ride provided students with a chance to apply knowledge about work and energy to predict the roller coaster ride. This could help students to provide more claim with justification or grounds, and with a rebuttal that addresses a weakness of the opposing argument and/or provides further support for their earlier argument (AG+R). The number of good quality scientific argumentations was high because of argumentation with warrants, qualifiers and backing and scientific concepts normally used as grounds.

Step 4: Decision making

Students listed possible ways to make decisions in developing and designing the playground equipment. Students explain the principles, methods and rationale for deciding the playground design. They then wrote model or designed a model of a fun and safe playground. The teacher then asked students to brainstorm the arguments until they reached a conclusion. The number of good quality scientific argumentation was high in this stage.

> G1 S1: If the ground under the seesaw is sand, it will be safer than grass. As you have seen from the videoclip, they use sand under the seesaw as well. It is the same with mine. (Claim Warrant Ground)
> G1 S2: Or should we use the cushion? (Claim)
> G1 S1: We have to start from building the metal base, then the arms. I played on one a long time ago. I think the base has to be firm, tight and strong. (Claim Warrant Ground)
> G1 S3: We have to balance them, even the weights are not equal. Actually, a heavier and a lighter objects must be placed in the opposite side. (Warrant Ground Backing)
> G1 S1: See the base, there is a hole to put another piece of metal pole to tight it up. (Warrant)
> G1 S2: The cushion seat is made by the handlers. (Warrant)
> G1 S1: With the handlers?
> G1 S2: Without the handlers, you will easily fall. (Claim Warrant)

> G1 S1: Make the handlers like bicycle handles. (Claim Warrant Backing)

Step 5: Socialization

The socialization process allowed students to validate their values and scientific concepts of their solutions during their sharing in classroom society. Each group of students presented their products or a prototype of a safe playground to the whole classroom. These sharing activities enhanced students' scientific argumentation through audience reflection. There was a high number of good quality scientific argumentation in this stage.

> G4 S1: My group developed the safety slide made from good materials. These include plastics, Grade A metal, galvanizing coating and cement. We provided some playing instruction…The height of slider should be 60 meters that makes people slide down at the speed of 40 km/hr. (Claim Warrant Ground Qualifier)
> G4 S3: It probably is dangerous based on that speed of moving down. And, the instrument needs a wide area for installation.
> G4 S2: At the highest point of slid, gravitational potential energy is greatest. This energy is changed when people are sliding down. Potential energy is changed into kinetic energy. Energy never lost but it can be changed into a new form. (Claim Warrant Ground)
> T: The 60-meter slide, it is too high. Imagine that, the slider will be as high as many high buildings around us.
> G4 S3: Yes, but we provide someone to suggest a player how to play. And, we think that it should be ok because we learn from VDO clip of Japanese slider. They also provided the sliders with the same high of our designing. And, we have to provide some playing instruction for more safety. (Claim Warrant Ground Qualifier)

The overall, the quality of students' scientific argumentation from learning with the STS learning unit at each stage of STS is presented as Table 3. High percentages of good quality scientific argumentation occurred in the Need for knowledge, Decision making and Socialization stages. Interestingly, there was no scientific argumentation in the AG+R category or one or more claim with justification or grounds and with a rebuttal addressing a weakness of the opposing argument and/or providing further support for an earlier argument.

This study shows that the STS approach is effectively help students develop their ability to generate their own argumentations when students try to access knowledge needed to solve problems and make their decision according to derived knowledge, they have more opportunity to develop their scientific argumentation (Abell, Anderson, & Chezem, 2000; Aufschnaiter et al., 2008; Zohar & Nemet, 2002). When students learn how to create scientific arguments and develop the rationale behind such arguments, they will be able to integrate their scientific understanding with the real problem. In argumentation, students must be able to develop a sensible reason to support their argument until reach quality argumentation that greatly helps them solve issues or conflicts (Lin & Mintzes, 2010).

This study supports Driver, Newton and Osborne (2000) that the STS approach helps students realize the importance of supporting their argumentations with reliable data sources. As we have known the degree of reliability of data source can improve the effectiveness of decision-making process. The students learned with the STS approach are beneficial from the development of searching skills for reliable data and creating relevant arguments that enable them to comfortably participate in social discussion and allow them to be responsible for their social responsibility. In addition, this study shows that one effective way to assist students to generate higher quality scientific argumentation skill can occur through a socialization process in classroom between student-student and/or student-teacher (Dawson & Venville, 2010; Vygotsky, 1978).

Table 3. Quality of students' scientific argumentation from learning with the STS learning unit

Code	**Frequency**				
	Identification of social issues	**Identification of potential solutions**	**Need for knowledge**	**Decision-making**	**Socialization**
AC	23	12	7	20	35
AG+	12	2	24	120	118
AG++	7	2	19	89	148
AG+R	4	2	14	46	73
Total	46	18	64	275	374

The quality of students' scientific argumentation from learning with the STS learning unit at each stage of STS in the issue of playground is illustrated by Figure 2.

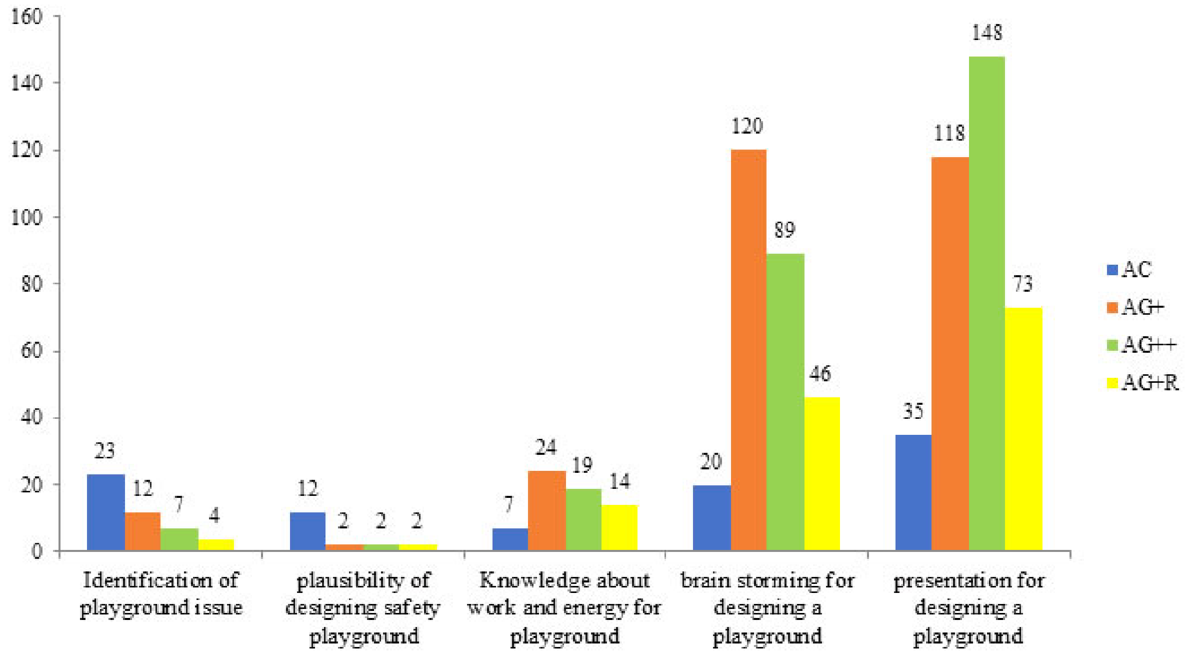


Figure 2. Quality of students' scientific argumentation from learning with the STS learning unit

Conclusion

Implications

This study presents the problems of teaching and learning to promote scientific argumentation in grade 10 science classrooms that reflects the strong emphasis on the students' learning to take a test strategy and classroom teaching and learning cultures in the educational context of Thailand. These problems lead to the employment of STS approach in developing the STS learning unit in Work and Energy in order to enhance grade 10 students' scientific argumentation. The topic of work and energy is raised as the targeted content and context in the STS approach because this topic presents several interesting socio-scientific issues and conflicts to make arguments on it. However, there is a difficulty in seeking for interesting, controversial issues to suit with the targeted physics topic. Science teachers who are interested in using the STS approach to promote their students' scientific argumentation may need to understand the basic principle of STS philosophy and approach. The history of what and how a scientist works and his or her life need to be provided. Also, a variety of examples of STS learning units covering different science subjects and grade levels of students should be provided in order to assist science teachers in gaining some ideas about what the STS teaching and learning look like. In addition, science teacher training on STS approach is demanded.

This study affirms that the STS approach is effective in helping science students enhance their scientific argumentation. The playground issue has appeared as being one interesting and effective controversial societal issue for students who learn with the STS approach. The STS playground unit can enhance students' ability to increase the quality of their scientific argumentation. Particularly, this study indicates that the Need for knowledge, Decision making and Socialization stages provide students with an opportunity to develop high quality scientific argumentation. In addition, the science teachers who are interested to employ the STS approach in developing scientific argumentation in their students can apply the STS learning unit presented in this study as an example to design their own STS learning unit in the same or different science topics.

Limitations

This study employed a case study research design and included a small number of participants; consequently, it has the limitations in generalizing the findings of this study to a large population and to the research contexts being much different from the research context of this study.

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