




A CASE STUDY OF HELPING IN-SERVICE SCIENCE TEACHER TO TEACH WITH THE SCIENCE-TECHNOLOGY-SOCIETY APPROACH AND ITS INFLUENCE ON STUDENTS' SCIENTIFIC ARGUMENTATION

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ABSTRACT

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This study aims to develop a training workshop to promote the in-service science teachers' ability to teach the topic of Force and Motion to grade 10 students by using the Science-Technology-Society (STS) approach and explore its impacts on students' scientific argumentation patterns. The research methodology was a case study with one participating science teacher, who fully attended the STS workshop designed by the authors. After finishing the workshop, the researchers followed up the teacher by observing his teaching and students' learning with the STS approach and collected all related artefacts. The students' scientific argumentation patterns were analyzed by using the Toulmin's Argument Pattern (TAP) framework. The findings showed that the training workshop helped the participating teacher design the STS-based learning unit in Force and Motion. Also, most of the learning stages in the STS approach promoted the students to generate high quality of scientific argumentation. The study concludes by suggesting further methods of enhancing high quality scientific argumentation in a STS-based training workshop for in-service science teachers.

Contribution/Originality: This study contributes to the existing literature by showing how to design a training workshop for promoting in-service science teachers' ability to teach a specific topic in science for grade 10 students by using the STS approach. The STS approach subsequently enhances students' high quality of scientific argumentation.

1. INTRODUCTION

The Basic Education Core Curriculum B.E. 2551 (Ministry of Education, 2008) of Thailand has the vision to enhance the capacity of all learners, who constitute the major force of the country, in order to attain a balanced development in all respects including physical strength, knowledge and morality. It implores the Thai citizens to express their commitment and responsibilities as members of a wider world community by adhering to a democratic form of government under constitutional monarchy. They should not only acquire basic knowledge and essential skills but also develop a favorable attitude towards further education, livelihood and lifelong learning. The *learner-centered approach* is therefore strongly advocated, based on the conviction that all are capable of learning and self-development to their highest potentiality.

The Basic Education Core Curriculum B.E. 2551 divides the curriculum content into eight learning areas: Thai Language; Mathematics; Science; Social Studies, Religion and Culture; Health and Physical Education; Arts; Occupations and Technology; and Foreign Languages. Particularly, in the Learning Area of Science, the learners are expected to:

...learn this subject (science) with emphasis on linking knowledge with processes, acquiring essential skills for investigation, building knowledge through investigative processes, seeking knowledge and *solving various problems*. Learners are allowed to participate in all stages of learning, with activities organized through diverse practical work suitable to their levels (MoE, 2008).

The learning domain of science consists of eight learning strands: 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. The two brand new learning strands in this curriculum are the Change Process of the Earth and Nature of Science and Technology.

The new science curriculum emphasizes science teaching and learning based on scientific inquiry that emphasizes learners to construct knowledge themselves through a scientific inquiry process. One important process of scientific inquiry is *scientific argumentation* (Berland and Reiser, 2009). In a science classroom, learners must utilize their scientific knowledge and cognitive processes to generate scientific argumentation and participate in a social process to communicate their arguments and exchange or defend them with their classmates. There is a relationship between the scientific argumentation skill and scientific understanding. Thus, promoting scientific argumentation through scientific inquiry classrooms is important in helping learners achieve learning objectives (Sampson *et al.*, 2009). The current science education movement also needs students to attain good argumentative skills because there are various societal-scientific issues and conflicts to argue about. In the argumentative process, students express their efforts, seeking reliable evidence to confirm and convince opposing students to agree with them (Toulmin, 2003). After argumentation, students have chance to make more reliable and appropriate decisions (Ziman, 1978).

Scientific argumentation is a part of communicative skills, a kind of rhetoric since science is based on reason. Scientific argumentation is also a process or action where a student expresses idea or provides a rationale with supporting evidence persuading others of the correctness of an opinion. Toulmin (1958) stated scientific argumentation as 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 thinks of the argument. It is the student's most general statement in disputation. It is also the student's common principle or affirmation made after students brainstorm in a group. Warrant means that the student has the argument consisting of a title versus the claim with supporting data and has warranties or backings with no rebuttals. Warrant is also 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 thus 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).

There are several constructivist teaching strategies having the potential to promote students' scientific argumentation; one of these is the Science-Technology-Society (STS) approach (Lin and Mintzes, 2010). The STS approach starts from a controversial issue or a 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. At the end, the students can plan their actions for sustaining their society (Aikenhead and Ryan, 1992; Erduran *et al.*, 2004). The STS approach helps 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 *et al.*, 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 and Mintzes, 2010). The STS approach can also encourage learners to be more interested in scientific learning and to regard science as a valuable method of learning inquiry and realize that science and technology are things around them (Protjanatanti, 2001).

Although the STS approach has its potential to help students develop their scientific argumentation, the literature review shows that there is no study in Thailand science education context having studied how to train in-service science teachers to understand about the STS approach and be able to utilize the STS approach in their science teaching. In addition, there is no study to examine the impact of the STS approach on students' scientific argumentation patterns.

1.1. Research Questions

The research questions of this study are:

- a) How can we design a training workshop to promote in-service science teachers' understanding about the STS approach and ability to use the STS approach to teach the topic of Force and Motion for grade 10 students?
- b) What is the impact of the STS-based learning unit in the topic of Force and Motion on grade 10 students' scientific argumentation patterns?

1.2. Research Objectives

The objectives of this study are:

- a) To design the training workshop for promoting in-service science teachers' understanding about the STS approach and ability to teach Force and Motion for grade 10 students by using the STS approach.
- b) To explore the impact of the STS learning unit on Force and Motion on grade 10 students' scientific argumentation patterns.

2. METHODOLOGY

This study employed a case study design (Sturman, 1997) to holistically study the complex phenomenon of students' scientific argumentation bound in the science classrooms in the Northeastern region of Thailand. There were two phases in this study: a) Designing and implementing a STS approach training workshop for in-service science teachers, and b) Investigating the impact of the STS learning unit on Force and Motion topic on grade 10 students' scientific argumentation patterns. The topic of Force and Motion was selected as the content and context of the 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 argumentations on them such as the issues about safety of children in playground and alternative choices of generating electricity.

2.1. Data Collection

The study was divided into two phases. In Phase 1, the researcher designed the training workshop for promoting in-service science teachers' understanding about the STS approach and ability to teach Force and

Motion for grade 10 students by using the STS approach. The research participants were 10 in-service science teachers from two different public schools in Khon Kaen province. The data sources were teachers' STS-based lesson plans and reflective journals and interviews with teachers. The Phase 2 aimed to explore the impact of the STS learning unit on Force and Motion on grade 10 students' scientific argumentation patterns. The research participant in this phase was only one in-service science teacher, who had fully attended the STS workshop and had volunteered to participate in this phase. The data collection involved classroom observation, interview with the teacher and collection of related artefacts.

2.2. Data Analysis

The data from Phases 1 and Phase 2 were analyzed and interpreted by employing the Toulmin (2003) framework as shown in Figure 1.

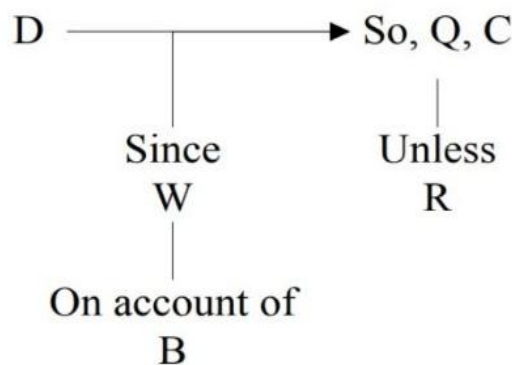


Figure-1. TAP analytical framework. Source: Toulmin (2003).

According to the TAP analytical framework as shown in Figure 1, 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 it sheds light on the claim. 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.

Table-1. Scientific argumentation pattern.

| Scientific argumentation pattern | 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).

Backing (B) further justifies the W with evidence arguing for the reasoning of the W. Such types of scientific argumentation can be classified into four types according to its complexity and how elaborate the evidence or grounds are, and how compatible they are with examples given as justification and the appearance of any rebuttals to counter-arguments. In addition, the students' scientific argumentation patterns were coded by using the codes in Table 1.

It should be noted that the numbers in the codes of scientific argumentation are not of hierarchical levels. Rather, the numerical order indicates the degree of complexity; Type 1 is the most rudimentary, while Type 4 is most 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 includes rebuttal.

3. RESULTS

3.1. *Designing a STS Approach Training Workshop for in-Service Science Teachers*

The training workshop for in-service science teachers for enhancing the use of STS approach in science classrooms for enhancing students' scientific argumentation was developed from these assumptions: a) the intensive literature review, b) the finding from the exploration of current situation about teaching and learning interactions regarding scientific argumentation in science classrooms in the Thai context and c) the findings from the initially training to enhance understanding about STS approach aimed at promoting students' scientific argumentation.

The workshop consisted of six sub-units, which needed one hour session every week for duration of eight-weeks. The first sub-unit traced the history of scientists and their works during 18th to 20th century. The participants were expected to understand and be aware of the relationship between science and society. Also, the participants together presented the history and impact of social scientists. Then, the participating teachers discussed about the philosophy of technology and it being a piece of work that is intended to operate. The participants should be able to tell the structure of technology and its impact on the demands of society. Finally, the participants were expected to realize the importance and interactive relationship between science, technology and society.

In the second sub-unit, teachers as well as the participants were expected to understand the meaning and definition of STS and how to apply STS pedagogy in teaching practice. In this sub-unit, the participants were required to study together and present their understanding to the whole class. The whole class then discussed about STS pedagogy and its application in science education.

The third sub-unit provided the examples of societal and technological issues based on the STS approach. Regarding this, the example of England SATIS learning unit was introduced and described to the participants. At the end of each England SATIS unit, the participants were required to discuss the characteristics of societal and technological issues based on the STS approach. Finally, they had chance to find some societal and technological issues for using in their STS lesson plans.

In the fourth sub-unit, the participants were required to read the science education graduate student's thesis using Yuenyong (2006) STS designing lesson plan approach. The participants were expected to discuss their learned ideas after reading the STS-based thesis and learned how to design their own STS learning activity for each stage of STS approach.

The fifth sub-unit aimed at increasing the participants' understanding about (Yuenyong, 2006) STS theoretical framework. The participants were required to reflect on what they learned from graduate students' STS lesson plan. The participants then discussed about their issues and problems in designing the STS lesson plan.

The sixth sub-unit aimed at enhancing the participants' ability to develop their lesson plans based on Yuenyong (2006) STS designing lesson plan framework. This sub-unit focuses on the participants' ability to select and raise the societal and technological issues for further exploring the potential solutions of the related societal

and technological problems. They raised societal and technological issues applicable for generating subsequent STS learning activities to fit the curriculum standards and learning indicators. Then, the sub-unit encouraged the participants to generate the subsequent STS learning activities aimed at applying students' knowledge and experience in finding possible solutions of the raised issues.

The activities of these six sub-units helped the participating science teachers to understand about STS approach and how to plan the STS lesson plans aimed at enhancing students' scientific argumentation through socialization of scientific enterprise. The participating teachers reflected that they had learned several ideas while developing their STS learning activities with the ultimate goal of advocating and promoting students' scientific argumentation. The designed sub-units encouraged the participating science teachers to understand about scientific argumentation regarding evaluating evidence, assessing alternatives, establishing the validity of scientific claims, and addressing counter evidence. The created workshop also effectively helped the participating teachers develop the STS-based learning units in order to enhance their students' scientific argumentation. The participants reflected that they were appreciated to attend the STS-based training workshop.

Researcher: How do you feel about the STS approach training workshop?

Teacher A: It's great. I feel I am so lucky to be here. The STS is fascinating and I think I can apply it in my future teaching. Thanks for inviting me!
(Interview after training, Teacher A).

In reflective journal writing, Teacher B, wrote that "It's my first time to know the STS approach. Normally, I teach by lecture. Now, I realized that the STS approach is better than the way normally I taught. However, I am so concerned about my STS skill and time for teaching. You know, I am inexperienced in STS teaching and I also have limited time in teaching science."

3.2. Impact of Participating Teachers' STS-Based Learning Unit in the Topic of Force and Motion on Grade 10 Students' Scientific Argumentation Patterns

The only participating teacher in stage 2, whose pseudonym was Teacher A, and who fully attended the STS approach training workshop, was followed up into her science classroom. Teacher A designed the STS-based learning unit on Force and Motion in order to enhance the students' scientific argumentation. The finding shows that the STS-based learning unit on Force and Motion could promote the participating students to gain more understanding about Force and Motion. The TAP analysis also shows that the students could develop key features of TAP argumentation. The students' ideas and conversations with the teacher and their classmates showed that they could develop more appropriate data, claim, warrants, qualifiers, rebuttals and backing through the raised social issues in relation to Force and Motion. Teacher A's STS learning unit on Force and Motion took four weeks and the activities could be depicted as in [Table 2](#).

The researcher and Teacher A worked cooperatively to examine students' scientific argumentation after learning from Teacher A's STS learning unit on Force and Motion. The results show that Teacher A's STS learning unit on Force and Motion could help the students to generate more positive quality scientific argumentations. The detailed description of students' scientific argumentation in Teacher A's classroom at each stage of STS approach is presented later in this study.

3.3. Identification of the Social Issues Stage

Students were engaged in societal and technological issues about disease issues caused by a lack of exercise in people such as heart disease, stress and so on. These issues allowed students to discuss about the importance of exercise. Then, Teacher a moved the classroom in order to enhance people exercise and develop some exercise instruments. Teacher an expected her students to apply their physics knowledge about Force and Motion to design exercise instruments. This stage allowed students to provide some scientific argumentation through their

discourses which could be interpreted as claims. The distribution of students' scientific argumentation in the Identification of the Social Issues Stage can be shown as Table 3.

Table-2. Teacher A's STS learning unit on Force and Motion for promoting grade 10 students' scientific argumentation.

| Targeted concept | Lesson plan | STS teaching and learning process | Time |
|---|-------------|---|------------------------|
| <ul style="list-style-type: none"> - Forces and net force - Magnitude and direction of net force - Newton's Law of Motion - Weight - Friction force - Application of Newton's Law of Motion | 1 | Identification of social issues stage Students watch the video clips of exercise and sport e.g. running, soccer, basketball, volleyball, etc. Then, students identify and describe forces acting on players and objects in each situation and possible causes of accidents and injury. Students discuss about the advantage of exercise on good health and possible cause of accidents and injury from exercise. The teacher leads students to discuss about designing exercise equipment to suit students' preference, time, place and budget. | 30 |
| | | Identification of potential solutions stage Students work in group (4-6 persons) to list the possible solutions of exercise equipment being appropriate to their preference, time, place and budget. Students also list knowledge they need for constructing the good exercise equipment. The teacher further suggests some science concepts as forces, net force, Newton's Law of Motion, weight and friction force. | 30 |
| | | Need for knowledge stage Students search and study science concepts needed for construction of each exercise equipment. Then, students write the diagram of forces and calculate net force acting on a player. | 60 |
| | 2 | Decision making stage Students in group evaluate pros and cons of each exercise equipment and finally make decision to create one exercise equipment. Students, then, design and develop prototypes of chosen exercise equipment. In this stage, students may need to seek more knowledge relevant for constructing the exercise equipment. Students keep reflecting their ideas or thoughts regarding their design and development of chosen exercise equipment. | 60 (plus home work) |
| | 3 | Socialization stage Students in group share and present their products and process to the class. They also present the scientific concepts associated with their chosen exercise equipment. | 100 |

Source: Example of teacher a's learning unit on force and motion.

Table-3. Distribution of students' scientific argumentation in the identification of the social issues stage.

| Scientific argumentation pattern | Code | Frequency |
|----------------------------------|-------|-----------|
| 1 | AC | 29 |
| 2 | AG+ | 5 |
| 3 | AG++ | 0 |
| 4A | AG+R | 0 |
| 4B | AG+RS | 0 |

Source: Students' scientific argumentation pattern in in the identification of the social issues stage.

The example of teacher-student and student-student discourses showing several patterns of scientific argumentation is as:

- T: Do you usually exercise every day?
S1: No, I don't. I am lazy. (value claim, warrant)
S2: No, I don't because I am very busy. I have no time. (value claim, warrant)
S3: No, I don't. I don't like exercising. (value claim, warrant)
S4: I have no time to go exercising because I have too much homework (value claim, warrant)
T: Do you guys know that the exercise is good for your body and your health?
S1: Yes, I do. It helps us to be strong. (claim, warrant)
S3: The exercise can give me six packs. (claim, warrant)
S4: The exercise gives me bright ideas. (claim, warrant)
S5: The exercise gives us fresh and healthy body. (claim, warrant)
S6: The exercise helps us to engage in activities with others. (claim, warrant)
S7: The exercise makes us handsome and beautiful. (claim, warrant)
S8: The exercise allows us to do good activities which keeps drugs away. (claim, warrant)
T: What may happen to you if you do not go exercising?
S1: Fat. (claim)
S2: Hypertension and diabetes. (claim)
S3: Stress. (claim)
S4: Fatty clogs. (claim)
T: (after students had read an article about diseases) what are the causes of hypertension?
S1: People eat instant noodle. (Claim)
S2: Canned food (claim)
S3: People eat salty, spicy, or greasy food. (Claim)
S4: People smoke and drink alcohol (Claim)
T: If you always go exercising, will it help?
S1: Yes, it will. The exercising gives us funny time. (Claim)
S2: The exercising decrease chance of Hypertension/ (Claim)
T: However, there are some limitations of exercising such as no time, too busy in their routine job, or living in down town. What can we do?
S1: People, who stay in downtown, could do some exercising in parks or gyms. (Claim, warrant)
S2: We can go fitness.
T: If you have no time, no exercising instrument or no space for exercising, what will you do?
S1: I will do yoga or aerobic dance. (Claim)
S2: I will develop my exercise instrument. (Claim)

According to Teacher A and her students' discussion about exercising and health, the issue motivated the students to identify some problems. Then, the students went to start their argument for understanding the involved problem. A majority of students provided claims to understand the problems. However, they considered the value claims focusing on their feelings and emotions. Some students could provide some warrants but their warrants were not based on proper scientific knowledge. This showed that most of the students provided simple claims without justification or grounds versus another claim or counterclaim.

3.4. Identification of Potential Solution Stage

Students were challenged to list possible ideas in developing exercising instruments and discuss about what knowledge they needed and the limitations of their knowledge. In doing so, Teacher A provided student learning

resources such as reflective sheet of what the students planned to do and a video clip of designing the exercise instruments. On the way of developing potential solutions, the students provided some scientific argumentation that could help them learn science.

Out of four groups of students' scientific argumentation about possibility of designing exercise instruments, it could be interpreted that a majority of students provided their claims without grounds. However, there were some grounds when they mentioned about warrant, rebuttal or backing. There were few concepts of Force and Motion which were provided for the ground, even though some grounds were misconceptions. The distribution of students' scientific argumentation in the Identification of Potential Solution Stage can be shown as Table 4.

Table-4. Distribution of students' scientific argumentation in the identification of potential solution stage.

| Scientific argumentation pattern | Code | Frequency |
|----------------------------------|-------|-----------|
| 1 | AC | 16 |
| 2 | AG+ | 2 |
| 3 | AG++ | 2 |
| 4A | AG+R | 3 |
| 4B | AG+RS | 0 |

Source: Students' scientific argumentation pattern in in the identification of potential solution stage.

Group 1: The students discussed through the sheets which represent some evidences of argumentation. The students provided scientific argumentation with no ground. This may happen because the students' practiced a culture of believing ones who propose the first claim. The scientific argumentation environment was quite relaxed on their sheets rather than face to others. The students provided only simple claims with some warrants and rebuttals. However, students' warrant and rebuttals were based on their emotions, values, and experiences rather than applying scientific knowledge as the given discourse. There was also low quality scientific argumentation in developing possible ideas of doing exercising instruments because the students' justification was based on their experiences.

Group 2: The students seemed to be aware of scientific argumentation. The students usually provided claims without ground. However, they provided some grounds about buoyance force and gravitational force for explaining how a pull-up bar could be recognized as one exercising instrument.

After students finished their scientific argumentation about possibility of designing exercising instruments, four groups of students presented their designs to the whole class that included a hula-hoop, a pull-up bar, a bike and a dumbbell.

Group 1 students presented a design of a hula-hoop. They presented that a hula-hoop would be made from a water hose. When the water was filled up in the water hose, it increased its weight. They also presented a plan of motivating people to do exercise through hula-hoop dancing as the head of a village invites his or her villagers to join. The students presented the advantages of exercising with hula-hoop like building big muscles, increasing blood circulation and increasing heartbeat rate. The students also presented the physics concept (i.e. gravitational force) to support the creation of exercising by the hula-hoop.

Group 2 students presented the design of a pull-up bar. They planned to make the pull-up bar from metal. They assumed that a pull-up bar could help people build up strong muscle strength. Group 2 students grounded their scientific argumentation on the buoyance force and gravitational force principles. However, it seemed that they possessed some misconceptions about buoyance force when they explained pulling body up. They also presented the strategies of encouraging people to do exercising via a pull-up bar.

Group 3 students presented the design of an exercising bike. They planned to make the exercising bike from an old re-usable bike. They cited a few physics concepts that could be viewed as warrants of scientific argumentation in order to invite people to use their exercising bike. They mentioned about the force and work on people's muscles in exercising with a bike. Then, they provided some support of scientific argumentation for the exercising bike when

they explained about the advantages and disadvantages of exercising bike. They also explained the prototype of exercising instrument as a bike that could be fixed in a house. The exercising bike prototype thus also encouraged the recycling of the used materials in creating an exercising bike.

Group 4 students presented the design of a dumbbell. They presented that the dumbbell could be made from re-usable materials such as bucket, metal, and cement. They started by explaining about their design background. Group 4 students' background related to the need of teenagers in their villages, who love to do sport such as volleyball and football. They liked sport and local professional footballers. To materialize their wish to become professional, the teenagers always wish to build a stronger body through exercising and their fitness. Teacher A supported Group 4 students to generate their warrants and backing of scientific argumentation in designing when she further explained about Force and Motion concepts.

3.5. Need for Knowledge Stage

Teacher A taught the STS learning unit on Force and Motion, based on a constructivist teaching method where students were required to construct knowledge by themselves. Therefore, Teacher A's classroom seemed to focus on scientific inquiry through discussion about phenomena and doing experiment. The students thus constructed scientific knowledge when they designed their exercising instruments. Teacher A's learning activities in the need for knowledge stage included: 1) computer simulation on Force and Motion, 2) force for equilibrium table; and 3) classroom discussion about Newton's first law of motion, balanced forces, equilibrium, free-body diagram of force in designing exercising instruments. These learning activities led students to develop scientific argumentation.

Teacher A required her students to set forces needed for balancing the table. Teacher A expected her students to perceive the characteristic of balanced forces when students designed their exercising instrument of TRX Suspension Training. The distribution of students' scientific argumentation in the Need for Knowledge Stage can be shown as Table 5.

Table-5. Distribution of students' scientific argumentation in the need for knowledge stage.

| Scientific argumentation pattern | Code | Frequency |
|----------------------------------|-------|-----------|
| 1 | AC | 16 |
| 2 | AG+ | 18 |
| 3 | AG++ | 20 |
| 4A | AG+R | 9 |
| 4B | AG+RS | 0 |

Source: Students' scientific argumentation pattern in in the need for knowledge stage.

According to discourse on three learning activities, scientific argumentation in scientific inquiry led the students to construct concepts of Force and Motion, balanced force and equilibrium. This indicated that Teacher A's STS teaching motivated her students to develop various types of quality scientific argumentation while her learning activities showed them to set their justifications on scientific inquiry. Therefore, there were a high number of claims with more detailed ground of warrant and backing appeared in these scientific inquiry learning activities.

3.6. Decision Making Stage

Each group of students discussed and decided what and how they should do for developing the exercising equipment. For this purpose, they not only provided scientific argumentation to come up with their design but also devised techniques for completing the tasks.

Group 1 students developed the hula-hoop. The hula-hoop was made from the water hose, water (inside the water hose), and sticky tape. The hula-hoop's shape was a circle by the property of water hose itself, which came from a central force acting from the tension of skin of water hose. The students devised their own techniques in

weighting the hula-hoop. They provided scientific argumentation about the materials to weigh the hula-hoop, which required ground of argumentation as warrant, claim, backing or rebuttals. Group 3 students developed the prototype of in-door exercising bike. The prototype of in-door exercising bike was made from paper. However, their prototype may not represent the real thing because they did not consider the scale of the bike. The distribution of students' scientific argumentation in the Decision Making Stage can be shown as Table 6.

Table-6. Distribution of students' scientific argumentation in the decision making stage.

| Scientific argumentation pattern | Code | Frequency |
|----------------------------------|-------|-----------|
| 1 | AC | 22 |
| 2 | AG+ | 37 |
| 3 | AG++ | 26 |
| 4A | AG+R | 16 |
| 4B | AG+RS | 0 |

Source: Students' scientific argumentation pattern in in the decision making stage.

When designing exercising instruments, Teacher A's students showed their ability to provide more quality-driven scientific argumentation. They could also apply their experiences and scientific knowledge to create their scientific argumentation. In summary, these STS learning activities enhanced the quality of student's scientific argumentation. The students' discussion on designing the prototype of exercising instruments allowed them to provide more quantity and quality of scientific argumentation. The students' scientific argumentation was enhanced by providing claims with more detailed grounds and rebuttal.

3.7. Socialization Stage

Each group of students presented their products or prototypes of exercising instruments to the whole class. This also reflected their pride in showcasing their exercising instruments while they learned their lessons. The atmosphere of students' presentation revealed that students and teachers were proud of the successful completion of tasks. In the socialization stage, interestingly, there was no scientific argumentation because there was no discussion during this stage.

4. DISCUSSION

This study shows that a well-designed STS approach training workshop can help the in-service science teachers in this study develop their understanding about the STS approach and ability to design the STS approach to promote grade 10 students' scientific argumentation. In addition, the participating teacher could implement the STS leaning unit in a real science classroom to promote grade 10 students' scientific argumentation. There were a high number of good scientific argumentation when the students tried to complete their tasks as finding possible solutions and developing solutions. It seemed that the raised issues engaged the students to find their possible solutions. The students had their own goals to accomplish and applied their knowledge and experience in designing exercising instruments and creating their scientific argumentation.

The STS learning unit brought students to learn science through a decision-making process requiring students' scientific argument and reasoning. It was realized during this study that students used scientific argumentation while sharing scientific knowledge with others in the form of a dialogic discourse. The students also made a decision in group or tried to reach a consensus on creating the designs and techniques for their prototypes or products. In argumentation, the students in this study can develop a sensible reason to support their argument until reaching quality argumentation that greatly helps them solve issues or conflicts (Lin and Mintzes, 2010).

The STS starts with socio-scientific issues and tries to link it with scientific content, application of technology and impact STS on society. The STS approach, therefore, is effective in helping students develop positive quality of scientific argumentation. As Driver *et al.* (2000) suggested, the debates on socio-scientific issues in the classroom

can help science students develop their scientific argumentation. The students in this study could connect science, technology, and society through the STS learning activities and finally develop their scientific argumentation. Toulmin (2003) describes that, in similar to what the students in this study have accomplished, in the argumentative process, students express their efforts, seeking for reliable evidence to confirm and convince opposing students to agree with them. The students also developed their critical thinking when they set questions, find possible solutions and make the rightest decisions or make more reliable and appropriate decisions (Ziman, 1978). The STS approach can also encourage learners to be more interested in science learning and to regard science as a valuable method of learning inquiry and realize that science and technology are things around them (Protjanatanti, 2001).

5. IMPLICATIONS

This study presents the way to utilize the STS approach in promoting students' scientific argumentation. Before that, the in-service science teachers themselves should be trained to attain adequate understanding about the STS approach and ability to implement the STS approach to promote students' scientific argumentation. In addition, the teachers should gain experience from implementing the STS learning unit in promoting students' scientific argumentation and reflect upon such experiences.

Science teachers should be more open mind and create more appropriate learning environment to support students to develop high quality scientific argumentation. Science teachers should also create more opportunities for their students to create, debate and defend their scientific argumentation. In addition, science teachers should apply the principles and findings from this study to create the science learning unit based on STS approach to enhance scientific argumentation in their students.

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