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Creating young scientists through community science projects

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Abstract

This research aimed to develop an STS-based learning unit on biological control to enhance scientific inquiry capability of secondary school students through community science projects. It was framed by the science-technology-society (STS) teaching approach, and focused on collaboration between individual students, peers, teachers, agriculturists, and local experts. Students were assessed for their scientific inquiry ability at the beginning and the end of the learning process using five instruments: experimental skill test, students’ laboratory reports, students’ science projects, semi-structured interview and classroom observation. The results showed that the STS-based learning unit on biological control helped students gain significant improvement in scientific inquiry. They were able to apply and integrate the scientific knowledge learned in both classroom and field studies to help solve agricultural problems in their own communities. Moreover, this learning unit encouraged students’ skills in solving problems in other situations.

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1. Introduction

Teaching and learning science in many countries does not seem to convey to students as to how scientists work. Learning is usually based on textbooks, laboratory manuals, and handouts rather than activities that support scientific inquiry skills. Laboratory activities do not represent good scientific models that support learning of science (Windschitl, 2004). Many teachers still use the traditional approach in which students have to memorize and follow the step-by-step expositions which are not the way scientists do (Crawford, 1998, as cited in Martin, 2003). Scientific inquiry is a way that scientists use for explaining the natural world and it is also the fundamental practice of science (Bybee, 2004). The teaching of scientific inquiry usually does not reflect authentic professionalism and thus distort the nature of science (Chinn & Mahotra, 2002; Park, Jang, & Kim, 2009).

Scientific inquiry skills include formulating and evaluating hypotheses, identifying and controlling variables, conducting experiments, interpreting and comparing results, and inferring conclusions (Ting & Phon-Ammuaisuk, 2010). Many educators have suggested that the process of inquiry is necessary to teach students to think scientifically (Park, Jang, & Kim, 2009; Windschitl, 2004). Windschitl (2004) claimed that the process of scientific inquiry is not a linear one. The process of scientific inquiry must proceed as a cyclical process (Park, Jang, & Kim, 2009) during which students can check their understanding of scientific inquiry process by themselves and with their peers. As mentioned above, these scientific characteristics must bring about improvement of students’ skills. It is
anticipated that students in the future need to be more able to apply the scientific inquiry to solve the problems in their everyday lives and understand the scientific process related to their daily life and community. Students should also transfer the scientific knowledge from their class to the society and community.

The STS approach, a learning process in human experiential context (NSTA, 2007), is one of the instructional methods that provide the human context for the use of scientific method. The STS approach enables students to understand the relationship between science and technology in society, allows the students to “feel and act like scientists” (Dass & Deal, 2007), and encourage them to exploit scientific inquiry in their problem solving (Wong, Kwan, Hodson, & Yung, 2009).

This research aimed to enhance scientific inquiry skills for students so that they can act like scientists. A project-based lesson plan on biological control that incorporated science, technology and society (STS) was developed to engage the students into real life situations in their own community. The following questions are addressed:

1. Can an STS-based learning unit on biological control promote students’ scientific inquiry?
2. Can the students apply the knowledge learned to solve the problems in their communities?

2. Methodology

2.1 Participants

Eighty-two grade nine students from two classes in a secondary school in rural area of central Thailand, aged 13 to 15 years, participated in this study. All participants were from families with agricultural background. One class of 40 students was used as the experimental group and the other class of 42 students as the control group. Both groups were taught for 21 hours with the same contents and learning objectives. The control received the traditional lecture, dry laboratory (without hands-on experiment), and report writing while the experimental group was given the STS-based learning unit, which included science projects.

2.2 Research Design

This unit on biological control focused on solving agricultural problems in students’ own communities. An STS approach was used as the framework for the learning unit. At the beginning of the learning process, the students were encouraged to discuss and list local problems with their group mates. Then they were given the opportunity to visit farms, plantations and had a chance to identify the problems with agriculturists in their community. Each group of students observed and identified plant diseases and insect pests and collected data on the given work sheets. The students interviewed farmers about using pesticides, impact of pesticides on their plots, the environment, and humans. Each group of students digested the collected data and made presentations to their class. They then explored how to solve these agricultural problems with teachers, peers, and local sages. They conducted basic experiments on controlling plant diseases by using yeast and/or mold with guidance from the teachers. Fruit-bearing plants in their community such as guavas, mangoes, tomatoes, and eggplants were used in their experiments.

In the following activity, each group of students conducted science projects of their own design on problems in their communities. They formed ideas for their projects from visiting farms in their community in which they observed and learned with local sages and experts. They also searched for information from internet and consulted science teachers before setting up the projects. They then conducted their experiments, collected data, and interpreted results by themselves. The students submitted reports and presented their findings to class. In all these activities teachers encouraged students to undergo various aspects of the scientific practice: asking questions, setting hypotheses, design experiments, identify and control variables, collect and interpret their data. Finally they visited their community again to share their results with agriculturists, local sages, local experts, their parents, and others.

2.3 Research instruments

All participants were assessed for scientific inquiry skills based on the experimental skill test (EST), students’ laboratory reports, students’ science projects, semi-structured interview, and classroom observation.

2.3.1 Experimental skill test (EST)

The experimental skill test is an open-response question consisting of three topics. These tests focused on the basic principles of experimental skill which consisted of four criteria: 1) asking questions and setting hypotheses; 2) identifying and controlling variables; 3) designing experiments; and 4) planning data collection (Dirks &
The overall scores were 36 points with the maximum of three points for each criterion. The test had been verified by three experts. The reliability test on one hundred students was estimated by SPSS for Window version 11.0 to be 0.89. The difficulty value was 0.59-0.70 and the discrimination index was 0.40-0.56. The experimental skill test was analyzed by using the scoring rubric adapted from Dirks and Cunningham (2006).

2.3.2 Students’ laboratory reports

Students’ laboratory reports were evaluated by a scoring rubric adapted from Merced Country Office of Education (2006). This rubric consisted of five main criteria: 1) hypothesis; 2) procedure; 3) results; 4) discussion and conclusion; and 5) knowledge transfer to community. The overall scores were 20 points with the maximum of four points for each criterion.

2.3.3 Students’ science projects

Students’ science projects were analyzed by using the scoring rubric adapted from Sutherland (2003). This rubric consisted of seven main criteria: 1) hypothesis; 2) experimental design; 3) data analysis; 4) discussion and conclusion; 5) presentation; 6) answering question; and 7) knowledge transfer to community. The overall scores were 35 points, a maximum of five points for each criterion.

2.3.4 Semi-structured interview

The semi-structured interview was used to assess changes in students’ experimental skills. The interviewing questions were as follows: 1) what skills did you acquire from the STS-based learning unit on biological control? And 2) what process skills do you use in everyday life? How? Individual interviews were carried out with 10 volunteer students both before and two weeks after the intervention to allow the students to transfer skills and knowledge to their community. The students’ responses were audiotaped and transcribed.

2.3.5 Classroom observation

Classroom observation was employed to explore the students’ activities both in and out of class. The data was analyzed according to Hammann and co-workers (2008) for the in-depth information on students’ behaviour in the planning and conducting of the experiment with an emphasis on experimental skills. Video and still cameras were used to record the learning process.

2.4 Data analysis

Quantitative data (EST, students’ laboratory reports, and students’ science projects) were analyzed by using the SPSS for Window version 11.0. The qualitative data (semi-structured interview and classroom observation) were analyzed by using a thematic approach.

3. Results

To determine the students’ scientific inquiry ability before and after the intervention, the results from EST, laboratory reports, science projects, semi-structured interview, and classroom observation were utilized to evaluate student self-efficacy. The quantitative data are shown in Tables 1, 2, and 3.

| Variable | Control group | Experimental group |
|----------|---------------|-------------------|
|          | Pre (Mean ± SD) | Post (Mean ± SD) | Pre (Mean ± SD) | Post (Mean ± SD) |
| 1. Pose questions and hypothesis (9) | 2.14 ± 1.24 | 2.57 ± 1.02 | 1.53 ± 1.41 | 7.65 ± 1.75 | t = 3.47 | t = 15.94*** |
| 2. Identify variables (9) | 1.62 ± 1.27 | 2.10 ± 1.27 | 2.18 ± 2.01 | 5.40 ± 1.68 | t = 3.27 | t = 8.17*** |
| 3. Design experiment (9) | 1.31 ± 1.14 | 1.38 ± 1.17 | 1.55 ± 1.38 | 7.15 ± 1.19 | t = 1.14 | t = 17.39*** |
| 4. Collect data (9) | 0.79 ± 1.05 | 0.86 ± 1.05 | 0.98 ± 1.09 | 6.40 ± 1.68 | t = 1.36 | t = 17.63*** |
| Total (36 pts) | 5.86 ± 3.25 | 6.90 ± 3.07 | 6.23 ± 4.35 | 26.60 ± 4.85 |
Table 1 shows a comparison of pre/post administration of the EST between experimental and control groups. These findings showed no significant difference between experimental and control groups in the pre-EST, while in the post-EST both control and experimental groups there was a significance difference ($p<0.001$). For the experimental group, there was a statistically significant increase ($p<0.001$) in post-EST for each item.

Table 2. Evaluation of students’ laboratory reports

| Criteria                                | Mean   | SD     | Quality*       |
|-----------------------------------------|--------|--------|----------------|
| 1. Hypothesis                           | 3.03   | 0.78   | Accomplished   |
| 2. Procedure                            | 3.00   | 0.72   | Accomplished   |
| 3. Results                              | 3.03   | 0.36   | Accomplished   |
| 4. Discussion and conclusion            | 2.05   | 0.64   | Developing     |
| 5. Knowledge transfer to community      | 3.00   | 0.32   | Accomplished   |
| **Total (20)**                          |        |        | 14.10          |
|                                         | **SD** |        | 1.84           |
|                                         | **Quality** |    | Developing     |

*1= beginning, 2= developing, 3 = accomplished, and 4 = exemplary.

The laboratory reports of students in the STS context were evaluated by rubric scoring using the five components. The results showed highest average score was in the hypothesis (3.03) and results (3.03). The lowest score was in the discussion and conclusion (2.05), which indicated that some students drew a conclusion that was not supported by the data and their discussions are not adequate and incomplete.

Table 3. The average scores of the science project report components (Sutherland, 2003)

| Project title                                      | Hypothesis | Experimental design | Data analysis | Discuss & conclusion | Presentation | Answering question | Knowledge transfer | Total (35)* |
|---------------------------------------------------|------------|---------------------|---------------|-----------------------|--------------|--------------------|--------------------|--------------|
| 1. Using yeast to protect anthracnose disease of eggplant. | 4          | 4                   | 4             | 3                     | 5            | 4                  | 3                  | 27           |
| 2. Using T. reesei to control anthracnose disease of tomato. | 4          | 4                   | 4             | 4                     | 5            | 4                  | 4                  | 29           |
| 3. Controlling of anthracnose disease in guava by using S. cerevisae. | 4          | 4                   | 4             | 4                     | 4            | 4                  | 5                  | 29           |
| 4. Using S. cerevisae to control the crown rot of banana. | 4          | 3                   | 3             | 3                     | 4            | 3                  | 4                  | 24           |
| 5. Using the basil and sweet basil to control insect pests. | 3          | 3                   | 3             | 3                     | 4            | 5                  | 5                  | 26           |
| **Total (25)**                                     | **3.80**  | **3.60**            | **3.60**      | **3.40**              | **4.40**     | **4.00**           | **4.20**          | **27.00**    |

*5= very good, 4= good, 3 = fair, 2 = poor, 1 = very poor

The science projects were evaluated by rubric scoring of the seven items. The results in Table 3 showed that most groups had high scores in the presentation component (4.40), knowledge transfer (4.20), and answering questions (4.00). The lowest score was in the discussion and conclusion (3.40). Moreover, the results from semi-structured interview supported the students’ acquisition of scientific inquiry skills. Before intervention, students were confused about independent and dependent variables. They could not set a hypothesis and did not practice the scientific method because they had up to then only learned from lecture. After the intervention, students understood more about scientific inquiry: they could identify and control variables, formulate and test hypotheses, and collect and conclude data by themselves.

The first interview question focused on the students’ scientific inquiry skills acquired in their learning. It was found that almost all students understood the process of scientific inquiry. Excerpts from the students are as follows:
“After this unit, I could design and conduct experiments for my science project. I formulated my hypothesis based on the problem. I could also identify and control variables.”

“I could set problems to conduct science project. I understood why we have to conduct the experiment. After I observed the plants in the field, I knew how to solve the problems.”

The second question focused on the students’ ability to transfer scientific inquiry skills to their daily life and community. Examples of students’ statements are as follows:

“I bring this skill to identify the problems in my community. When I know exactly what the problem is, I can find the way to solve it.”

“I can exploit the skills in various ways such as solving the waste problems and solving the agricultural problems.”

The results from classroom observation showed that in the first period of learning students could not use the tools for conducting their experiments. Some groups could not even design their experiment. They did not comprehend such terms as hypothesis, variables, and data collection. Teacher must guide and help them all the time. After finishing the core experiment the students made presentation to the class in which some groups were still very bashful.

Nevertheless, when students conducted their own science projects, they could search for issues and information that they were interested in and design experiments with their peers. Group members helped one another. Some groups formulated and tested hypothesis, identified and controlled variables by themselves, but at times they consulted the teacher about the way to collect and analyze data.

4. Discussion

This research showed that the project was successful in turning students into young scientists and thereby their scientific skills were enhanced. We found that students involved in an STS-based learning unit on biological control had indeed shown significant improvement in scientific inquiry: they could use the process skills to solve problems, ask questions, formulate hypotheses, identify variables, and reach conclusions with their peers. Most importantly they were able to exploit the scientific method to identify and solve agricultural problems in their local community through the science project of their design. Success in promoting scientific skills through the STS approach is in agreement with several other reports. For example, Yager, Choi, Yager, and Akcay (2009) found that students taught with an STS approach had significantly higher science process skills, creativity, attitude, and ability to apply concepts in a new context, when compared to those taught by a directed approach. Dass and Deal (2007) found that students in an STS project gained scientific skills; i.e. taking specific action, designing, conducting and reporting experiments. Additionally, Akcay and Yager (2010) used an STS approach for improving students’ ability to apply major science concepts and process skills in new situations. Students were well able to use the scientific method to conduct their science projects relevant to their community.

The key success in this study is in the activities in the learning unit that encouraged students to learn science process skills that help them think while they were discovering new things scientifically. In the STS classroom, the students were encouraged to identify their local agricultural problems and explore appropriate ways to solve them. They had the opportunity to observe and ask questions about the existing problems with local sages in their community. These activities encouraged students to learn and use scientific inquiry in situations that are close to real life. The findings that the STS approach calls for students to use the scientific method to learn and apply to their community is similar to those of Dass and Deal (2007) who employed STS approach to teach students through environmental projects, and found that students in STS projects could implement original action plan within the local community. Yager, Choi, Yager, and Akcay (2009) reported that science project in STS approach improved students’ ability to solve problems identified in schools and the local communities. In our studies, the students had opportunity to work in the laboratory to practice the experimental skills needed for the subsequent science projects on real agricultural problems in their community. As a result, the students could apply the knowledge learned in designing and conducting the science projects on local problems. The activities in the science project helped promote science inquiry skills for students. They had to ask good questions, formulate hypotheses and design the methodology by themselves, collect and analyze data, discuss and conclude with their peers as scientists do. Results
from evaluation of the science project as well as from classroom observation and semi-structured interview indicated that the students were able to act out the scientific method and possessed scientific inquiry skills. The finding in this study is in accordance with Roth and Roychoudhury (1993) that authentic contexts supported the scientific process skills. We can conclude that STS instruction provides the students with the ability to identify problems, seek scientific knowledge to solve real-life problems, and promote process skills in problem solving, as stated in NSTA (2007).

Most importantly, although some groups' science project results were not promising for lack of experience in handling aseptic technique in biological control experiment, most students could transfer knowledge and ideas (on using biological control instead of chemical methods) to their community, as evidenced from the interview. The results suggested that the students could apply the knowledge learned to help solve problems in their communities. This study offers a guideline for educators and school teachers in adapting and adopting this learning unit for teaching-learning, especially for schools in agricultural area.

5. Conclusion

A learning unit based on the STS approach on solving problems in agricultural society has been shown to enhance students’ scientific inquiry skills. The learning activity that included discussion with local experts in the field trip helped the students to integrate local wisdom with scientific knowledge from the classroom, resulting in students’ abilities to create practical science projects that could actually be used in their local community. The students could apply the scientific method to solve problems in new situations, they used their knowledge and skills to design and conduct useful science projects on their local agricultural problems by themselves. The results revealed that the STS-based learning unit on biological control also supported students’ decision making, communication and problem solving in the real context. The students had meaningful experiences that were relevant to their real life in the community. They could develop new ideas to be utilized in their real-life context rather than just learn to pass tests.

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