Cultivating Problem-solving Ability by Utilizing Scientific Views and Ways of Thinking: Introducing Science Communication into Earthquake Disasters Game

Ayako Mio and Toshiki Matsuda
Graduate School of Decision Science and Technology, Tokyo Institute of Technology, Japan
mio@et.hum.titech.ac.jp and matsuda@et4te.org

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Abstract
In this study, we developed science communication gaming material to cultivate scientific views and ways of thinking about issues concerning daily life. From the perspective of citizens’ science communication, learners’ roles were set as earthquake supporters/tsunami survivors. These learners constituted people who lived in areas neighboring quake-hit ones or far from quake-hit areas. As supporters, these people considered what the quake/tsunami survivors needed and thought about and how to transport materials to them. This experience was meant to prepare learners for natural disasters of this nature and make them aware of what course of action to adopt to survive in these situations. Each supporter, in isolation, cannot do enough to help survivors; however, when supporters communicate with each other, they can support survivors effectively. Consensus formation is part of this communication and is needed to make decisions. By utilizing scientific views and ways of thinking, we believe that consensus formation can be a rational and reasonable process. This material is to be implemented in e-learning courses.

Introduction

Science Literacy for Problem Solving
Science technology, while benefiting humanity, has also created several problems. Although information abounds on the Internet, sometimes, even information provided by the media or government is not accurate. Therefore, all citizens must think, judge, and decide on their own. For this reason, they must acquire and develop science literacy, especially when linked to problem solving in daily life.

There are several terms related to science technology literacy, such as “science literacy,” “scientific literacy,” and so on, as used here. Additionally, the terms “science technology” and “science and technology” should be distinguished. Since our purpose in this study is not to discuss this difference, we will roughly assume a containment relationship between them.
As expanded upon later, our theme is “earthquake disaster education,” which relates to both science and technology. In essence, school education does not address technology education, except for “industrial arts and home economics” in junior high school and “information study” as a common subject in high school. Hence, we will focus on scientific literacy in problem solving; in other words, we focus on better decision-making based on scientific reasoning as the present educational goal.

The current task involves aspects of thinking, judging, and attitude. The objective of science, as a subject, also consists of thinking, judging, and attitude, combined with knowledge, understanding, and skill. Aspects of thinking, judging, and attitude are related to scientific views and ways of thinking and the attitude involved with how to use them, which should be taught in schools as the objective of science education. However, scientific views and ways of thinking are not as clearly defined as they are in mathematics (Hosonoya, 1999). Moreover, some scholars argue that scientific views and ways of thinking do not bring results (Shibue, Y., & Okada, Koichi., 2011).

To focus on the above aspects, the new National Education Guidelines, presented in 2009 and 2010, emphasize the activities of writing reports and making presentations by increasing opportunities for experimentation and observation (Central Council for Education, 2008). In our opinion, while this is an important improvement, it does not provide sufficient opportunities for activities. The curriculum contains few explicit instructions on scientific views and ways of thinking. The important roles among scientific views and ways of thinking are instruction and facilitation.

Relationship with Science Technology Communication

We believe that science communication should be citizen-centered. However, currently, science communication activities focus on scientists explaining science in a “friendly” and “understandable” way for citizens, with scientists playing the main role. If a citizen is expected to think, judge, and make decisions regarding science technology literacy, then science communication should be citizen-centered, and the target of the research should focus on communication among citizens. To make citizens focus on scientific views and ways of thinking, it is important for them to cultivate related knowledge and critically evaluate how they and others think when problems need to be solved.

Purpose

In the National Education Guidelines, the necessity of scientific views and ways of thinking is acknowledged, and it is set as one of the targets of science education; however, it does not achieve results. According to us, this is because there is “less correlation with daily life” and “few explicit instructions on scientific views and ways of thinking.” Therefore, we developed the material for solving these problems. Specifically, by teaching scientific views and ways of thinking, and adapting the material in the syllabus so that it clearly relates to daily life, we can enable learners to adopt this way of thinking for daily problem solving. Since our theme is earthquake disaster prevention education, learners will be given explicit problem-solving questions connected with the situation of earthquake disaster. They must then utilize scientific views and ways of thinking to solve the problem, which cannot be solved directly by research alone.

Scientific Views and Ways of Thinking

The word “science” can be described as “verification, reproducibility, and objectivity.” The procedure for examining these conditions is referred to as “scientific ways.” However, scientific views and ways of thinking do not merely involve procedures but points of view or a checklist when considering target issues from a scientific perspective.

According to Matsuda (2012), scientific views and ways of thinking can be broken down in the form of a checklist. The items on the checklist below were selected from the Matsuda’s checkiset for general problem solving from a scientific perspective to be used as guidelines.
1. Make a hypothesis with cause and effect relationships and determine ways of verification
2. Consider factors when solving the problem
3. Consider the case that does not take into account a certain factor
4. Check through experimentation or observation
5. Consider matters quantitatively
6. Consider consistency with rules or known facts
7. Consider by analogy

“Generating a hypothesis” is important in terms of scientific views and ways of thinking, as indicated by the following two studies: (1) the method for problem solving in developing products and (2) the method in common among three scientific inquiry methods. (1) The generation of a hypothesis is already being used as one of the necessary skills for problem solving in order to develop products like the plan-do-check-act (PDCA) cycle, which identifies cause and effect relationships. The implementation of the PDCA cycle is widely recognized in the scientific world as “kaizen” or “improvement” in Japanese (Watanabe, 2011). (2) Watanabe’s report (2011) compares three scientific inquiry methods and shows “a hypothesis with cause and effect relationships in common among them.” One of three methods is a process for scientific inquiry by R Reiff, Harwood and Phillipson (2002), the second, a process of scientific thinking by Wada (2010), and the other, a process adopted from Klett’s textbook.

**Instructional Methodology**

There are two precedent studies on instructional methodology, and we will now point out the drawbacks of these studies from the viewpoint of instructional methodology for scientific views and ways of thinking.

First, in the study by Magara (1991)—that verifies how to support students by using scientific views and ways of thinking—the author relates a rule of science to a situation in daily life and creates a story, applying the rule to it. He then compares the results with those of a laboratory situation. The results are well verified; however, the application range is limited because the application requires many rules, depending on each case. Tamada and Matsuda (2004) suggest that case studies and rule-based lessons cannot be applied to every situation a student may face and that views and ways of thinking can cover a range of applications, similar to the three types of knowledge for information on moral instruction.

Second, the study “E-portfolio for self-regulated learning” by Sato, Matsuda, and Ishi (2010) develops ideas on teaching views and ways of thinking and successfully supports students’ study of views and ways of thinking. However, it does not deal with scientific views and ways of thinking.

**Theme: Earthquake Disaster Prevention Education**

The primary reason for choosing earthquake disaster prevention education is that the conventional thinking of “experts teach citizens in a way that is easy to understand, and citizens follow this” is not necessarily appropriate. This was based on the so-called Kamaishi Miracle (The Kahoku Shimpo, 2011) at the time of the Tohoku earthquake, and was the impetus for focusing on the cultivation of scientific views and ways of thinking and reconsidering the definition of “science communication.”

We therefore defined the issue: “come up with a proposal for better food and a delivery method thereof for delivering food to disaster-stricken areas.” As a theme, this satisfies various requirements such as “not greatly dependent on the region where one lives”; “helpful not only at the time of disaster but also in reassessing everyday life”; “considers one’s own position by considering other’s position”; “the knowledge already acquired by high-school-level students can be used, but it is also necessary to acquire some new knowledge”; and “rather than by oneself, it is necessary to cooperate with others for better problem resolution.”
We selected a food-related issue for the following reason also: It was suggested that at the time of the Kobe earthquake, situations could have been improved if citizens had a proper understanding of volunteer activities for disasters and supply shortages in evacuation shelters, and prepared daily for them (Matuda, T. and Morikawa, H., 2008).

When undertaking earthquake disaster prevention education, we must consider how to increase the probability that learners will actually face these situations; this is because learners are apt to lose interest in learning if the time and place of a disaster cannot be specified. In addition, the probability of their falling victim to such disasters is low. There is a higher likelihood that they will serve as supporters of the actual victims. By taking the supporters’ role, their motivation can be raised. Moreover through their experience in supporting victims, we expect that they will be able to identify what they themselves would really need if they find themselves in a similar situation.

**Design Principle of the Instructional Materials**

This study aims to teach the importance of scientific views and ways of thinking. Making decisions that are based on private experience as well as scientific reasoning leads to better problem solving when faced with important decisions. In this study, there are no right answers, but learners are required to think using logic and reasoning.

**Subject**

The subject for this material is an undergraduate student for preparatory experience, though the supposed learner is a high school student. The reason for this is that this study aims to cultivate the ability of science literacy for citizens through school education.

Considering the percentage of junior high school students moving to high school at present in Japan, it is not necessary to limit the target to junior high students on the compulsory education stage, as fixed by PISA.

It is suitable to target high school students at present because logical thinking training is important for them, and scientific knowledge related to nutrition and cooking is taught in high school.

**Situation for Learning**

Learners’ roles are set as supporters for earthquake/tsunami survivors. They might live in neighboring areas or far from the earthquake-hit area (Fig. 1).

As the possibility of being supporters is much higher than that of being survivors, it motivates learners.

We also propose that it is useful to make them consider how to prepare for such eventualities in their daily lives and how to survive in such situations, like earthquakes, by themselves.
In order to support them effectively, it is necessary for citizens to cooperate and build consensus. At this time, they will be required to utilize scientific views and ways of thinking to arrive at more persuasive suggestions (Fig. 2).

Framework of the Material
The framework of the material is based on the gaming material for information education (Matsuda, Hirabayashi, & Tamada, 2012). This framework responds to that of problem-based instruction (Savery, 2009). Further, Matsuda (2012) suggests that this framework can be used as the basic framework for all gaming material. There are several steps involved in this framework. Each step consists of explicit problem-solving questions that are connected with the situation of an earthquake disaster. Scientific views and ways of thinking are used as the viewpoints for problem solving. An evaluation list with four grades was also prepared to check the level in the debriefing step.

The framework comprises the following five steps.

1. Goal setting
2. Technical understanding
3. Rational judgment
4. Derivation of optimized solutions
5. Debriefing

Outline of Material
1. Goal Setting: In this stage, the task is presented (Figs. 3 and 4), and a situation with explicit problem-solving questions is given, considering the factor of “best support.” Learners are encouraged to use scientific views and ways of thinking in the form of analogical thinking and reasoning to solve the problem.

2. Technical Understanding: The learner is given a situation whereby he/she has to consider the task based on quantification and data. Learners are encouraged to use scientific views and ways of thinking. There are only two food selections—rice and cup noodles—and learners are required to compare them from a quantitative point of view.

3. Rational Judgment: The learners are given a situation and asked to evaluate several possibilities in terms of “beyond imagination” or “the risks of making errors,” and consider how to respond to and deal with this situation. Learners are encouraged to consider the issues critically.

4. Derivation of Optimized Solutions: Through the above steps, learners are asked to use reasoning and arrive at a consensus about the final answer.
5. Debriefing: The learners have to self-evaluate the problem-solving activities based on their written records of the activities. They are also asked to evaluate others’ activities. In this way, the learners are able to reflect upon, consider how they can best be prepared for, and survive in this situation in their daily lives.

**Task**

You will consider how to support survivors when the earthquake occurs.

Please read the following situation and consider how to deliver the food to the quake-hit area.

A big earthquake has occurred with an intensity of 7 on the Japanese seismic scale in area A. You want to send the food to the survivors for support. At this moment, there is no information about the quake-hit area, so you do not know what they need or what they have.

Fig. 3 Task Description

**Lesson 1**

You will determine the goal: “what is the better* solution”. It is important to consider by focusing on various “goodness” when solving the problem.

First, consider “what is the better support” for better decision.

Please write down “the better support” in order to attain the goal of “delivering food as support” as much as possible.

* you are seeking for the better for improvement not necessary to be the best.

1. Ex. To keep well (Better preservation)

Fig. 4 Description of Lesson 1

**Preparatory Experiment: Results and Considerations**

Dialogical. 1 facilitator, two participants (college students). Time required: 30 minutes.

**Results**

1. Although learners were able to come up with many factors for “best support” using reasoning with analogical thinking and brainstorming, these factors were not comprehensive without the use of scientific views and ways of thinking.

2. Facilitation is needed for learners when making quantitative comparisons.

   The aim of the task was to quantitatively compare the merits between rice and cup noodles. However, learners concentrated on “the lack of water” and focused on a solution wherein water was in short supply. They did not focus on a quantitative comparison. Therefore, this task needed to be facilitated so that students would consider a hypothesis both with water and without it.
3. “Unexpected issues” like the garbage generated after eating the food selected in the rational judgment part of the task brought about other viewpoints, enabling the learners to consider the problem and its solution.

4. This experiment ends with rational judgment; however, we were unable to complete the last step, “debriefing”, due to time constraints.

Considerations
Learners were able to use analogical thinking or reasoning naturally, without reference to scientific views and ways of thinking. They were familiar with brainstorming and critical thinking and tended to enjoy brushing up on their thinking abilities.

Facilitation was required for quantification and rational judgment. The evaluation standard was then changed based on these findings.

In this study, the number of subjects was small, and it is necessary to increase this number in order to check when and how to introduce scientific views and ways of thinking in each of the abovementioned steps.

Conclusions and Future Work
In order to encourage learners to think, judge, and make decisions in a given situation with the information offered—which is not always accurate—we designed and developed instructional material to encourage learners to use scientific views and ways of thinking to solve problems.

By way of future work, we will make this material available online, on the instructional activities game (IAG) system. This will be developed based on our gaming material on information education, the framework of which works on the same design principles. We also plan to conduct trial sessions at both the high school affiliated with the Tokyo Institute of Technology and a public lower secondary school.
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