An Assessment of Civic Scientific Literacy and Its Long-term Formation

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An Assessment of Civic Scientific Literacy and Its Long-term Formation

市民的科学的リテラシーの評価と

その長期的形成に関する研究

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The Abbreviations for the Technical Terms in this Dissertation

Abbreviation	Explanation
ACSEL	Assessment of Civic Scientific Literacy
CSL	Civic Scientific Literacy
ESI	Explaining Scientific Inquiry
GE	Greenhouse Effect
GMO	Genetically Modified Organisms
MD	Making Decisions
SLASH	Science Learning Aids for Students in a Humanities track
SLC	Smoking and Lung Cancer
USE	Using Scientific Evidence

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Chapter 1. A Field to Be Pioneered in Civic Scientific Literacy Study

1.1. Civic Scientific Literacy in Trans-science Era

1.1.1. Science in the society.

In our modern society, we cannot ignore the existence of science and technology. The advance of the iPS cell research has brought large possibilities for the field of the regenerative medicine. The GPS systems using satellite communication has enabled us to easily know our location. Now we can easily reach our destination even in a strange place only with a smartphone.

Behind the development of science and technology, however, its negative influence has gradually started to be recognized over this 70 years. Nuclear weapons used in WWII in *Hiroshima* and *Nagasaki* in 1945 triggered the discussion of whether to promote scientific discovery and technological invention. After this, a biologist Rachael Carson in the early 1960s warned in her book titled *Silent Spring* about the dangers of chemical substances such as pesticides. Also, in Japan, the four major pollution problems (Itai-itai disease, Minamata disease, Niigata Minamata disease, and Yokkaichi Asthma) got our attention during the high economic growth periods from the latter half of the 1950s to the 1970s. Around 1990 in Britain, over 100 people who ate cattle with *Bovine Spongiform Encephalopathy* (BSE) got infected, while the expert committee submitted a report stating that an infection was unlikely to happen. On 11th March, 2011, an unprecedented catastrophe called *Great East Japan Earthquake* hit Japan. The *Fukushima Daiichi Nuclear Power Plant* accident caused by this earthquake still plagues the victims.

Those incidents directed our eyes towards dark sides of science and technology. In response to this, we have begun to recognize the need to discuss science and technology in our society and how to accept them, instead of uncritically accepting them. The *Budapest Declaration* in 1999 has been meaningful in that it represented the idea of *Science in the Society*. Influenced by these dark sides of science and technology, political topics involving them have started to increase since the 1970s (Durant, Evans, & Thomas, 1989; Shen, 1975). Shen (1975) pointed out that the number of science-related issues—health, energy, natural resources, transportation, etc.—amounted to over 50% of legislative bills in the Congress in the U.S.

1.1.2. Arrival of the trans-science era.

This situation gradually emerged a new relationship between science and politics. In 1972, Alvin Weinberg, an American nuclear physicist, pointed out the limitation of scientific knowledge or scientists toward solving type of issues called "trans-scientific" questions. Trans-scientific questions are different from scientific questions in that they cannot be answered by science while they can be asked of science (Weinberg, 1972). See Figure 1-1. In order to explain trans-scientific questions, Weinberg used nuclear reactors as an example.

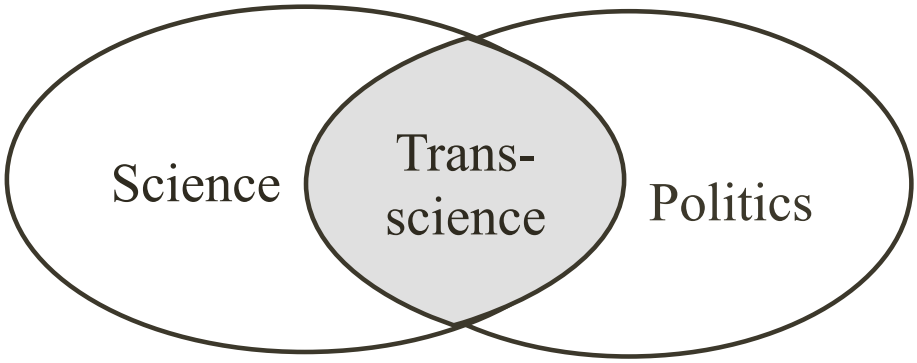


Figure 1-1. Science and Trans-science
(Kobayashi, 2007, p.123)

There is no disagreement in the opinion among experts for that if all safety devices of a nuclear power plant in operation were to fail at the same time, a serious catastrophe would happen. This belongs to "scientific" question since science alone can answer this question. On the other hand, the question of whether all the safety devices can ever fail simultaneously is a "trans-scientific" question since we cannot expect agreement among scientists for it. Therefore, science itself does not provide clear answer for whether or not we should operate nuclear power plants. Also, genetically modified organisms (GMO) are often seen to include trans-scientific aspects (e.g., Hirakawa, 2012; Mitsuishi, 2011). This is because scientific findings for the risk of GMO include "uncertainty." For example, it is unknown whether a GMO does not have any risk for human being or other ecosystems in a longtime view. However, we have to decide how to treat GMO in our society under such situation. The resolution on trans-scientific questions is not obtained from science only but requires non-scientific mechanisms (Weinberg, 1972). Weinberg (1972) insisted that citizens need to

participate in democratic discussions for making decisions on such trans-scientific questions.

1.1.3. Towards civic scientific literacy.

This situation is promoting the neccesity of communication between scientists and the general public. These movements have become active since the second half of the 20th century. They have promoted *science communication* activities in Japan since 2005 and lots of activities including *science cafes* have been held. Under such circumstances, a notion of *scientific literacy* has gained importance.

Tanaka (2006) viewed scientific literacy as a basic requirement to establish communication between science, technology, and society. Todayama (2011) and Suzuki (2014) also insisted that citizens need scientific literacy because they cannot leave decision-making on trans-scientific questions only to scientists. This is why citizens living in the trans-science era are required to equip themselves with scientific literacy. In this dissertation, the author will refer to scientific literacy necessary for citizens in the trans-science era to participate in discussions dealing with science-related topics including trans-scientific questions as *civic scientific literacy* (CSL) as Shen (1975) proposed, in order to distinguish it from general scientific literacy.

In the present time, we have to pay attention to nurturing informed reflective citizens (OECD, 2006, p.72) with CSL who can effectively join in public science-related discussions. It is necessary not only for some scientists but also for society as a whole, and each individual, to be interested in science and technology to participate in such public discussions. Providing citizens with CSL is one of the most important roles expected for modern science education. Then, what kind of CSL is needed? To clarify the concrete competencies to be included in CSL, let us review literatures on scientific literacy.

1.2. Transition of Scientific Literacy Theory

The beginnings of the word scientific literacy date back to the 1950s America (Hurd, 1958). In the U.S. of the day, finding the eggs of leading scientists who would lead the nation was the most urgent duty in science education. As a result, many children gave up science learning. For such *Science for Excellence* trends, scientific literacy stands for the idea of *Science for All*.

In an early literature review, Pella, O'hearn, & Gale (1966) concluded that the scientifically literate individual is characterized as one with an understanding of the (1) interrelationships of science and society; (2) ethics that control the scientist in his work; (3) nature of science; (4) difference between science and technology; (5) basic concepts in science; and (6) interrelationships of science and the humanities. Similarly, Shen (1975) categorized scientific literacy into three parts: practical scientific literacy, civic scientific literacy, and cultural scientific literacy.

- *Practical scientific literacy* is scientific knowledge that can be applied to help solve practical problems.
- *Civic scientific literacy* enables a citizen to become more aware of science and science-related issues so that he and his representatives would not shy away from bringing their common sense to bear upon such issues and thus participate more fully in the democratic processes of an increasing technological society.
- *Cultural scientific literacy* is an appreciation of science as a major human achievement, arguably the greatest achievement of our culture.

  (Burns, O'Connor, & Stocklmayer, 2003, p.187)

While practical and cultural scientific literacy are oriented towards individual life, civic scientific literacy views social life. According to Shen, with civic scientific literacy, citizens can "become more aware of science and science-related issues" and "participate more fully in the democratic process of an increasingly technological society" (p.48). Miller, who has conducted surveys since the 1980s in the U.S., developed a tool based on the framework of civic scientific literacy as proposed by Shen. He indicated three dimensions under civic scientific literacy (Miller, 1998, p.205).

1. a vocabulary of basic scientific constructs sufficient to read competing views in a newspaper or magazine (content)
2. an understanding of the process or nature of scientific inquiry (process)
3. some level of understanding of the impact of science and technology on individuals and society (social factors)

While Miller's view of scientific literacy emphasized the importance of vocabulary and understanding of scientific process to read and comprehend science-related articles, recently researchers insisted the importance of the use of scientific knowledge or process to everyday life.

There are two globally well-known definitions. Firstly, the AAAS has described a scientific literate person as "one who … uses scientific knowledge and scientific ways of thinking for individual and social purposes (AAAS, 1989, p.4)." Secondly, scientific literacy in PISA is defined as "the capacity to use scientific knowledge, to identify questions and to draw evidence-based conclusions in order to understand and help make decisions about the natural world and the changes made to it through human activity (OECD, 1999, p.60; OECD, 2009, p.7)." It is noticeable that these definitions have stressed the importance of making use of scientific knowledge and skills in personal and social contexts to make decisions on science-related issues based on evidence or information. Burns et al. (2003) described this transition as "moving from the ability to read and comprehend science-related articles to its present emphasis on understanding and applying scientific principles to everyday life" (p.187).

In addition, although these definitions did not recognize decision-making ability as a competency of scientific literacy, recent definitions tend to include it (Kusumi, 2011; Twenty First Century Science, n.d.). For instance, *Twenty First Century Science* (n.d.) in the U.K. stated that a scientifically literate person should be able to:

1. appreciate and understand the impact of science and technology on everyday life;
2. take informed personal decisions about things that involve science, such as health, diet, use of energy resources;
3. read and understand the essential points of media reports about matters that involve science;
4. reflect critically on the information included in, and (often more important) omitted from such reports; and
5. take part confidently in discussions with others about issues involving science

All five elements emphasize the situation where citizens will encounter in their real-life and society. Especially, the second one stresses decision-making ability as an element of scientific literacy. For decision-making ability, Todayama (2011) cautioned that reliable scientific knowledge for trans-scientific issues is often unavailable, because of uncertainty or financial, time, and social constraints. So according to him, citizens need to propose multifaceted framing with respect to society, politics, ethics, responsibility, and credibility, while respecting scientific knowledge.

Moreover, recently, some researchers have proposed other elements. For instance, Choi, Lee, Shin, Kim, & Krajcik (2011) included metacognition, which

enables people to recognize when they need additional information. Lin (2014) insisted that a scientifically literate person should be able to engage and critique science news reports about socio-scientific issues from a variety of information sources. Furthermore, rather than focusing only on the cognitive aspects described thus far, attitudinal aspects such as habit of mind, critical attitude, individual responsibility, character and value, and attitude toward science were included as elements of scientific literacy by some researchers (e.g., Blanco-López, España-Ramos, González-García, & Franco-Marisc, 2015; Choi et al., 2011; Chang & Chiu, 2005; OECD, 2007).

1.3. Civic Scientific Literacy in Trans-science Era

Then, let us exemplify CSL. The author is going straight to the point, the following competencies belonging to cognitive domain are considered to be required though not sufficient. Attitudinal domains were excluded from here because of the intention to separate it from cognitive domain.

a Knowledge of basic scientific vocabulary

b Understanding of the relationship between scientific evidence and conclusion

c Knowledge of scientific inquiry

d Decision-making

First of all, citizens need basic scientific knowledge to understand what scientists say in the communication. It would be almost impossible to understand the discussion of genetically modified organisms without knowing the meaning of the term "genetics." Secondly, without understanding the relationship between scientific evidence and conclusion, we cannot distinguish trans-science from science. In that case, we might over trust science and leave trans-scientific questions on the hands of scientist. To avoid this, we should have some knowledge of scientific inquiry that produces scientific evidence. Finally, citizens need to make decisions on trans-scientific questions based on multiple information not limited to but including scientific knowledge and skills. They are not the all competencies required for citizens in trans-science era, but can be considered necessary. In this study, CSL is considered to embrace the above four competencies and defined as "the ability to understand socio-scientific or trans-scientific issues related to science and technology based on scientific knowledge and skills and to make informed decisions in order to fully participate in a democratic society."

1.4. Scientific Literacy Survey

Scientific literacy in general has been assessed with a variety of assessment tools in the past few decades in response to the transition of definitions. Hereafter, we will focus on the large-scale survey on scientific literacy for children and adults respectively to examine whether four competencies of CSL proposed above have been sufficiently assessed as far.

1.4.1. Children.

There are two internationally well-known investigations for school aged children: *Trends in International Mathematics and Science Study* (TIMSS) and the *Programme for International Student Assessment* (PISA). TIMSS focuses on 10- and 14-year-old children's scientific knowledge to a greater extent than does PISA. For example, students are asked to answer "how long does it take for the earth to roll on its axis?" TIMSS attempts to assess whether students master what their teachers have taught in the science class. It has been revealed that participating Japanese students showed the top-level ability in TIMSS implemented as far.

On the other hand, PISA assesses 15-year-old students' ability to use scientific knowledge and skills in the life situation. For instance, participating students are required to criticize the scientific claim of the effect of carbon dioxide on global warming based on the graphic data. Similarly, Japanese school children have shown the world top-class science ability in PISA as well as in TIMSS. As one of the big influences PISA brought to the Japanese educational sphere, the MEXT has decided to incorporate similar questions in the *National Achievement Test* for sixth and ninth graders since 2007.

1.4.2. Adults.

While TIMSS and PISA focus on youth's scientific literacy, the *Oxford Scales* developed by Miller has been used to investigate adult scientific knowledge since the 1980s (in Stocklmayer & Bryant, 2012), which is now used internationally including the U.S. (National Science Board, 2000), the U.K. (Durant, Evans, & Thomas, 1989), some European countries (European Commission, 2001), and Japan (Kuriyama, Sekiguchi, Otake, & Chagawa, 2011; Okamoto, Niwa, Shimizu, & Sugiman, 2001). As a result, Miller's view of scientific literacy has been located in the center of adult' or

public scientific literacy.

His measurement scale includes questions such as whether the Earth goes round the Sun. The impact of this survey was very significant. In Britain, the survey results fueled the *public understanding of science* movement (Stocklmayer & Bryant, 2012). In Japan, too, results of an international survey using the Oxford Scales produced a large shock, when Japan was ranked 13th out of 14 participating countries in 2001 (Okamoto et al., 2001). This was despite Japanese children consistently showing their world-top class scientific literacy through TIMSS and PISA. It implies that we should not estimate adults' scientific literacy level from current children's ability measures. This result has been used to give a basis for the necessity of science communication in Japan (Kobayashi, 2007). In 2009, Japan, the U.K. and the U.S. participated in the subsequent international comparative survey by the Internet for adults over 20 years old. The results indicated that the basic understanding of science and technology of Japanese adults is statistically significantly lower than one in the U.K. and the U.S. (Kuriyama et al., 2011)

1.4.3. Narrow scope of adults' survey.

Against this long and wide use of the Oxford Scales, Roberts (2007) criticized Miller's measurement for its narrow scope. He employed two categories, *Vision I* and *Vision II*, to view scientific literacy. Vision I is obtained "by looking inward at the canon of orthodox natural science, that is, the products and process of science itself", while Vision II "derives its meaning from the character of situations with a scientific components, situations that students are likely to encounter as citizens"(p.730). In the context of these categories, scientific contents and process themselves are close to Vision I, while critical reading of scientific data in the newspaper or decision-making on socio-scientific issues would be more related to Vision II. Using these categories, Roberts criticized that Miller's measurement was based on Vision I, though initially it was planned to embrace Vision II as well (Roberts, 2007). In fact, Miller's third dimension (some level of understanding of the impact of science and technology on individuals and society) seems to belong to Vision II, but this is excluded from current international survey using Oxford Scales.

This means that assessment of CSL for adults has not been well developed, while theoretically it was already mentioned few decades ago. A lack of recorded usage of Vision II will make it difficult to understand how citizens are prepared to discuss

science-related issues in a democratic society, where citizens are required to make their own decisions based on their knowledge, beliefs and experience. This criticism made by Roberts is important here because as the author mentioned in section 1.1., citizens are required to participate in science-related issues in trans-science era. Referring competencies in CSL in section 1.3., the competency *a* is assessed both for children and adults; the competency *b* and *c* are assessed for children in PISA but not for adults. In addition, even PISA does not include items for decision-making ability (Matsushita, 2011). The reason might be that PISA only targets 15-year-old children and these children do not presumably face situations in which they have to make decisions on science-related issues. So the competency *d* is not assessed both for children and adults.

Therefore, it is hard to say that the actual situation of CSL of adults has been assessed sufficiently. It is necessary for us to make a new instrument that can assess CSL embracing Vision II for adults with looking at the uncovered aspects discussed above—the competency b, c, and d. Also, as a matter of course, how to improve these competeicies has not been fully examined yet. Without these perspectives, it would be difficult to educate citizens who can effectively participate in current society involving trans-scientific questions. This study aims to solve such problems with an educational approach.

1.5. Research Questions

Based on the problem described above, this study set six research questions to be answered through this dissertation.

1) What is the current situation of adults' CSL in Japan? (Chapter 2)
2) Does a new instrument (ACSEL) satisfy allowable level of the reliability and validity? (Chapter 2)
3) What demographic factors influence CSL? (Chapter 2)
4) Do nature of science teaching, interest in science at high school level, and scientific knowledge determine CSL? (Chapter 3)
5) What are promising and feasible approaches to increase interest in science? (Chapter 4)
6) To whom are the new learning aids (SLASH) effective in order to change the belief in the relevance of science, one of the key factors to increase interest in science? (Chapter 5)

1.6. Dissertation Organization

Following this introductory chapter, Chapter 2 depicts how a new assessment tool (ACSEL) was developed to see unassessed competencies of CSL of adults—*Using Scientific Evidence* (USE), *Explaining Scientific Inquiry* (ESI), and *Making Decisions* (MD). Using data from adult participants, the reliability and validity of ACSEL are examined. This chapter also explores the effects of demographic variables (gender, age, and educational background) on CSL in ACSEL. In Chapter 4, in order to see the long-term impact of school science education on CSL, the effects of nature of science teaching, interest in science at high school level, and scientific knowledge on adults' CSL are examined. It is expected to obtain practical suggestions for how to enhance the MD competency, a weak competency of CSL revealed in Chapter 2. Chapter 5 concerns how to improve interest in science to enhance the MD competency. Based on the findings obtained from Chapter 4, Chapter 5 employs an action research to positively change the belief in the relevance of science, one of the significant determinants to heighten interest in science of high school students. It is reported to whom the developed learning aids (SLASH) was effective. The last chapter presents the answers for each research question and implications for future research. This chapter concludes this Ph.D. study. The following figure shows the organization of this dissertation as a whole (Figure 1-2).

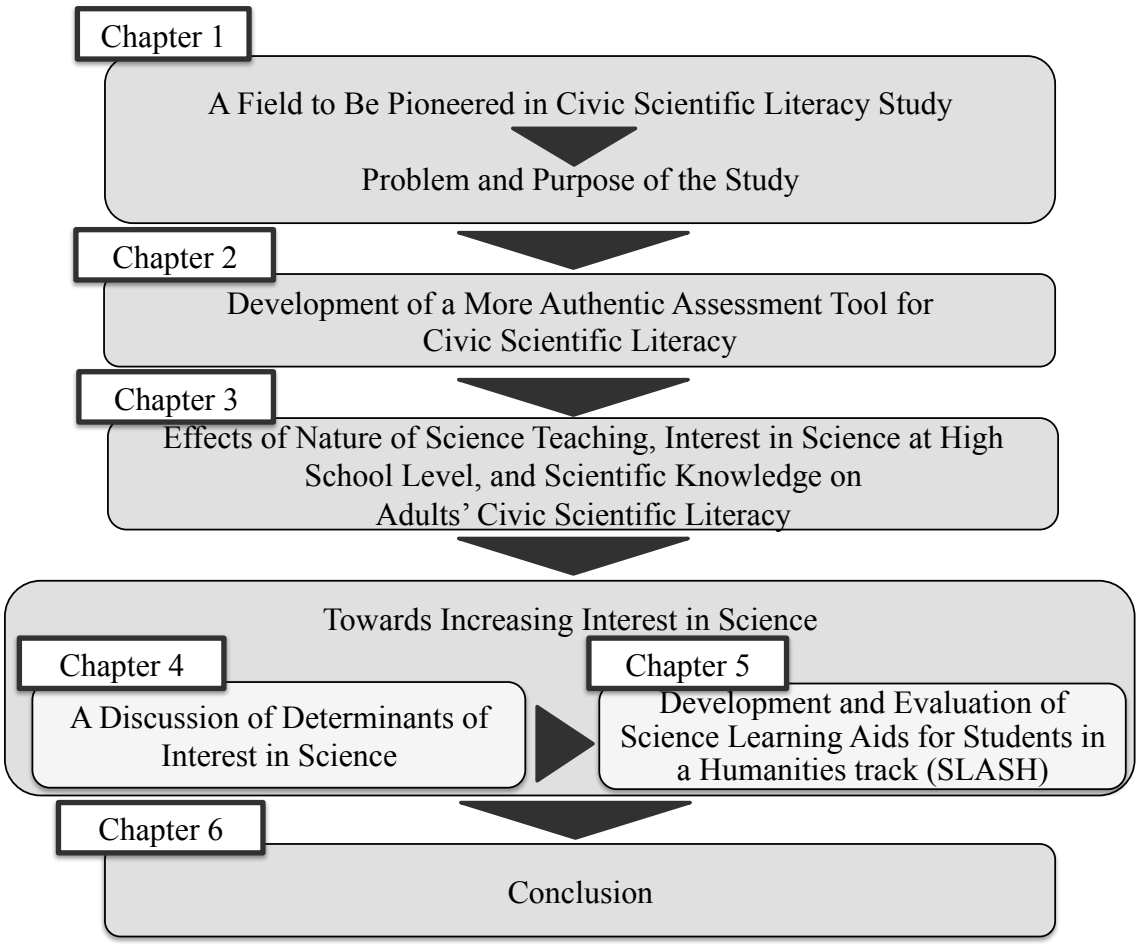


Figure 1-2. Dissertation organization.

Chapter 2. Development of a More Authentic Assessment Tool for Civic Scientific Literacy

In this chapter, the author depicted the process of developing a new assessment tool, ACSEL, examined the reliability and validity of ACSEL, and reported the results from 401 Japanese citizens (66.6% female; ages 20-69) for the three competencies assessed in ACSEL: *Using Scientific Evidence*, *Explaining Scientific Inquiry*, and *Making Decisions*. Further, it was examined whether demographic variables (gender, age, and educational background) would influence the *civic scientific literacy* (CSL). The results show that ACSEL had reliability and validity to some extent. Also, it was revealed that Japanese citizens were less able to make their decisions on trans-science issues with multiple objective information. Moreover, educational background influenced the ESI competency slightly while the other variable did not statistically influence CSL.

2.1. Introduction

In the previous chapter, a historical overview of scientific literacy was offered. Then, criticism by Roberts (2007) towards the scope of Millers' Oxford Scales was mentioned. The author concluded that some competencies to be included in CSL had not been assessed, while theoretically this term was already mentioned few decades ago by Shen (1975). A lack of recorded usage of CSL will make it difficult to understand how citizens are prepared to discuss trans-scientific issues in a democratic society, where citizens are required to make their own decisions based on their knowledge, beliefs and experience. Therefore, it is necessary for us to make a new instrument with an acceptable reliability and validity that can assess CSL for adults while covering the aspects described in the previous chapter. It is also rather significant to grasp the trend of adults' response and find contributions to their CSL.

While the idea of assessing scientific literacy may seem to be inclined to the "deficit model" in the context of science communication, the author takes a view that even in the "dialogue model", understanding and improving public scientific literacy will make conversation between scientists and citizens easier and meaningful (Fujikaki & Hirono, 2008; Tanaka, 2006). In fact, Miyake & Norman (1979) argued that it takes considerable domain-specific knowledge to ask good questions in the context of cognitive science. Based on their research finding, in the dialogue between scientists

and citizens, it can occur that citizens with insufficient CSL cannot understand what scientists say and they cannot ask a question, which will lead to poor communication.

Therefore, in this chapter, the author describes the development of a new instrument (ACSEL) and analyzes the collected data to identify possible determinants of adults' CSL with regard to their demographic variables. A total of 460 Japanese general citizens over 20 years old participated in this study via an Internet Research System. First of all, the reliability and validity of ACSEL were examined in order to confirm whether it can be practically used or not. Secondly, the author reported the responses of those who participated for each item. Finally, the individual contributions of gender, age, and educational background as a potential determinant of CSL were investigated.

2.2. Development of ACSEL

In this study, the author focuses on three competencies—*Using Scientific Evidence* (USE), *Explaining Scientific Inquiry* (ESI), and *Making Decisions* (MD)—in response to uncovered competencies (b, c, d) in section 1.3. It has become a significant issue to provide an instrument capable of assessing these competencies in CSL of adults.

2.2.1. Using scientific evidence.

The importance of this competency has been emphasized in PISA surveys (OECD, 2007). In media such as newspapers or television, we see a lot of scientific evidence in the form of graphs or tables. A scientifically literate person should not only know the features of such scientific evidence, but also use and criticize it appropriately. The author prepared items to assess the following sub-competencies.

- Draws conclusions from scientific data
- Criticizes scientific claims based on given data
- States expected data to verify hypothesis

2.2.2. Explaining scientific inquiry.

Without comprehension of scientific inquiry, which produces scientific evidence, people might overvalue the capability or outcomes of science, although science has its own limitations. Here, the author used the following three sub-competencies to assess participants' ability to explain scientific inquiry.

- Explains the design of the control group in experiments
- States the limitations society have on scientific inquiry
- Criticizes provided information with regard to causality

2.2.3. Making decisions based on objective information.

For trans-scientific questions, we cannot leave the solution as a responsibility of scientist (Weinberg, 1972). We have to refer scientific claims and take informed decisions on such questions in a democratic process (Ikeuchi, 2014; Todayama, 2011). In order to make decisions, we have to frame the question from various perspectives: society, economics, ethics, etc.

- States own standpoint for trans-scientific issues based on multiple objective information from science, economics, politics, ethics and so on

2.2.4. Development process.

In order to assess the three aforementioned competencies, the author referred to the idea of an *authentic assessment* approach, where tasks are used that are replicas of the kinds of problems faced by adult and consumers or professionals in this field or analogous to those problems (Wiggins, 1989; Wiggins & McTighe, 2005). This approach was adopted since it is compatible with assessing ability to use learned knowledge. So PISA has adopted this approach (Tanaka, 2008). In this approach, "authentic" context plays an important role.

Based on the assumption of this approach, the author firstly prepared three contexts: environmental quality, health, and the frontiers of science and technology. They are three of PISA's five contexts: health, natural resources, environmental quality, hazards, and the frontier of science and technology (OECD, 2007). *Greenhouse Effect* (GE), *Smoking and Lung Cancer* (SLC), and *Genetically Modified Organisms* (GMO) were chosen as representatives for environmental quality, health, and frontiers of science and technology, respectively. These contexts were selected since they were considered to be trans-scientific questions and to include scientific aspects. The contexts of GE and GMO present the uncertainty of scientific knowledge, whereas SLC deals with the situation where it is almost impossible to collect reliable scientific evidence by following the scientific process. Constructed-response questions were adopted since participants are less likely to guess correct answer than in using multiple-choice questions. Responses from participants were scored using a scoring rubric and three assessors in order to reduce scoring bias (see subsection 2.4.2. for the rubric development process).

In total, ten items were developed to assess the three competencies described above. For each competency and context, three or four questions were used. Two

Table 2-1

Origin of Each Item

	Greenhouse Effect	Smoking and Lung Cancer	Genetically Modified Organisms
Q1	PISA	New	New
Q2	PISA	New	New
Q3	New	New	New
Q4	n.a.	New	n.a.

Note. PISA: Released item used in PISA 2006 (OECD, 2007, pp. 108-111), New: Newly developed item in this study

released items from the PISA 2006 study were used since their validity has already been examined through professional refinement (OECD, 2007). The other eight items were newly developed for this study (Table 2-1).

After developing a draft of instrument, the author had it checked with two professionals with specialty in educational assessment and science education respectively. A pilot study with 10 graduate students from various majors including humanities, social sciences and natural sciences was followed to check whether the draft instrument contained any unclear expressions. In addition, they were required to judge whether the expected competencies were well reflected. Through these processes, the instrument was refined and named *Assessment of Civic Scientific Literacy* (ACSEL). Developed tasks and rubrics are attached in Appendix A, B, C, and D.

2.3. Purpose

The following three questions guided this study:

1) Does ACSEL show acceptable levels of reliability and validity?
2) What is the overall CSL level of Japanese citizens?
3) Is there any significant difference in the CSL level of Japanese citizens based on their:
   a. Gender
   b. Age
   c. Educational background?

2.4. Methods

2.4.1. Procedure and participants.

Data was collected from those who had registered in an Internet Research System in Japan called *Nikkei Research*. This Internet Research company was selected since it was used in the national survey by the government agency in 2009 (Kuriyama, Sekiguchi, Otake, & Chagawa, 2011).

460 people participated in this survey in December 2015, and data from 401 participants were used in the actual study after excluding 59 insufficient responses. The sample consisted of 134 men and 267 women. Their ages ranged from 20 to 69. At least 50 participants were collected from every generation, although there were more female participants in the study who were either in their 20s or 60s (Table 2-2). It is generally documented that there is a tendency for more women and people with higher educational background to participate in Internet Research (Kuriyama et al., 2011). The sample of this study also indicated a similar tendency. Participants were assured that their responses would be kept confidential. In addition, they would not be connected to their names or e-mail addresses, and would only be used for academic purposes.

Table 2-2

Distribution of Gender and Age among Participants

	20s	30s	40s	50s	60s	Total
Male	19	23	33	26	33	134
Female	104	32	32	31	68	267
Total	123	55	57	57	101	401

2.4.2. Scoring.

All collected responses were organized into spreadsheets. To score the open responses, the author developed scoring rubrics. In order to develop the rubrics, the author referred to a process suggested by Matsushita (2007). At first, the author made draft rubrics. Then, three scorers, who were studying educational assessment in the graduate school including the author, scored 20 samples separately using the draft rubrics. The descriptors were continuously refined when scores did not match. After this modification and calibration process, the author added some words to the rubrics description and attached several anchoring samples to refer to. After scoring, the intraclass correlation was calculated to check if all three assessors could reach an

acceptable level of agreement (inter-rater reliability). Then, the median of three scores was used as the final score for each response.

2.4.3. Reliability and validity.

Reliability.

This study focused on internal consistency and inter-rater reliability as indicators of reliability.

Internal consistency.

Internal consistency is a measure of what extent the items on a test measure the same construct. Cronbach's α was used for this indicator in this study.

Inter-rater reliability.

Intraclass correlation (ICC) is a measure of how raters reach an absolute or relative agreement on the score for each item. There are two kinds of ICC which can be used for this study: ICC (2,1), ICC (3,1). In general, ICC (2,1) is used to check absolute correspondence among raters' scores while ICC (3,1) is used to check relative correspondence among them. Since it was revealed that one rater tended to score severely while another rater scored generously, the author used ICC (3,1) as the indicator of ICC in this study.

Validity.

Face validity and content validity were examined for this study as indicators of validity of ACSEL.

Face validity.

Face validity refers to the extent to which items appear to assess the desired construct (OECD, 2013, p.13). For this study, face validity was checked by two professionals' and 10 graduate students' check.

Content validity.

Content validity refers to the extent to which all items are measuring the assessment instrument adequately the contents and competency of the domain of interest (OECD, 2013, p.13). In this study, the author asked two professionals with specialty in educational assessment and science education respectively to judge whether developed instrument satisfies content validity or not.

2.4.4. Selection of possible contributors.

Existing researches have revealed some variables that affect scientific literacy, although meaning and indicators of scientific literacy differs in each study (Garner-O'Neale,

Maughan, & Ogunkola, 2013; Miller, 2002; 2012; Lin, 2014). Using the Oxford Scales, Miller (2002, 2012) indicates that number of college science courses, gender and age influenced scientific knowledge. Similarly, Garner-O'Neale et al. (2013) suggested that female students in university score lower than male students on understanding of the nature of science. Also, Lin (2014) examined the differences between science and non-science undergraduate students' ability to read and critique socio-scientific news reports. The result revealed that undergraduate science or applied science majors show higher performance than non-science majors do.

Based on these research findings, the author hypothesized that "gender," "age," and "educational background" would influence adults' CSL.

2.5. Results

2.5.1. Reliability and validity.

Reliability.

Internal consistency.

Cronbach's α coefficients for the three competencies were calculated. Cronbach's α coefficients for the questions assessing the USE competency, ESI competency and MD competency were .73, .63, and .39, respectively. The former two competencies indicated an acceptable internal consistency, while the latter one fell into the low-value category. Although the low value did not satisfy the common acceptable internal consistency (α = 0.6), any item exclusion could not enhance the value. Therefore, in this study, all items were used as competencies of construct as it had been assumed.

Inter-rater reliability.

Table 2-3 shows the intraclass correlation coefficient for all items. It ranged from .42 to .82, indicating that all raters could reach moderate or more levels of agreement.

Table 2-3

Intraclass Correlation Coefficients

Item	GE1	GE2	GE3	SLC1	SLC2	SLC3	SLC4	GMO1	GMO2	GMO3
ICC (3,1)	.78	.82	.42	.82	.64	.71	.54	.77	.79	.63

Validity.

Face validity.

Face validity was examined through professionals and students interviews in the developmental process of ACSEL (see subsection 2.2.4.). It was revealed that ACSEL seemed to assess the competencies the author had aimed to assess.

Content validity.

Two professionals checked content validity in both developmental and final stage. It was confirmed that used items were consisting CSL.

2.5.2. Level of CSL

Figure 2-1, 2-2, and 2-3 show the results of participants' scores for each question under the three competencies. The horizontal axis indicates the scores, while the vertical axis shows the percentage of people per each score.

USE.

Figure 2-1 shows the results of participants' scores for items in order to assess the USE competency. The highest points for these four questions were two, while the others had three points at maximum. The reason for this was that compared with the ESI competency and MD competency, there was less diversity for responses in this competency. GE1 and GE2 are the same questions used in PISA 2006 (OECD, 2007, pp.108-111), while SLC1 and GMO1 are newly developed for this study, with the origin of all items examined being presented in Table 2-1.

Although the scoring scale of GE1 in the original PISA item set maximum point achievable to one, this study has set the maximum score to two to make it consistent with the other questions provided in this competency. The value of each point is as follows: two point equals "understand well," one point equals "understand somewhat," and zero points means "not understand at all." With this consistency, it

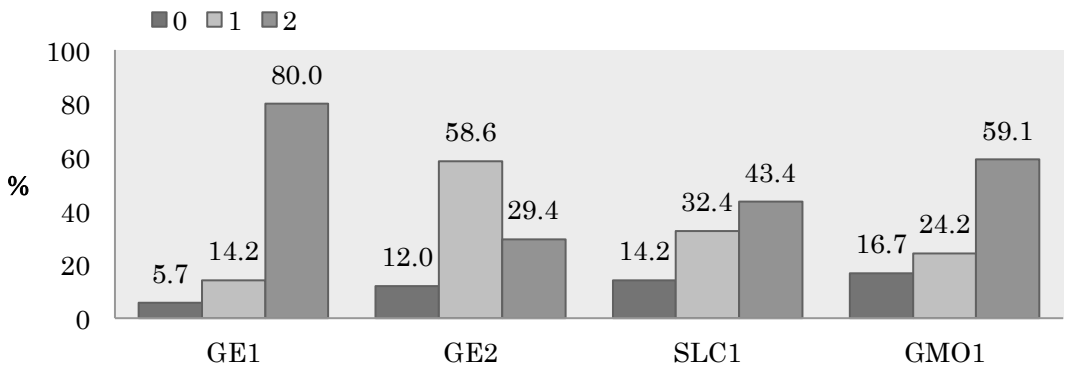


Figure 2-1. Responses for the USE questions.

becomes easy for us to interpret the score. Regarding this, the original one point's answer in PISA 2006 for GE1 was assigned two points, and zero points' answer was assigned either one or zero points according to the quality of the answer.

For GE1 and GMO1, many participants seemed to reach the correct answer easily. On the other hand, some participants might have struggled to reach correct answers for GE2 and SLC1 considering that only about 30 to 40% could get the full score. GE2 required participants to criticize a scientific claim based on given data, while SLC1 asked them to state a desired result of the experiment.

ESI.

Figure 2-2 shows the results for participants' scores for items in order to assess the ESI competency. Four questions were used to assess this competency. The highest points for these three questions were three. The value of each point is as follows: three equals "understand quite well," two means "understand well," one equals "understand little," and zero means "not understand at all." Compared with the USE competency, it was observed that distribution differed and those with full points (three points) decreased in number.

The results of SLC2 indicated that 70% of the participants could not understand why we had to prepare a control group to demonstrate the effect of smoking on lung cancer. The situation changed in SLC3 where over 60% of participants could raise at least one critique for the research design from scientific or social viewpoints. Also, for GMO2, which asked participants to answer possible critiques for a claim considering the limitations of the given graph, over 60% could raise a somewhat meaningful answer while those with full scores were only 9%.

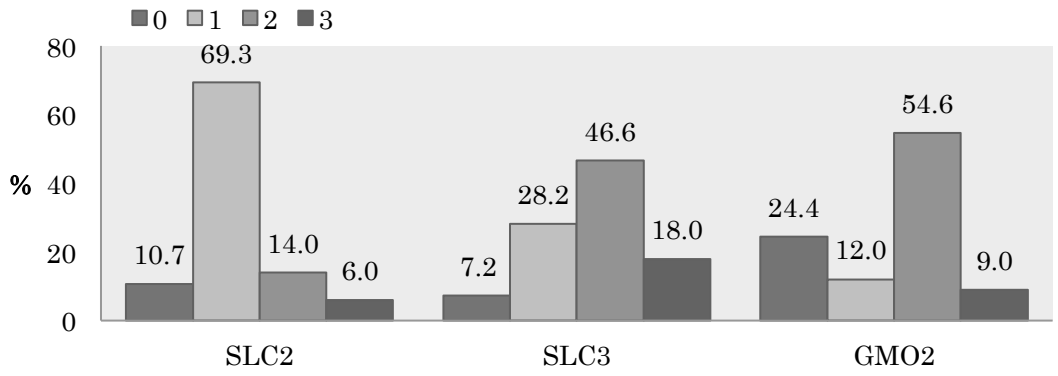


Figure 2-2. Responses for the ESI questions.

MD.

Figure 2-3 shows the results for participants' scores on items assessing the MD competency. Three questions were used to assess this competency. The highest points for these three questions were three. The value of each point is as follows: three equals "understand quite well," two means "understand well," one equals "understand little," and zero means "not understand at all." Participants were asked to state their position against the following controversial, trans-scientific issues: the pros and cons of a strategy to reduce carbon dioxide, policy to ban smoking in the whole town, and introduction of a genetically modified organisms. Then, they were required to support their opinion with as many reasons as possible. If two or three points are assigned for the answers, it means that respondents can raise at least one objective or persuasive answer to support their standpoint. Only if they can raise two or more valid reasons to support their view, they are assigned full scores (three points).

The results showed that few participants could give two or more persuasive reasons. Also, it is noticeable that the number of people who were assigned one point was the majority across three items.

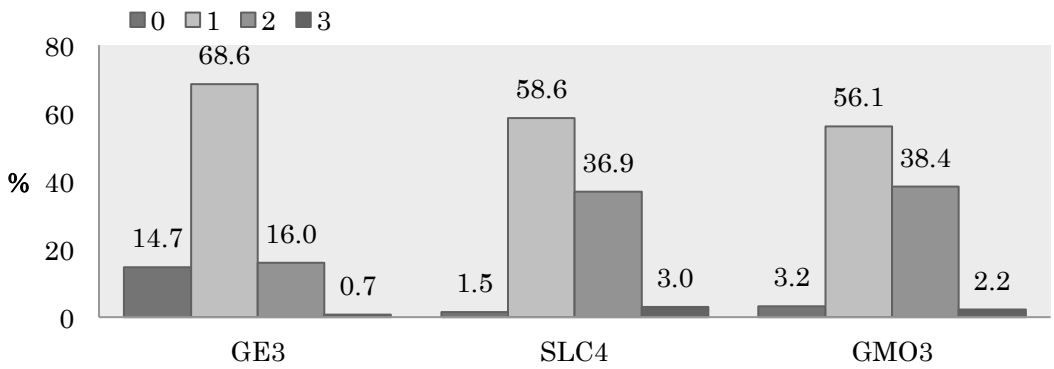


Figure 2-3. Responses for the MD questions.

2.5.3. Influence of possible determinants.

As far, we have seen the participants' responses for each item under the three competencies. The question here is what are the determinants for these competencies. Hereafter, the author will examine whether demographic variables such as gender, age, and educational background produce significant differences on their CSL.

Gender.

The mean scores of males' responses for all the three competencies were lower than females'. To determine if there was any significant difference in the level of the three competencies in CSL due to gender, an Independent Sample *t*-test was performed. The result showed that there was no significant difference between males' and females' mean scores (significance level set at 5%).

Age.

In Japan, curriculum guidance reform roughly takes place every 10 years. It was assumed that this curriculum difference might have influenced CSL of each generation.

Comparison of the means showed there was a minute mean difference across all age ranges for all the three competencies. The results of the One-factor Analysis of Variance (ANOVA), however, indicated that statistically, there was no significant difference in the level of CSL based on age range (significance level set at 5%).

Educational background.

The final variable analyzed in determining any significant difference in the level of CSL was educational background of the participants. The author hypothesized that CSL would differ depending on participants' educational background since the science learning experience of those in each category would be different. For this analysis, the

Table 2-4

Four Educational Background Categories

	Category	Qualified Person	Frequency
①	High School or Junior High School Diploma	People who finished their academic career in high school or lower.	75
②	Associates of Arts	People who finished their academic career in junior college, or vocational school.	72
③	Bachelor or higher (non-science)	People who majored/are majoring in humanities (including social science) in university.	176
④	Bachelor or higher (science)	People who majored/are majoring in natural science in university.	78

author divided educational background into four categories: *High School or Junior High School Diploma, Associates of Arts, Bachelor or more (non-science),* and *Bachelor or more (science)*, based on participants' academic degree (Table 2-4). The results of One-factor ANOVA are shown in Table 2-5.

On analysis of the results in Table 2-5, there was a gradual increase in the mean score for all the three competencies from High School or Junior High School Diploma to Bachelor or more (science). This trend lends to the notion that the level of CSL increases as the level of science study increases. The results of the ANOVA test showed that there was statistically significant difference between High School or Junior High School Diploma and Bachelor or more (science) in the level of the ESI competency. For the other two competencies, however, there was no significant difference (significance level set at 5%).

Table 2-5

Differences Based on Educational Background

Competency	①		②		③		④			Multiple
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*F*(3,397)	Comparison
USE	5.17	0.002	5.33	0.45	5.83	0.32	5.91	0.31	3.05	-
ESI	3.96	0.22	4.13	0.22	4.48	0.14	4.82	0.21	3.30*	① < ④
MD	3.63	0.14	3.71	0.14	3.89	0.09	4.04	0.13	2.00	-

Note. * $p < .05$

2.6. Discussion

2.6.1. Reliability and validity of ACSEL.

In this study, an assessment instrument, ACSEL, was developed to assess the three competencies. As for the reliability, ACSEL showed a low internal reliability for the MD questions. The reason for this low internal consistency cannot be identified from this result alone, but it might have been caused by the contexts included in the task. That is, if participants felt that the context was very close to their own situations, then they might have raised more emotionally grounded reasons rather than objective and persuasive ones to support their standpoint. For example, even participants with a high

score for GMO might have stated sentimental reasons to support their agreement for banning smoking policy if they dislike the smell of cigarettes personally. Future research can delve more into this issue by addressing why people tend to be less or more objective in solving a given problem depending on their own feelings about it. Internal reliability for the other two competencies and inter-rater reliability were confirmed as acceptable.

In terms of validity, interviews with 10 graduate students and discussion with two professionals suggest that ACSEL seems to have face validity and content validity. Through this validity check, it was decided to incorporate some PISA items since their validity were examined in detail. This incorporation further guarantees the validity of ACSEL.

Although there is clearly some room to improvement in ACSEL, we can conclude that ACSEL is, to some extent, useful in assessing adults' CSL.

2.6.2. Participants' responses.

The reported results were based on 401 Japanese Internet monitor responses on this instrument. The distribution of the USE scores for each question means that they could recognize how a scientific claim was constructed based on the given graph. The SLC2 scores in ESI teach us that 80% people could not understand the necessity of control group in scientific experiments. On the other hand, fortunately, over 60% respondents could state the limitation of scientific research implementation (SLC3) or criticize a scientific claim using provided graph (GMO2). The low percentage of people who got high MD scores means that this group of people could not raise even one objective and persuasive reason to support their standpoint, and their answers tended to fall into subjective, emotional, and ambiguous ones. Without clearly established criteria to judge minimum score necessary for adults, it is difficult to evaluate the quality of the scores. But as Weinberg (1972) or Todayama (2011) mentioned, scientific supports for trans-scientific questions are limited. So citizens have to frame trans-scientific issues from multiple angles. Current results do not seem to satisfy such demand since very few participants could provide multiple frames beyond science.

2.6.3. Influences of demographic variables.

Finally, the examination of statistical tests with variables of gender, age, and educational background to determine if any significant difference existed in the level of the three CSL competencies revealed that gender and age were not significantly

decisive. However, there was a significant difference between two categories of educational backgrounds (i.e. High School or Junior High School Diploma vs. Bachelor or more (science)) with respect to the ESI competency. Here, the author discusses the variables of gender and educational background in more detail.

The result that there was no statistically significant difference between males and females is not in line with the general and traditional idea that males do better in science than females. For example, even recently Garner–O'Neale et al. (2013) have indicated that there appears to be statistically significant difference on the comprehension of the nature of science as an indicator of scientific literacy based on gender. Other studies, however, have shown that these differences are minimal and decreasing and are only observed in some exceptional cases—especially for knowledge questions (Amelink, 2009). Moreover, the PISA 2006 survey reported that there is no statistical difference between boys and girls in the great majority of participating countries (OECD, 2007). To sum up, the result of this study is against the traditional notion that there is a significant gender difference on science ability.

With regard to educational background, Bachelor or more (science) scored statistically higher than High School or Junior High School Diploma on the ESI scores. The reason why we could not identify differences among four categories for the other two competencies (USE competency, MD competency) might be due to the fact that the distribution graph of participants' points did not follow a normal distribution. First, as Figure 2-4 shows, the *mean* score and *SD* for the USE competency were 5.63 and 1.97 respectively, suggesting that the questions were easy for most participants. Also, the score distribution was not normally distributed but skewed-right, which was the high points' side. The situation was different for the MD competency. The mean score and *SD* for the MD scores were 3.84 and 1.17 respectively (see Figure 2-6), and score distribution was skewed-left. These indicated that items assessing the MD competency were too difficult for most participants to receive high points and their score concentrated around four out of nine. On the other hand, we see that the distribution graph of the ESI scores was closer to normal distribution (see Figure 2-5). In other words, the average score was almost half of the full score, which was close to the center of a symmetrical distribution. These score biases might have affected the results of the statistical tests of this study. The results need to be confirmed by future research, but for now it can encourage us to rethink the added value of higher education in Japan.

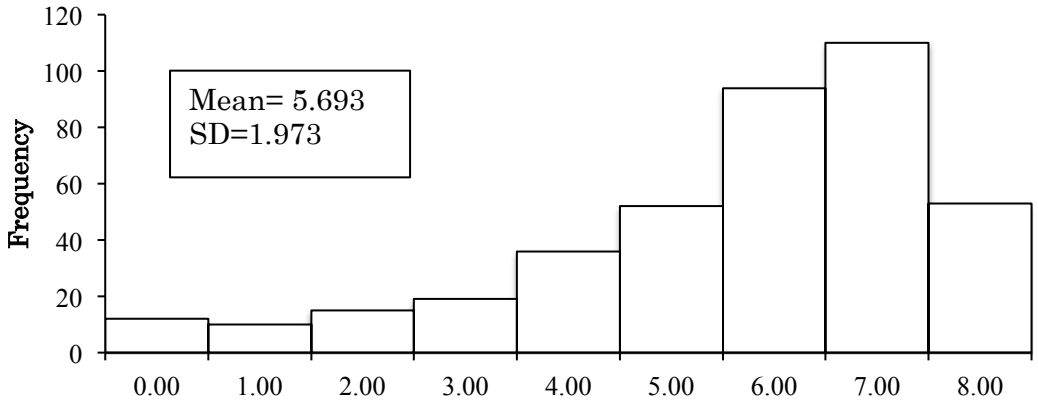


Figure 2-4. Distribution of the USE scores.

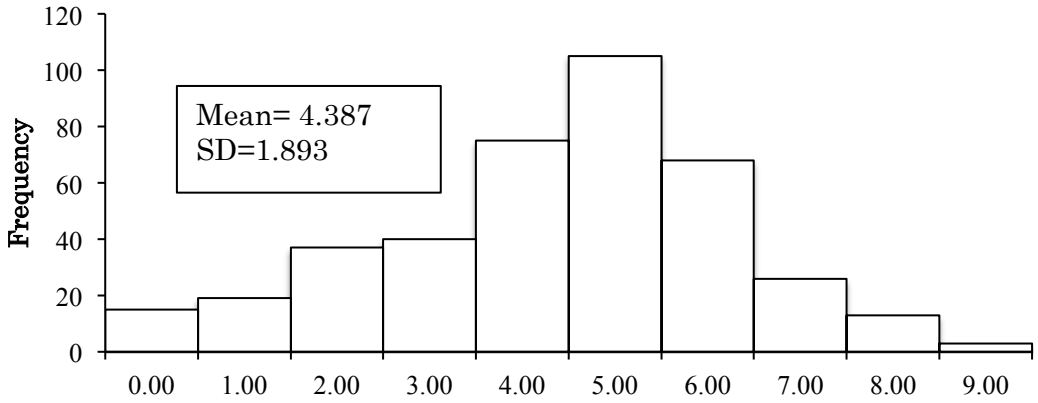


Figure 2-5. Distribution of the ESI scores.

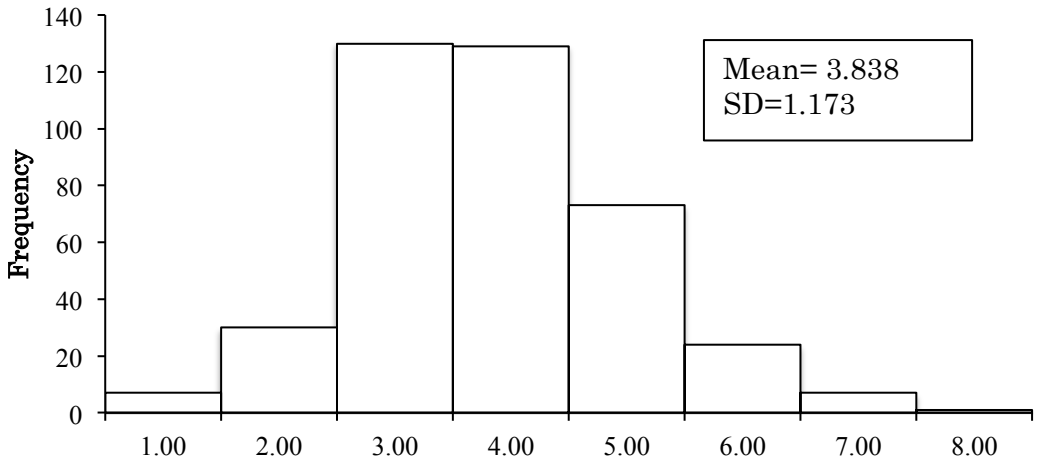


Figure 2-6. Distribution of the MD scores.

2.6.4. Limitation of this study.

This research has some limitation in terms of participants, concurrent validity, and competencies' coverage. Participants were collected via Internet research system, which is more familiar to educated people. In fact, in the study, more than 80% people had at least associate degree, while recent Japanese national census in 2010 indicated that only about one-third of all population had one (Statistics Japan, n.d.). Therefore, attempting generalizations for the overall Japanese adult population becomes impossible. Secondly, this research could not compare the isntrument with another external index with similar construct such as Cornel Critical Thinking Tests. This limitation derived from the notion that the large number of items would discourage participants from answering all questions properly. Thirdly, while this research aimed to assess CSL, the coverage of the competencies is limited. Other proposed competencies such as metacognition (Choi, Lee, Shin, Kim, & Krajcik, 2011) or affective aspects (Blanco-López, España-Ramos, González-García, & Franco-Marisc, 2015; Choi et al. 2011; Chang & Chiu, 2005; OECD, 2007) were not included here.

2.6.5. Implications for future study.

While this study focused on the effects of demographic variables on CSL, a broader approach will be required for future research projects to examine the role of other possible determinants. For example, Shimizu (2006) concluded that elementary or junior high school students' interest in science would influence their future scientific literacy (in this case, scientific knowledge). Also, Miller (2002, 2012) maintained that informal learning experience could affect the amount of scientific knowledge. Gormally, Brickman, Hallar, & Armstrong (2009) stressed that utilized pedagogical style affects scientific literacy. Improving interest in science, introducing opportunities for informal learning, and improving teaching methods can all be adapted, while demographic variables analyzed in this study are difficult to alter through intervention. In future research, the relationship between these variables and CSL should be investigated.

Notes. This chapter was based on the following research paper.

Naganuma, S. (2017). An Assessment of Civic scientific Literacy in Japan -development of a more authentic assessment task and scoring rubric-. *International Journal of Science Education Part B Communication and Public Engagement.*

Chapter 3. Effects of Nature of Science Teaching, Interest in Science at High School Level, and Scientific Knowledge on Adults' Civic Scientific Literacy

This chapter explored whether nature of science teaching (interactive teaching, hands-on activities, student investigations, and use of applications), interest in science (e.g., I enjoyed learning about science) at the high school level, and scientific knowledge would influence adults' CSL in a retrospective way. Participants included 133 males and 264 females in Japan, ranging in age from 20 to 69. Multiple regression analysis showed that hands-on activities and scientific knowledge did influence all the three CSL competencies and interest in science did influence the MD competency significantly. All tested models were statistically significant and explained approximately 10 to 20% of the variance in each competency. This study highlights the importance of interest in science for the MD competency. On the other hand, the other three promising teaching approaches (interactive teaching, student investigations, and use of applications) had either no significant impact or even significant negative impact.

3.1. Introduction

In Chapter 2, adults' *civic scientific literacy* (CSL) in Japan was assessed with a newly developed tool, ACSEL. It was also examined whether demographic variables would significantly influence the three competencies in CSL. The results indicated that those who majored, or are currently majoring in a science courses perform significantly higher on the ESI competency than those who did not receive higher education. However, this difference was small. In addition, it was also found that the other variables do not have any statistically significant effect on all the three competencies. Without the knowledge of what other determining factors can affect CSL assessed in ACSEL, we cannot provide practical suggestions to improve it. Therefore, this chapter aims to find out what other variables have significant effects on CSL.

3.1.1. Related work.

Previous research puts forth several educational approaches to improve scientific literacy (e.g., AAAS, 1993; Gormally, Brickman, Hallar, & Armstrong, 2009) while the definition of scientific literacy, instrument measuring the concept, or its scope differ in

each study. AAAS (1993) argued that inquiry-based teaching methods are the best path to achieving scientific literacy because they provide students with the opportunity to discuss scientific ideas. Also, Gormally et al. (2009) reported the positive effect of a utilized science teaching style on scientific literacy through a comparison between an experimental group (guided-inquiry lab methods) and a control group (traditional lab methods). In their findings, inquiry-based learning enhanced college students' ability to transfer conceptual understanding, and accurately interpreting and evaluating texts dealing with scientific concepts (Gormally et al., 2009). Some teaching strategies such as scaffolding, modeling, guided inquiry, explicit instruction, individual study and practice, computer-mediated learning, and group problem solving and discussion have all been shown to be effective in various circumstances (NRC, 2014). Schroeder, Scott, Tolson, Huan, & Lee (2007) conducted meta-analysis of some popular science teaching styles. They reported strong influences of inquiry strategies, collaborative learning strategies on science achievements.

As for interest in science, Osborne, Collins, & Simon (2003) and Tytler (2014) insisted the importance of interest in science for scientific literacy of citizen. Shimizu (2006) concluded that adults' scientific knowledge is determined by their interest in science shaped during elementary school or junior high school. He found that this relationship between scientific knowledge and interest in science is partly mediated by adults' current interest in science and technology. Scientific knowledge used in Shimizu's work was assessed with Oxford Scales.

Also, Sudo (2013) pointed out an interesting finding for scientific knowledge. According to his research, the correlation coefficient between TIMSS 2007 score and PISA 2006 score on science ability using international data was .897. This means that one can be used to predict the other strongly though the former focuses on scientific knowledge itself; the latter assesses the ability to use scientific knowledge and skills. Some researchers focused on the content knowledge–argumentation skills relationship (Jho, Yoon, & Kim, 2014; Sadler & Zeidler, 2005; Sadler & Fowler, 2006). Differences in students' content knowledge were related to variations in qualities of informal reasoning (Sadler & Zeidler, 2005). Sadler & Fowler (2006) suggested that scientific knowledge promotes the justification of claims on socio-scientific issues. This influence is, however, not decisive. Jho, Yoon, & Kim (2014) revealed that scientific knowledge

does not show a significant relationship to the ability to raise an alternative solution on socio-scientific issues.

3.1.2. Purpose.

Based on preceding works, the author hypothesized that nature of science teaching and interest in science at the high school level, and scientific knowledge (independent variables) would determine CSL (dependent variables) in ACSEL. High school level was selected in this study because it is generally the last opportunity of formal science learning for students who are not planning to take advanced science courses in higher education. Another reason for selecting the high school level was that interest in science declines dramatically in secondary education. This is especially the case with high schools in Japan (Ogura, 2008).

3.2. Methods

3.2.1. Participants.

Data was collected from those participants who had registered in *Nikkei Research*, an Internet research system in Japan. The survey was conducted in December 2015. The study was carried out using 397 subjects' responses on the survey. Table 3-1 shows the ratio of male and female respondents and their age range. They are the same participants in Chapter 2, with excluding four people who did not finish high school.

Table 3-1

Distribution of Gender and Age among Participants

	20s	30s	40s	50s	60s	Total
Male	19	23	33	26	33	134
Female	102	31	32	31	67	263
Total	121	54	57	57	100	397

3.2.2. Dependent and independent variables.

Nature of science teaching.

To collect information about the kind of science teaching participants experienced at high school, 17 questions in PISA 2006 (National Institute of Educational Policy Research, 2007; OECD, 2005; 2007; 2009) were used, asking *students' view of nature of science teaching* at school. This consisted of four categories: *interactive teaching, hands-on activities, student investigations* and *use of applications* (OECD, 2009, p. 59) and was used after minor revisions on using the instruments in a retrospective way (see

Table 3-2

Items for PISA 2006 on nature of science teaching, and interest in science

Interactive teaching	Hands-on activities	Student investigations	Use of applications	Interest in science
1. Students were given opportunities to explain their ideas.	1. Students spent time in the laboratory doing practical experiments.	1. Students were allowed to design their own experiments.	1. The teacher explained a how school science idea can be applied to a number of different phenomena	1. I generally had fun when I am learning natural science topics.
2. The lessons involved students' opinions about the topics.	2. Experiments were done by the teacher as demonstrations.	2. Students were given the chance to choose their own investigations.	2. The teacher used school science to help students understand the world outside school.	2. I liked reading about natural science.
3. There was a class debate or discussion.	3. Students were asked to draw conclusions from an experiment they have conducted.	3. Students were asked to do an investigation to test out their own ideas.	3. The teacher clearly explained the relevance of natural science concepts to our lives.	3. I was happy doing natural science problems.
4. The students had discussions about the topics.	4. Students did experiments by following the instructions of the teacher.	4. Students had discussions about the topics.	4. The students were asked to apply a school science concept to everyday problems.	4. I enjoyed acquiring new knowledge in natural science.
n.a.	n.a.	n.a.	5. The teacher used examples of technological application to show how school science is relevant to society	5. I was interested in learning about natural science.

Table 3-2). Participants were asked if they had experienced each characteristic of science teaching in high school choosing from five response options across a Likert Scale, ranging from 1 (*not appropriate at all*) to 5 (*most appropriate*). The mean scores of the four constructs were used in the analysis.

Interest in science.

There are a lot of scales measuring interest in science (Zubair & Nasir, 2011). Among them, the internationally implemented scale in PISA 2006 (National Institute of Educational Policy Research, 2007; OECD, 2007; 2009) was used in this study. The Enjoyment of Science indicator under Students' Views on Science was specifically selected since this concept has been widely investigated in Japan for decades since the early 1990s. This construct is measured by five questions (see Table 3-2). Participants were asked to rate their attitudes toward science at the high school level choosing from five options across a Likert scale, this time, ranging from 1 (strongly disagree) to 5 (strongly agree). The mean score of these responses was also used in the analysis.

Scientific knowledge.

Scientific knowledge is also incorporated into the analysis model as a independent variable. Miller's Oxford Scales' score was used as a representative of scientific knowledge. Miller's Oxford Scales seem suitable to use here because they question the basic scientific content (e.g., whether the Earth goes around the sun) obtained through secondary education which precede adults age. The total number of correct answers out of 12 questions in Oxford Scales was used as an indicator of scientific knowledge for this study (Table 3-3).

CSL scores.

In this study, the scores of the three competencies in ACSEL were used as indicators of CSL: *Using Scientific Evidence* (USE) competency, *Explaining Scientific Inquiry* (ESI) competency, and *Making Decisions* (MD) competency. See Chapter 2 and Appendix for the detail of them.

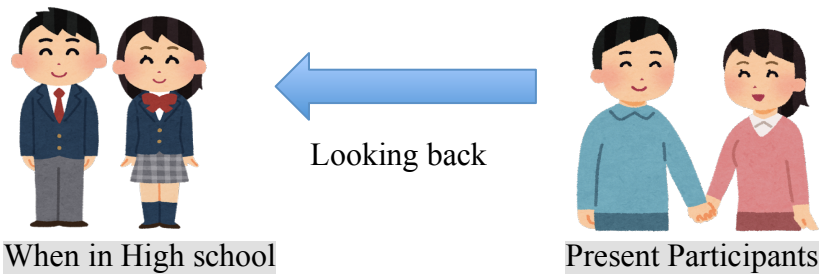
3.2.3. Framework.

Table 3-3

Questions Used for Measuring Scientific Knowledge

Questions
1. The center of the Earth is very hot.
2. All radioactivity is man-made.
3. The oxygen we breathe comes from plants.
4. It is the fathers' gene which decides whether the baby is a boy or a girl.
5. Lasers work by focusing sound waves.
6. Electrons are smaller than atoms.
7. Antibiotics kill viruses as well as bacteria.
8. The universe begins with a huge explosion.
9. The continents have been moving their location for millions of years and will continue to move.
10. Human beings, as we know them today, developed from earlier species of animals.
11. The earliest humans lived at the same time as the dinosaurs.
12. Radioactive milk can be made safe by boiling it.

Note. Participants are asked to select "True," "False," and "Don't know" for each question.



- Nature of science teaching
  - Interactive teaching
  - Hands-on activities
  - Student investigations
  - Use of application
- Interest in science
  - Interest in science

- Civic Scientific Literacy (CSL)
  - USE
  - ESL
  - MD
- Scientific Knowledge
  - Scientific knowledge

Figure 3-1. Framework of this analysis.

The framework of this study is shown in Figure 3-1. The author used multiple regression analysis to examine whether 1) nature of science teaching, 2) interest in science, and 3) scientific knowledge would determine CSL scores. Figure 3-2 shows the applied model for the USE competency and the same models were also used for the ESI competency and MD competency. Educational background category was converted into dummy variables with "High school" as the basis. The number of people in each educational background category is shown in Table 3-4.

3.3. Results

3.3.1. Basic statistics for each variable.

Table 3-5 shows basic statistics for each variable used in the analysis. It was revealed that many participants received hands-on science lessons in high school while the other three teaching approaches were not fully or necessarily implemented in the classes.

As for interest in science, participants' average score was about three, which is the midpoint on the 5-points Likert scale. It is already indicated that interest in science in high school has a strong relationship with adults' interest in science (Hayakawa, 2014; MEXT, 2004). Other researches show that almost half of the Japanese citizens are

Table 3-4

Number of Participants in Four Educational Background Categories

Category	Qualified Person	Frequency
High School Diploma	People who finished their academic career in high school.	71
Associates of Arts	People who finished their academic career in junior college, or vocational school.	72
Bachelor or higher (non-science)	People who majored/are majoring in humanities (including social science) in university.	176
Bachelor or higher (science)	People who majored/are majoring in natural science in university.	78

interested in science as measured on a larger-scale survey (Kano et al., 2013; MEXT, 2004). With these findings, we can conclude that the sample population in this study was close to the Japanese overall population in terms of their interest in science.

The mean score of scientific knowledge was around 7.6 out of 12 questions with 2.57 of *SD*. This means that approximately 70% participants' score ranged from 5 to 10 points.

Table 3-5

Basic Statistics

	Mean score	*SD*	Min	Max	Cronbach's α
Nature of Science Teaching					
Interactive teaching	2.31	0.84	1	5	.87
Hands-on activities	3.43	0.73	1	5	.69
Student investigations	2.44	0.81	1	5	.80
Use of applications	2.49	0.87	1	5	.90
Interest in science					
Interest in science	2.93	1.18	1	5	.94
Scientific knowledge					
Scientific knowledge	7.66	2.57	0	12	.72
CSL score					
USE	5.63	1.97	0	8	.73
ESI	4.39	1.90	0	9	.63
MD	3.84	1.18	1	8	.39

3.3.2. Correlation coefficients.

Correlation coefficients for all constructs are shown in Table 3-6. The highest positive correlation is between indices of interactive teaching and student investigations. Also, the next highest correlation is between the indices of student investigations and the use of applications. All values of *Variance Inflation Factor* (VIF) were revealed to be below 10. Thus, there was no evidence for a serious multi-collinearity.

Table 3-6

Correlation Coefficients

	Nature of Science Teaching				Interest in Science	Scientific knowledge	CSL score		
	Interactive teaching	Hands-on activities	Student investigations	Use of applications	Interest in science	Scientific knowledge	USE	ESI	MD
Nature of Science Teaching									
Interactive teaching	1								
Hands-on activities	.41**	1							
Student investigations	.85**	.50*	1						
Use of application	.77**	.48**	.79**	1					
Interest in Science									
Interest in science	.34**	.30**	.29**	.39**	1				
Scientific knowledge									
Scientific knowledge	.04	.17**	.09*	.15**	.40**	1			
CSL Score									
USE	.09*	.29**	-.05	-.03	.11*	.30**	1		
ESI	-.02	.28**	-.01	-.01	.20**	.34**	.64**	1	
MD	-.12*	.11*	-.09*	-.05	.18**	.24**	.40**	.41*	1

Note. ** $p < .01$, * $p < .05$

3.3.3. Multiple regression analysis.

Table 3-7 presents the results of multiple regression analysis for the three dependent variables: USE, ESI, and MD. According to the results, all the three models are statistically significant (F= 12.20; $p < .05$, F= 11.53; $p < .05$, F= 5.74; $p < .05$). The

independent variables count approximately for 10 to 20% of the total variance in each competency in CSL. The results for each model are examined in detail as follows.

Table 3-7

Results of Regression Analysis

		USE	ESI	MD
Nature of science teaching	Interactive teaching	-.06	-.05	-.14*
	hands-on activities	.39**	.33**	.15**
	student investigations	-.14	-.11	-.10
	use of applications	-.10	-.19*	-.02
Interest in science	Interest in science	-.01	.08**	.15*
Scientific knowledge	Scientific knowledge	.27**	.29**	.18**
Educational background	Associates of Arts	-.01	-.02	-.003
	Bachelor or higher (non-science)	.13*	.08	.09
	Bachelor or higher (science)	.04	.03	.01
Coefficient of determination (= Adjusted R^2)		.20**	.19**	.10**

Note. ** $p < .01$, * $p < .05$, value: standardized regression coefficient

Using scientific evidence (USE).

Table 3-7 shows the results of the standardized regression coefficients. The independent variables count approximately for 20% of the total variance in USE scores. According to the *t*-test results with regard to the statistical significance of regression coefficients, it became evident that the indices of interactive teaching, student investigations, use of application, interest in science, and two educational categories—Associates of art and Bachelor's degree or higher (science)—are not significant determinants. The results of

the *t*-test show that only the effects of hands-on activities, scientific knowledge, and Bachelor's degree or higher (non-science) were statistically significant.

Explaining scientific inquiry (ESI).

The independent variables count for approximately 20% of the total variance in the ESI scores (Table 3-7). According to the *t*-test results with regard to the statistical significance of regression coefficients, it becomes evident that the indices of interactive teaching, student investigations, and all the three educational background variables are not significant. According to the results of *t*-test, all other variables are revealed to be statistically significant.

The regression coefficients values show that the index of use of applications has a significantly negative effect on the participants' ESI scores. In other words, as the scores in this index increase, the participants' ESI scores tend to decrease. On the other hand, the index of hands-on activities and the index of interest in science, and amount of scientific knowledge affect the ESI scores positively.

Making decisions (MD).

According to multiple regression analysis, the independent variables count approximately for 10% of the total variance in the MD scores. According to the *t*-test results, it becomes evident that the indices of use of applications, student investigations, and the all three educational background variables are not significant. Based on the sign of the regression coefficients, the indices of hands-on activities, interest in science and scientific knowledge affected the MD scores positively.

3.4. Discussion

Using a multiple regression analysis, this study attempted to identify several factors that might affect CSL.

3.4.1. Using scientific evidence.

The fact that hands-on activities had a positive impact on the USE competency supports general assumption that the more opportunities participants were given for operating scientific data in the laboratory during high school days, the better they can manipulate and interpret such data. Thus, a high USE competency could be attributed to the experience of hands-on activities. However, why Bachelor's degree or more (non-science) had positive significant effect on CSL cannot be logically explained. Thus,

we should not view the causal relationship between them.

We cannot conclude that improving scientific knowledge will raise a USE score based on this result at this moment because we cannot theoretically explain why obtaining more scientific knowledge can enhance the USE competency, which can be considered as generic skills rather than domain-specific skills. Or, it could be that participants with more knowledge tend to feel that the contexts are familiar to them, which might promote their active engagement in the questions. This is another possible interpretation, which needs further studies to identify the causality.

It is interesting that the significant influence of enhancing interest in science was not observed on the USE competency because this means that how to use and interpret scientific evidence can be directly taught with the appropriate pedagogy—hands-on activities—apart from the affective domain. While hands-on activities are often criticized if they do not give rise to students' active engagement and interpretation of output data (e.g., NRC, 2014), this result supports the effectiveness of hands-on activities in science classes in that students can handle scientific data.

The fact that student investigations had no significant impact on the USE competency is somewhat a contradiction to a finding of Gormally et al. (2009). They found greater improvement in students' ability to interpret scientific reports using inquiry lab instruction. However, they also noted that students' frustration in inquiry labs derived from the struggle of figuring out what they are doing without detailed guide. Based on this observation, one possible explanation for why student investigations had no positive association with the USE scores is that participants could not conduct their hands-on activities without sufficient direct guidance from their teachers at high school. This, in turn, might have led to decreased opportunities for operating scientific data.

3.4.2. Explaining scientific inquiry.

In order to obtain higher the ESI scores, participants needed to explain the role of the control group in experiments, state scientific and social limitations on scientific inquiry, and criticize provided information with regard to causality. These competencies are closely related to laboratory experiments. Thus, it is possible to conclude that increased hands-on activities would heighten the ESI competency.

However, why the other teaching styles (i.e. interactive teaching, student

investigations, and use of applications) had either no significant impact or even significant negative impact on the ESI competency was unclear. Although the four teaching styles focused on in this study are considered to be effective in various circumstances (NRC, 2014), the results of this study do not support this view in terms of the ESI competency. Further studies are needed to identify why these methods did not show a positive impact on CSL.

For the fact that scientific knowledge indicated significant value, we cannot conclude that improving scientific knowledge will raise the ESI competency for the same reason as for the USE competency. We should view this scientific knowledge indicator as one of the strong predictors for the ESI scores at this moment, until further researches will reveal a process of how domain-specific knowledge can impact generic skills.

3.4.3. Making decisions.

To view the causality between interest in science and the MD competency, we need to consider that the topics dealt with in this survey (greenhouse effect, smoking and lung cancer, and genetically modified organisms) have started to be mainly discussed in recent years. This means that educational curriculum for the old generation barely covered such emerging issues. So these participants might be in need of life-long, informal learning to upgrade themselves with new information from the media such as newspapers or television. Hayakawa (2014) has already revealed that interest in science is strongly related to informal learning motivation. Thus, it stands to reason that enhancing interest in science could be an effective teaching intervention to improve the MD competency by encouraging people to learn in informal environments.

Also, the result indicates the importance of improving scientific knowledge to enhance the MD competency. This result supports the suggestion by Sadler & Fowler (2006) quantitatively and for another population—adults. Although the USE competency and the ESI competency cannot be theoretically associated with scientific knowledge itself since they are considered to be generic skills rather than domain-specific skills, the MD competency is based on domain-specific knowledge. Miller (1998) stated that some basic scientific knowledge is considered necessary to understand the scientific information in the media. As he implied, it could be very difficult to comprehend new scientific information without basic scientific knowledge.

The reason why hands-on activities have a positive impact on the MD competency is because participants could use the provided scientific data in the ACSEL to support their opinion to obtain high MD scores. Therefore, if they were familiar with interpreting scientific data, it would be even more advantageous to obtain higher scores.

However, as with the USE competency and ESI, why the other three teaching styles had either no significant impact or even significant negative impact on the MD competency was still unclear. The result of this study, again, did not support the notion that these popular teaching styles positively impact science ability (e.g., NRC, 2014) in terms of the MD competency.

3.4.4. Limitation of this study.

Based on the discussion above, it could be concluded that allocating more time for hands-on activities in high school are generally beneficial to improve CSL in ACSEL in that this would provide the opportunities for high school students to operate and interpret scientific data. Also, in terms of the MD competency, it should be noted that encouraging interest in science and equipping students in high school with scientific knowledge could improve ability in adulthood to formulate their opinion on trans-scientific issues objectively.

However, this study has three limitations. Firstly, the author attempted to identify the possible effects of some of the variables on CSL. Nevertheless, the decisive causal association should be revealed through a longitudinal experimental-control design. Employing this design was not an option in this study due to the time and financial constraints.

Secondly, although the author included some of the popular teaching approaches as independent variables in this study, three of them did not yield the expected results. The scope of this study did not allow for a further analysis of why this has happened. This unexpected result could be attributed to the fact that the three teaching approaches (interactive teaching, student investigations, and use of applications) were not major styles used in high school for most participants, as the mean scores and SD in Table 3-5 indicated. In fact, unfamiliarity with these teaching styles was still common in high school science classes in Japan during the implementation of PISA 2006 survey (National Institute of Educational Policy Research, 2007). We need further investigations to know why these promising teaching

approaches did not show positive results in this study.

Thirdly, the author could find some variables to improve CSL in this study. However, the coefficients of determination in the applied regression models were 10 to 20% for the three competencies, which suggests a need for future research to investigate other possible variables.

Notes. This chapter developed the oral presentation below.

Naganuma, S. (2016). The Examination of Impact of Interest in Science of School Stage on Adults' Scientific Literacy -Focusing on Decision-Making and Relevant Components-. *Fifth International Conference of East-Asian Association for Science Education*, Tokyo.

Chapter 4. A Discussion of Determinants of Interest in Science

Chapter 4 focused on interest in science that would enhance the *Making Decision* competency of *civic scientific literacy* supported by the results from Chapter 3. Previous studies in Japan on interest in sciecne from elementary to secondary school level were reviewed. This aimed to clarify some features of the *Flight from Science* phenomenon in Japan since the late 1980s and to obtain practical suggestions for how to enhance interest in science. Major determinants abstracted from these literatures were categorized into six: *teachers, parents, teaching methods, informal experiences, difficulty of science,* and *relevance of science*. Since increasing the opportunities to conduct scientific experiments in the current Course of Study had limited impact though still effective, the author attempted to find promising and feasible approaches to enhance interest in science for high school students. The author suggests that focusing on relevance of science to improve interest in science is a promising approach.

4.1. Introduction

In Chapter 3, it was revealed that enhancing interest in science at a high school level would improve the *Making Decisions* (MD) competency among *civic scientific literacy* (CSL). In Chapter 4 and 5, the author will focus on the influence of interest in science on the MD competency for the following two reasons. One is that as the analysis in Chapter 2 revealed, most people could not raise at least two objective reasons to support their decisions on trans-scientific issues. Considering the unavailableness of reliable scientific knowledge for trans-scientific questions (Kobayashi, 2007; Weinberg, 1972), we can conclude that this competency matters. The other reason is that interest in science has been the major theme in science education community in Japan for around 30 years, since the latter of the 1980s. Therefore, we will shed light on interest in science, which would improve the MD competency. In this chapter, we will find promising and feasible approaches before the intervention held in Chapter 5.

4.1.1. Trends on interest in science.

Interest in science has been the focus of science education in Japan for approximately 30 years. In the late 1980s, the word *Flight form Science*, meaning decline in students' interest in science, showed up in the Japanese educational world (Kouno, 2004). In 1994, the Science and Technology Agency (1994) showed data indicating that while

interest in science had tended to increase as age rose until then, teenagers in the 1980s grew up into their twenties with less interest in science, which was observed for the first time in this generation. This phenomenon had great impact on Japan since science and technology is essential for Japan with poor natural resource and energy. The data below shows recent trend on interest in science from 1995 to 2015 for fourth, eighth, and 10th grader (National Institute of Educational Policy Research, 2016a; 2016b). Obviously, the same trend is continuing in very recent years.

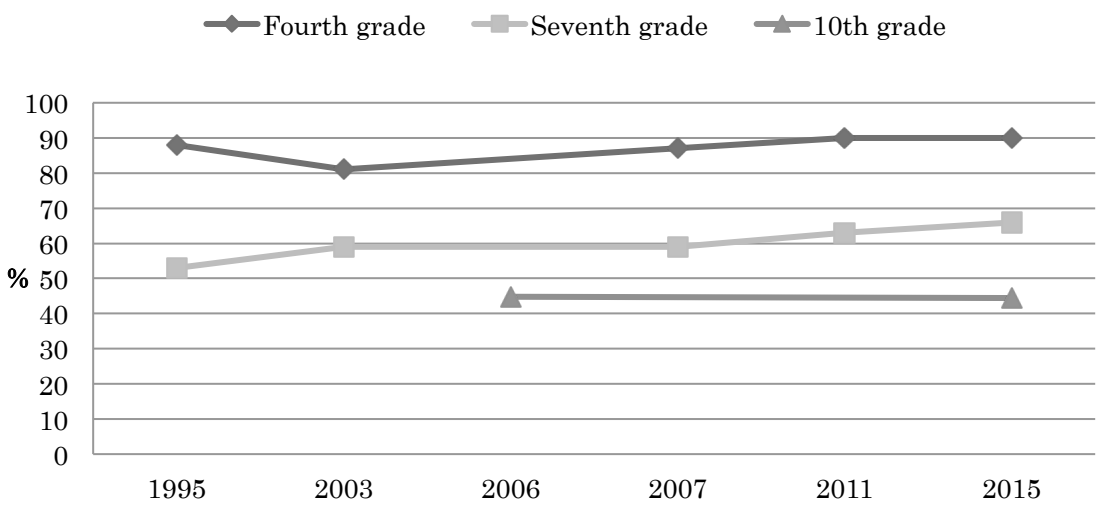


Figure 4-1. Ratio of students feeling "Science is fun."

Table 4-1

Annual Time for Science Lessons in Junior High School

Year	1972	1981	1993	2002	2012
7th	140	105	105	105	105
8th	140	105	105	105	140
9th	140	140	105-140	80	140

Note. This table was created from http://www.mext.go.jp/b_menu/shingi/chukyo/chukyo3/siryo/07061432/005/003.htm.

From 1982, a new curriculum was implemented in junior high school, which decreased the number of time for science education. This change was regarded as a main cause of the Flight from Science phenomenon and was criticized (e.g., Benesse, n.d.). To tackle this phenomenon, the MEXT has started *The Plan to Let Students Enjoy Science and Technology* such as *Super Science High school* (SSH) and *Science Partnership Program* (SPP) from 2002 and declared increases of time for science lessons in the 2008 new Course of Study. This new Course of Study took in effect from 2012 in junior high school (Table 4-1). If these interventions had worked, interest in science in seventh and 10th grade would have risen. Unfortunately, as shown in Figure 4-1, these strategies could not change the situation. We have to direct our eyes to other approaches to enhance interest in science other than focusing on experiments and observations.

4.1.2. Purpose.

In this chapter, we purport to identify possible determinants of interest in science through a narrative review. Then, we will find promising and feasible approaches to enhance interest in science, with considering educational environments and social situation.

4.2. Determinants of Interest in Science

In Japan, there have been lots of studies on interest in science. Many studies inquired the difference between students who prefer science and those who do not. As a result, various determinates were revealed to influence interest in science, which can be roughly categorized into the six variables below.

4.2.1. Teachers.

From elementary to secondary school, it is consistent that teachers' influence determines students' preference of science. If they meet a good teacher, in character or in teaching skills, they tend to like science, and vice versa (Itoi, Aoki, Okubo, Okamura, & Nonomiya, 1998; Kato, 2008; 2009; Morishita & Kozuma, 2011; Nakazawa, 2004).

Nakazawa (2004) submitted unique findings focusing on teachers' expectation for students. This indicated that almost all male students in junior high school with low science preference do not feel expectation from their teachers to get good grades.

4.2.2. Parents.

Murakami (1999) investigated the influence of parental behavior on children's preference in science. Based on questionnaires from 507 elementary school students, he concluded that when their parents help them to think and inquire what they want to know, students are more interested in science. Fujiwara (2004) demonstrated by 907 seventh grader data that children tend to like science when their parents are familiar with science, regard science learning as important, or appreciate that their children hope to get a job in science or technology.

4.2.3. Teaching methods.

Researches revealed strong influences of scientific experiments or observation on whether students like science in the secondary school level (e.g., Itoi et al., 1998; Inoue & Ikeda, 2008; Nagoshi, 2011). Based on qualitative observation of science lessons, Akai (1997) and Kouno et al. (2004) found the typical role difference between boys and girls in group experiments: boys take a main role and girls support it. Such a gender perspective is especially important in Japan since PISA 2006 and 2015 revealed that girls' interest in science is much lower than boys' interest statistically significantly (National Institute of Educational Policy Research, 2007; 2016b). Findings from Morishita & Kozuma (2011), however, suggest the caution for just increasing the opportunities to experiment. They pointed out that if the experiments or observations are completely guided by the teachers, it unfortunately lowers students' interest in science. Also, Tokunaga & Fujimori (1996) indicated that at any level from elementary to secondary school, the number of students favoring experiments excess those favoring science. These findings showed the limitation of increasing the opportunities to enhance students' interest in science.

Other researchers suggested that transmission-dominated pedagogy styles for just university entrance examination decreases students' interest in science (e.g., Deno & Yasuda, 2003; Morishita & Kozuma, 2011; Nagoshi, 2011). In Nagoshi's survey, 20% of students strongly dislike transmission-dominated pedagogy since it does not involve the time for students to think (Nagoshi, 2011).

4.2.4. Informal experiences.

Nature experiences have been one of the focuses of the Flight from Science discussion since the 1990s (e.g., Kobayashi, Amemiya, & Yamada, 1992). This emphasis seemed to come from rapid change of our social environments from the latter of the 20th

century. It is empirically demonstrated that nature experiences (playing in the river, mountain, and going camping, etc.) correlate with interest in science positively (Ikegami, 2004; Iwakoshi & Hatta, 1997; Murakami, 1999).

Also, decreased experiences of crafting in modern society are mentioned as one of the reasons. Ikegami (2004) revealed that junior high school boys with more experience of building a plastic model are more interested in science. However, these findings are contrary to the finding by Itoi et al. (1998). They indicated that early nature experience in childhood do not strongly determine interest in science, with a retrospective survey on 400 undergraduates in the department of education. This indicates that the impact of nature experience has not necessarily been conclusive.

4.2.5. Difficulty of science.

As students move on to upper grades, more students tend to feel that science is a difficult subject to study, then leading to decline their interest in science (e.g., Inoue & Ikeda, 2008; Kato, 2008; 2009; Nagoshi, 2011; Tanaka et al., 1996). Especially, many scientific formulas, theories, or numerical expressions in science lessons further this belief about science (Itoi et al., 1998; Inoue & Ikeda, 2008; Moroshita & Kozuma, 2011; Tanaka et al., 1996). Itoi et al. (1998) revealed the large impact of contents comprehension on interest in science especially in secondary school level.

4.2.6. Relevance of science.

Relevance of science refers to relationship between individuals and science, including personal and social situations. The results of multiple regression analysis by Itoi et al. (1998) revealed that whether students view science as important for daily life, relevant to real life, and useful or not influences interest in science at high school level significantly. These influences are observed only at high school level, not at elementary and junior high school level. Inoue & Ikeda (2008) submitted a similar finding. They demonstrated that students who like science less since secondary school mention that science is irrelevant to their future occupation. This reason is seen for more girls than boys.

4.3. Room for Interventions

We have derived six factors from the previous studies so far. Here, we will examine the feasibility of interventions for each factor.

4.3.1. Teachers.

Currently, teachers are working really hard. According to the TALIS survey (National Institute of Educational Policy Research, 2014), teachers in Japan are much busier than ones in other countries. So the frequency of participation in skill development opportunities is low. The MEXT's survey also pointed out that teachers in 2006 are very busy, compared with teachers in 1966 (MEXT, 2015). Also, there are more teachers who are poor at giving self-confidence to students than international average. Under these circumstances, it is practically difficult to expect teachers to raise teaching skills, to make fun classes, to expect for their students. An educational reform at the policy level is required to change this busy working situation of teachers.

4.3.2. Parents.

When we look at the current working environment in our country, interventions for parents can be really limited, too. The white paper by the Ministry of Health, Labor and Welfare showed that the number of dual-income families has increased steady in recent years (Ministry of Health, Labor and Welfare, 2015). Under such circumstances, it can be inferred that it is very difficult to increase parents who can stay close to their children and help them think what they want to inquire.

4.3.3. Teaching methods.

As shown in Figure 4-1, interventions focusing on scientific experiments and observations have limited influence. In the survey by Tokunaga & Fujimori (1996), it was found that the number of students who like experiments and observations doubles the one who like science. It means that experiments and observations alone are still insufficient. In addition, some evidences were submitted to indicate the limitation of approaches that emphasize the enjoyment of science theoretically and empirically. Kobayashi (1991) mentioned that the *Savage in Civilized Society* seemed to increase. Savages in civilized society are young people born in a world surrounded by highly matured science and technology. One of their features is that they are not interested in the process of science and technology. Instead, they are more likely to be interest in the products of science and technology. Even in the recent survey for high school students by Nagoshi (2011), many students agreed to the following reasons as general causes of declining interest in science.

"Daily products such as mobile phones can be fully utilized without knowing its

principle." (30.7% respondents strongly agreed)

"Because science and technology have developed highly, using these products is more interesting than making them." (15.8% respondents strongly agreed)

For the savages in the civilized society, it seems not promising to teach science is fun through scientific experiments or observations.

From an international perspective, in the ROSE survey by Sjoberg (2008), he concluded that "the more developed, the less interested in science and technology we become" if we compare developed countries with emerging countries. This thought provides us with another perspective to see the Flight from Science. That is, it was not the results of decreased science lesson hours (e.g., Benesse, n.d.), but the results of matured science and technology, which needs further examination.

4.3.4. Informal experiences.

The effects of nature experiences are not decisive as shown in subsection 4.2.4. Despite an increase in the number of opportunities for nature observations in the Course of Study issued in 2008, it did not lead to an improvement of interest in science. Ikegami (2004) also pointed out that the ratio of children who had nature experiences is not necessarily small. Taking these into consideration, it is ambiguous whether interventions to compensate a loss of nature experiences in school are effective. In addition, it became clear that there are more teachers in younger generation than older generations who think that knowledge and skills related to experiments and observations are poor (JST, 2013).

4.3.5. Difficulty of science.

Subsection 4.2.5. shows that feeling that science as a difficult subject to understand largely lowers interest in science. According to the JST survey, it is clear that there are lots of young teachers who feel that they are not good at teaching science, while the proportion of young teachers in the whole is growing (JST, 2013). In addition, many teachers cannot take time for capacity development during their busy work (National Institute of Educational Policy Research, 2014). Therefore, it is considered becoming more difficult to raise students' content understanding with refined pedagogies than before.

4.3.6. Relevance of science.

JST survey for junior high school teachers reported that 88% of teachers agreed that in the science class, they often explained that science is closely related to everyday life (JST, 2013). This may be partly because of the change of the Course of Study released in 2008, which declares the importance of focusing on the relationship between science and real life. PISA's questionnaire survey conducted in 2015, however, reported that only 33% of students answered positively for the following statement: "The teacher clearly explains the relevance of science concepts to our lives." (National Institute of Educational Policy Research, 2016b). It reflects differences in teaching at junior and senior high schools. In addition, only 46% of junior high school teachers agreed that they often explained the relationship between learning content and occupations. Descriptions about the related occupations cannot be seen in the current textbook (Iguchi, Aihara et al., 2012; Tatsumi et al., 2012).

4.4. Discussion

In this chapter, we have seen various factors that determine interest in science. Because many of the possible interventions require heavy loads on teachers, policy-level reforms, and transformation of social structure, they are poorly feasible. Among them, the author insists that deepening *recognition of relevance of science* as an effective and feasible approach to enhancing interest in science. Firstly, as Itoi et al. (1998) and Inoue & Ikeda (2008) stated, the recognition that science is useful for future life can directly influence whether students like science or not after secondary school level. The current educational policy emphasizes the relationship between science and everyday life (MEXT, 2008; 2009). Among some aspects of relevance of science (daily-life, career, or social aspect), however, the daily-life aspect has been emphasized much more than the others. In fact, not many science teachers explain about the linkage of contents with students' future occupation. While the importance of STEM career in the current society is increasing, more than 40% of students cannot find a relevance between their future occupations and learning contents in science (National Institute of Educational Policy Research, 2016b). In addition, despite the importance of learning science not only for experts but also for non-expert general citizens in the era of trans-science (Kobayashi, 2007; Weinberg, 1972), this relationship is currently not attracting much attention in science education. But this should be also included in the "relevance of science" for

students who live in this trans-science era.

Secondly, the relevance of science can also indirectly influence interest in science through enhancing content comprehension. According to Eccles et al. (1983), when we recognize the value for the task, the motivation for achieving that task will be stronger. In a similar study, Glynn, Taassobshirazi, & Brickman (2007) investigated for university students in non-science majors. They empirically revealed that motivation is higher for students who recognize that science is related to their disciplines in the university, and as a result, science grades are also high. By interpreting these findings along with the strong influence of content comprehension (see subsection 4.2.5.), we can conclude that deepening the recognition of the relevance of science can lead to increase motivation and content understanding, resulting in engendering interest in science. Students need to understand the contents to some extent for them to feel that science is fun. For those reasons, it is desired to let students be firmly aware of the necessity to understand the contents and to motivate them at secondary school level.

Furthermore, Harackiewicz, Rozek, Hulleman, & Hyde (2012) reported the positive result of a relatively simple intervention on the students' motivation for science learning. They highlighted the usefulness of STEM courses for students through showing the relevance of science and mathematics to daily life and preparation for college and careers. In their intervention, they prepared some brochure and a website. Therefore, an approach focusing on the recognition of relevance of science with researcher-made materials can be very promising and feasible to enhance interest in science.

Notes. This chapter developed the following research.

Naganuma, S. (2015). *Rikabanare no Doukou nikansuru Ichikousatus -Jittai oyobi Geninn ni Shotenn wo Atete-* [A Study of Research Trends in "Decline in Students' Positive Attitude toward Science" –Focusing on Its Current Condition and Causes]. *Journal of Science Education in Japan, 39*(2), 114-123.

Chapter 5. Development and Evaluation of Science Learning Aids for Students in a Humanities track (SLASH)

In this chapter, the author developed *Science Learning Aids for Students in a Humanities track* (SLASH) for high school students, who could not recognize the relevance of science. SLASH is a supplementary learning material containing video clips and various questions that contextualizes how science relates to university courses or civic life. The author first described its development process and then analyzed its effectiveness on the *belief in the relevance of science* with the post-questionnaire data from 208 high school students. The results showed that there were no significant differences in terms of school, science ability, gender, and initial interest in the topics in their effect on the change of the belief, while 95% confidence intervals were above 3 (*unchanged at all*). On the other hand, SLASH could not positively influence those who had already been familiar with the contents. The author suggests that SLASH can change the belief in the relevance of science for a wide range of high school students in a humanities track.

5.1. Introduction

In the previous chapter, it was discussed that only increasing the opportunities to conduct scientific experiments and observations would not be sufficient to improve interest in science, especially for secondary school students. This might be because they start to think how science is related to their future life. In order to improve their interest in science, we need to show the importance of science in their future life as described in Chapter 4. Let us start with the present trend of relevance of science.

5.1.1. Background.

It has been a while since science education community emphasized "usefulness" or "relevance" of science. In TIMSS 2003, the question "Is it necessary to take good grades in order to get the job you wants?" was asked. Only 39% eighth grade students agreed to this question (National Institute of Educational Policy Research, 2005), while the international average was 66%. Also, in the questionnaire survey of PISA 2006, the 15-year-old Japanese children's "instrumental motivation to learn science" was the lowest level among participating countries (National Institute of Educational Policy Research, 2007). This is an indicator to see whether a motivation for science learning is

determined by the prospects of future job. These results have had a considerable influence on subsequent educational policies. For example, the Course of Study for high school released in 2009 emphasized “connection with daily life and society” in physics, chemistry, biology, and earth science. Also, a new subject “science and human life” was established (MEXT, 2009). In the textbooks, it is introduced how scientific knowledge is used in our daily life in the form of metal, plastic, food, etc. (Iguchi, Aihara et al., 2012; Tatsumi et al., 2012). As a result, in PISA 2015, the percentage of positive answers to the item of “The teacher clearly explains the relevance of broad science concepts to our lives.” has increased to 33% from 19% in 2006. Also, students’ instrumental motivation to learn science, increased in 2015 compared to 2006. In specific, we can see 14% improvement from 47% in 2006 for “Making an effort in my school science subject(s) is worth it because this will help me in the work I want to do later on.”; 15% improvement from 42% in 2006 in “Studying my school science subject(s) is worthwhile for me because what I learn will improve my career prospects.” (National Institute of Educational Policy Research, 2016).

To see these figures, it appears that the national policy has made certain positive impacts. However, still it is hard to say that most students are aware of the relationship between science and themselves. It is true that the proportion of positive answers on instrumental motivation improved in 2015, but it is still lower than the OECD average and over 40% of students cannot find a relevance between their future occupations and learning contents in science (National Institute of Educational Policy Research, 2016). It would not be sufficient that some of the students recognize the relevance of science in this society surrounded by science and technology. This indicates the need to continually discuss how to stimulate students’ interests and motivation at the educational policy and practice level. In order to enhance interest in science discussed in Chapter 4, it is expected to increase students who recognize that science is relevant to them.

5.1.2. Previous approach.

In Japan, some interventions to improve the belief in the relevance of science were developed besides the educational policy mentioned above. For example, Okubo & Hitomi (2004) and Hitomi & Kobayashi (2012; 2014) developed some modules focusing chemistry in daily life for high school students. Students investigated the differences between wine and brandy, and the function of vitamin C in the module.

These interventions resulted in that many students agreed to “I feel that chemistry is useful for me.” Osaki (2010) introduced some familiar technologies or products such as Wii remote control and digital camera for junior high school students to understand the concept of “acceleration.” Utsumi (2015) reported that in the physics textbooks, “principle of work” is introduced with wheelchairs, cranes, and bicycle. These cases focus on how science relates to things familiar to the students and emphasizes the involvement of science at the “individual” level in everyday life.

However, for example, in Hitomi & Kobayashi's survey, although whole positive answer is around 80%, the students who answered “I strongly agree that science is useful for me.” were approximately just from 10 to 20% (Hitomi & Kobayashi, 2012). The rest 60 to 70% agreed a little. Therefore, it seems difficult to make more students understand the relationship between science and themselves with these interventions alone. More multifaceted and multilateral interventions are required.

5.1.3. Possible new approach.

Then, what kind of interventions can be effective? In this study, the author will consider the intervention targeting on the high school students in a humanities track who will have more shallow connection with science than ones in a science track. First, aside from the daily life connection as described above, an approach from career viewpoints deserves attention. (Here, the meaning of career is broad and includes not only occupations but also desired university courses.) This approach focuses on the connection between science and humanities disciplines (including social science) in university. The fact that the boundary between the humanities and science has become unclear was pointed out in the 1980s (Ota, 1981). Today, science is becoming more involved in the humanities disciplines. Take the archeology for example. The archeologists are using radiocarbon dating technique to determine the age of an object containing organic material. Recent development of science has been advancing archeological research further. However, little attention has been given to science involved in a humanities track described above in high school science education. A study suggested that when students in non-science major have a belief that science is related to their disciplines in the university, their motivation to learn science tend to be high (Glynn, Taassobshirazi, & Brickman, 2007). Thus, it is empirically supported that focusing on connection between science in humanities disciplines is one possible and promising approach.

In addition, how science is involved in everyday life is not limited to the individual level. We live not only as "individuals" but also as "citizens" in the society. This civic role has nothing to do with whether a person is from a science track or a humanities track. Particularly in a democratic society, it is required for all citizens to be interested in various social issues and to have own opinion. Such social issues are sometimes controversial, trans-scientific questions (Kobayashi, 2007; Weinberg 1972). High school students in Japan have to seriously consider these social issues soon since voting rights have been lowered to be given to 18 years old.

In summary, interventions emphasizing the connection between science, and "humanities disciplines in university" and "social controversial, science-related issues" for high school students in a humanities track seem effective in making them recognize the relevance of science with them.

5.1.4. Purpose.

The purpose of this study is to develop the *Science Learning Aids for Students in a Humanities track* (SLASH) in order for high school student to develop positive recognition of the relevance of science with them. Then the author will evaluate the effectiveness of SLASH after action researches using SLASH in the classroom. A post-questionnaire is also developed to measure students' belief in the relevance of science. It is analyzed to what kind of students SLASH is effective to positively alter students' belief in science.

5.2. Development of SLASH

5.2.1. Overview.

SLASH is a multiple-choice, question-typed drill. It incorporates the contexts of humanities disciplines that students possibly learn in the university and of social situations where they will encounter as citizens. Considering feasibility, the author adopted learning aids instead of teaching intervention. Once developed, learning materials are easy to use in the classroom. Moreover, it is intended that answering questions in the learning materials would engage students more deeply than just listing to the lecture in general.

The notion of answering questions could positively influence the affective domain in this study is theoretically based on the "consequential validity" (Messick, 1996) in the test theory. So far, consequential validity concerns whether or not the use

of the scale will adversely affect participants in short-term or long-term. In this study, however, the author stands on the position that tests or questions can have a positive effect on the affective domain of participants.

For example, *Big Science Competition* in Australia—the science ability test for secondary school students—stands on this notion. This test refers to state-of-the-art scientific research in the test development process (ASI, n.d.). Test developers provide some information for participants to understand and answer questions dealing with leading scientific topics. It is intended to enhance students' motivation to learn science. This is a novel idea since answering questions has been mainly used to deepen understanding of the contents or to assess knowledge and skills.

In the development of SLASH, some academic field generally classified as humanities disciplines in Japanese university and the social topics which citizen will encounter are used as contexts of the questions. It is intended that students can recognize how science is used in these contexts in answering the questions. SLASH questioned scientific knowledge and skills in the basic chemistry and biology that many high school students in a humanities track take up. That is, SLASH not only has a function to assess wide cognitive domains such as scientific knowledge and skills, but also is designed to positively influence students' belief in the relevance of science. In the following subsection, the development process of SLASH is explained.

5.2.2. Making questions.

Development process of SLASH started with finding out science-related academic disciplines from humanities disciplines. The author interviewed graduate students or faculty members who were conducting researches in humanities disciplines including economics, law, philosophy, geography, archeology, etc. The interview question was "Is what you have learned about science utilized in your academic fields or in your current research in university or graduate school?" With the response for this interview, the author selected some academic fields while referring to the current science textbooks (basic chemistry and basic biology). Through this process, four humanities disciplines—psychology, economics, criminology, and archeology—were judged to satisfy the purpose of this study. Table 5-1 shows how each discipline incorporates science. Then, with reference to the authentic topic in each academic discipline, questions were developed at an understandable level for high school students.

Next, in order to find out how science is involved in the daily life beyond the

Table 5-1

Contents of SLASH

		Humanities Disciplines				Civic Contexts	
Discipline or Context		**Psychology**	**Economics**	**Criminology**	**Archeology**	**Environment**	**Complex Area**
Topics		Psychological investigation with Twins	Economic Approach to Diversity Conservation	Evolutionary Approach to Criminal mind	Carbon usage to know age and food culture	Global Warming and Carbon Dioxide	Safety of GMO
Relationship with Science	**Contents**	Gene	Biodiversity	Evolutionary Theory	Carbon Isotope	Global Warming	Ecosystem
	Methods	Scientific Evidence	n.a.	Scientific Evidence	Scientific Evidence	Scientific Evidence	Scientific Inquiry
Competency	**Q1**	Predicts the expected result that supports genetic influence.	Understands the necessity of biodiversity.	Predicts the results that supports criminal hypothesis.	Applies knowledge of food chain and photosynthesis.	Relates global warming with the increasing carbon dioxide with scientific evidence.	Identifies the variables controlled intentionally in this experiment.
	Q2	Draws conclusion on the influence of gene vs. nurture with scientific evidence.	Predicts behaviour from provided information.	Understands the features of scientific inquiry.	Dates the age of bone from scientific evidence.	Refutes the hypothesis with referring the same graph	Understands how samples are selected in scientific inquiry.
	Q3	n.a.	n.a.	Logically aligns the information to generate a hypothesis.	Predicts the food culture in the ancient era from scientific evidence.	Remembers the knowledge of another possible determinant on global warming.	n.a.
School A (order)		○ (1)	○ (3)	×	×	○ (2)	○ (4)
School B (order)		○ (3)	×	○ (1)	○ (5)	○ (2)	○ (4)

individual level, some PISA open questions were examined. Beyond the individual level, some controversial science-related issues in the society exist involving conflicting groups. While current textbooks deal with some subjects such as global warming, they are not presented as controversial issues in society. Instead, they are often used as materials to improve students' environmental-awareness. Therefore, the aspects of social conflict over global warming are not dealt with there. In this study, among PISA published questions, those dealing with "global warming" and "genetically modified organisms" were judged to have such controversial aspects, and then used (National Institute of Educational Policy Research, 2007).

See Table 5-1 for the detail. Figure 5-1 shows an example of the question under the topic of "psychology." In making SLASH questions, the author also consulted with teachers of the participating school, and discussed in detail the contents. Ethical and cultural problems were checked, too.

Which Determines our Character, *Nature* or *Nurture*? (Psychology)

<Summary of the Clip>

- Psychology is a discipline to understand human behavior or mind.
- Example of the Topics:
  - Is my naïve character attributed to my surrounding or my parents?
  - How can we study in an efficient way?
  - In different groups, do we perform differently? Etc.

A question was sent to a psychology association.

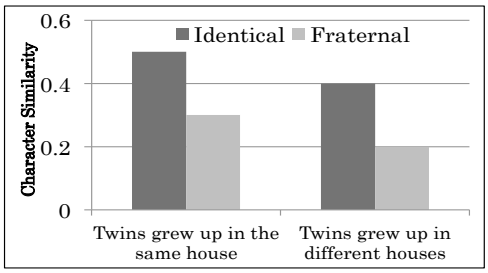
Q. My sensitive character is very similar to my mum's. Is this attributed to genetic influence? Or is it because I grew up beside my mum?

As in the clip, psychologists have long studied genetic and environmental influences on human character. One approach is to compare twins. Identical twins have very similar hair and eye color, and face. On the other hand, fraternal twins have different gene with each other, so their appearances are not so similar.

Q1. If our character is determined by gene instead of our environmental factor, which one most like happens?

① Identical twins grew up in the same house have different characters.
② Fraternal twins grew up in the same house have similar character.
③ Identical twins grew up in different houses have similar characters.
④ Identical twins grew up in different houses have different character.

Q2. Researchers compared couple of twins based on where they grew up. The results below were obtained on how each twin is similar with each other.



*When their characters are similar, *Character Similartity* is close to *1*.

Based on this result, for the initial question—*Is my sensitie character attributed to genetic influence? Or is it because I grew up beside my mum?*—how should you answer?

① Neither genetic nor environmental influences are observed.
② The environmental influence is larger than genetic one.
③ The genetic influence is larger than environmental one.
④ We cannot say anything from these results.

Figure 5-1. Sample of SLASH (Psychology).

5.2.3. Making video clips.

Not only questions but also introductory video clips for each topic were made as learning aids. The first reason is to decrease students' burden to read long sentences before answering the questions. When introducing unfamiliar contexts for students, introductory sentences tend to become long. Therefore, reading long sentences

themselves requires high reading ability, which becomes a heavy burden. In PISA surveys with long introductory sentences, it has already been pointed out that much of the variance of scientific literacy can be explained by reading literacy (Ercikan et al., 2015). To overcome this challenge, movie-typed clips were proposed to use to reduce reading burden. This is a pioneering attempt to see the recent rapid dissemination of ICT in educational practices. Secondly, it is intended that many high school student who worries about their future (NHK, 2012) be motivated for university courses with some university faculties' and graduate students' talk.

In the making of video clips, the author prepared a draft of a manuscript and a slide. It was used after modification by collaborators (graduate students and faculty members). The author edited the clips at first. Then an educational researcher specializing educational assessment and competency checked them. Approximately two minutes clips for each topic was created as the products of these process (see Figure 5-2). The contents of these clips are summarized on the booklet distributed to students, so that they can watch the video in a relaxed mood. The role of these clips is to bridge students from unfamiliar contents to the questions on the booklet. The set of these clips and questions is SLASH. All clips and questions in the SLASH can be openly accessed and used from the following URL (https://www.gsais.kyoto-u.ac.jp/st/SLASH/).

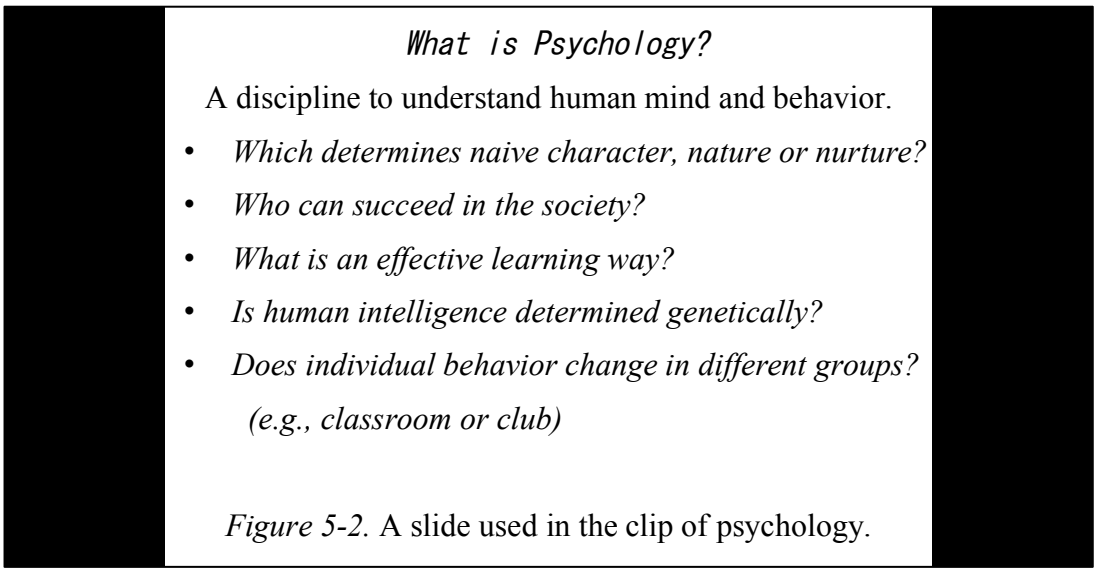


Figure 5-2. A slide used in the clip of psychology.

5.3. Evaluation of SLASH

5.3.1. Perspective of evaluation.

In the evaluation of SLASH, the author examines what kind of students can be

positively influenced in detail. This is because teachers can use this information when they try to use SLASH for their students.

PISA analysis for Japanese high school students revealed that scientific literacy scores influence positively the index of instrumental motivation to learn science, a construct similar to belief in relevance of science in the present study. As well, male students tend to have higher instrumental motivation than female students (National Institute of Educational Policy Research, 2016).

Supported by these findings, the author analyzes whether or not the school, SLASH points (science ability), and gender produce significant difference in the change of the belief. Moreover, in addition to these three variables, it is added to the fourth independent variable whether students have interest in the topics in the SLASH before using it.

5.3.2. Participants.

Two high schools, *School A* and *School B,* participated in this survey: School A is a public, middle level school; School B is a private, advanced level school. The author asked the second-year students for participation. This is because the teachers in the school reported that more students could not find the significance of learning science from that grade. This selection seems appropriate considering the narrow scope of learned contents of the first-year students and the heavy burden on the third-year students preparing for the university examination. Participants finished or were taking courses on basic chemistry and basic biology at that time. They had already learned the scientific knowledge questioned in the SLASH.

185 students participated from School A; 27 students joined from School B. The action research was conducted in the August and September of 2017, respectively. Participants were informed that the data of this survey would be used only for academic purposes, be processed as a group data, and be presented in the anonymous form. After excluding inappropriate responses from four students, data from 184 School A students (80 male; 104 female), and 24 School B students (all male) were used in the following analysis.

5.3.3. Methods.

One topic consists of two minutes' clip-part and five to six minutes' question-part. After distributing the booklet, participants watched the movie for each topic and answered the questions (see Figure 5-3). The author prepared four topics for School A; five topics for

School B (see Table 5-1). The reason of the number of differences is that School B is a higher-rank school than School A in students' ability. Also, the time for each topic is decreased for School A for the same reason. The total time taken for video viewing and answering the question was 37 minutes for School A school; 38 minutes for School B.

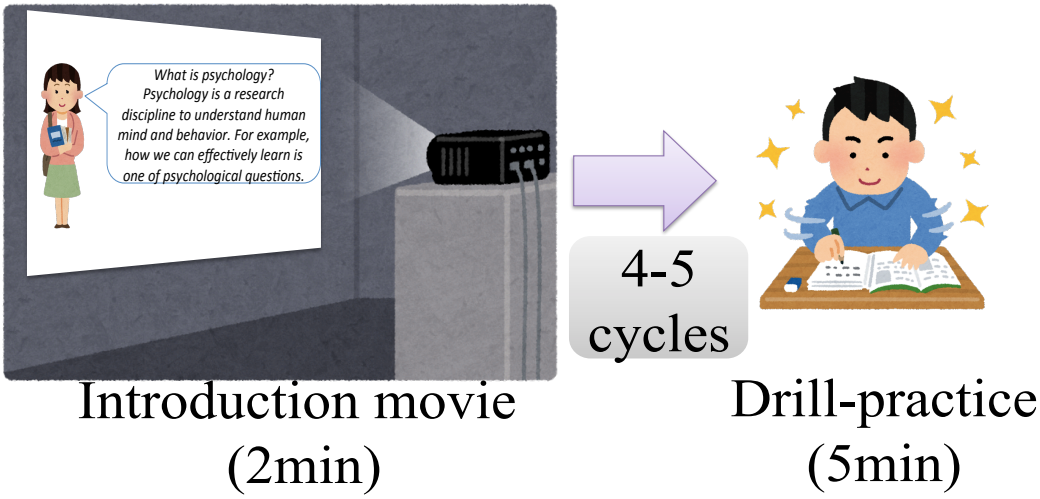


Figure 5-3. Implementation of action research.

The survey completed with the post-questionnaire session after the trial. Then, the author showed correct answers to students and briefly explained about the answers. The total time for this action research was arranged to be within one period—50 minutes.

Demographic information and students' future plan at that time were asked in

What extent did your recognition toward following statement change compared with pre-condition?

1. What I learn in science will be useful in my future life.
2. What I learn in science will be useful in my daily life or civic life.
3. What I learn in science is related to various issues I face.
4. What I learn in science is useful for me to understand various issues I face.
5. What I learn in science is useful for me to make decisions on various issues I face.

Figure 5-4. Belief in the Relevance of Science indicator.

the questionnaire. To ask the desired courses in the university, the questionnaire used in *The 2nd Survey on University Students Learning and Life* was referred (Benesse, n.d.). Next, the author asked students to answer what they felt with SLASH in the free description form. Subsequently, students were asked whether their belief in the relevance of science changed or not (see Figure 5-4 for the index).

The index to measure this change was developed with the following process. First, in McLeod's (1992) mathematics education research, belief is put under the concept of affective domain (Krathwohl, Bloom, & Masia, 1964) as one of the three aspects along with attitude and emotion. Under belief, "about mathematics," "about self," "about mathematics education," and "about social context" line up. Applying this category in the context of science education, "belief in the relevance of science" is considered to be included in "about science" among these concepts.

After this theoretical founding, the author referred to Adachi et al. (2017) in order to make concrete items. Their scale based on the expectancy-value theory by Eccles et al. (1983). In Adachi et al. (2017), those items developed to measure utility value of science for junior high students were employed after modification for high school students. This scale was created with the aim of asking whether science learning is useful or not. In the modification process, the author, majoring science education, and an educational assessment researcher examined content validity together. The item was ranked on a scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*). In addition, students in School B were required to write down the reason of their responses.

5.3.4. Result.

Basic statistics.

The mean and SD were calculated from the students' answers to the change in the belief in the relevance of science. The mean score were 3.76 (SD = 0.49) for School A; 3.65 (SD = 0.52) for School B (Figure 5-5 shows the distributions of 208 responses).

The Cronbach α coefficient to check the reliability of the measures is .80 with 208 students' responses. This indicates that high reliability was ensured. In the following, the author used a mean score of five items as a change in belief in the relevance of science.

The mean scores of SLASH were 5.72 (SD = 1.69) out of 9 for School A, and 10.79 (SD = 1.82) out of 13 for School B.

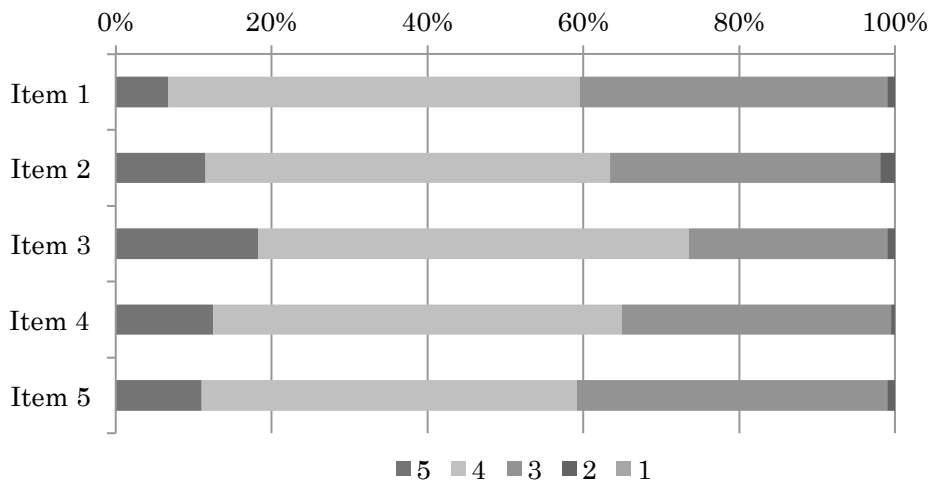


Figure 5-5. Distribution of responses.

School.

As a result of Welch's *t* test, a difference in the beliefs in the relevance of science between School A and School B was non-significant (t (28.72) = 1.03, d = 0.23, *ns*). We cannot conclude that there is a difference between schools. Also, 95% confidence interval was 3.69-3.84 in School A; 3.44-3.86 in School B, indicating that both are higher than 3—the theoretical expected value meaning *no change.* Therefore, it is inferred that there was a positive change in both schools.

SLASH points.

The correlation analysis examined the relationship between the number of correct answers (referred to as *SLASH points*) and the belief in the relevance of science. This analysis was expected to suggest whether there was a difference between the student who had more correct answers and one who had less correct answers. For one question, one point was given if the answer was correct. Partial correct answer was not considered. The following results were obtained: r = .10 for School A and r = -.09 for School B. Both coefficients were non-significant at 5% level (Figure 5-6 shows the scatter diagram for School A.) In other words, no tendency was observed that students with higher SLASH points had a greater change in their beliefs. Along with the results that no significant difference was observed between schools, it can be interpreted that positive change was expected regardless of SLASH points.

Gender.

Similarly, by using the gender as an independent variable, the author examined the

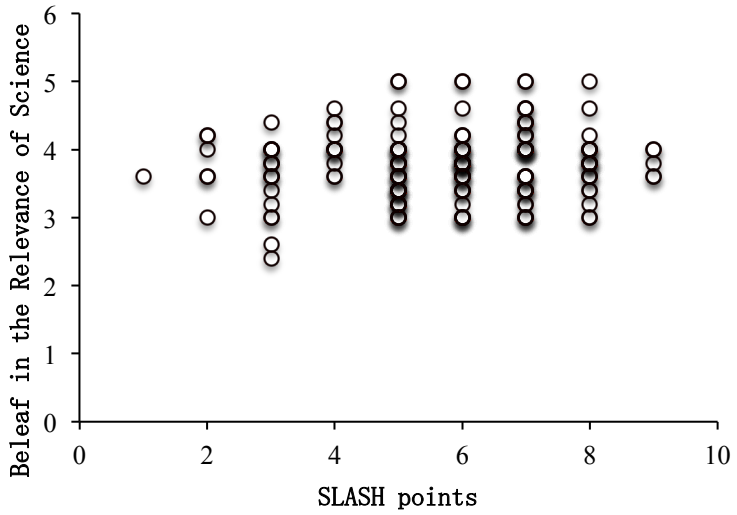


Figure 5-6. Scatter plot (School A).

difference of the mean score (this analysis was not carried out at the School B, which is a boys' school). Boy's mean score was 3.79 (*SD* = 0.50), while girls mean score was 3.74 (*SD* = 0.49). Welch's *t* test shows no significant difference between them (*t* (170.90) = .64, *d* = 0.094, *ns*). That is, we cannot say that there is a difference depending on gender. In addition, 95% confidence interval was 3.68-3.90 for boys; 3.65-3.84 for girls, indicating that both are higher than 3 (*no change*). Therefore, it is inferred that there was a positive change in both boys and girls.

Initial interest.

The last analysis examined whether initial interest in specific topics in the SLASH would determine the change of the belief in the relevance of science. First of all, some humanities fields were classified as follows according to the proximity.

· Psychology category: Psychology, Education, and Childcare

· Economics category: Economics and Business administration

· Archaeology category: Archeology and History

· Criminology category: Criminology and Law

For example, a student who chose "education" was classified in the "Psychology category." 208 students were classified referring to these categories, and divided into four groups: *Group 0* (not interested in any category in advance); *Group 1* (interested in one category in advance; *Group 2* (interested in two categories in advance); *Group 3* (interested in three categories in advance). When a student is interested in business administration and history before a trial, he or she is classified in

Group 2. While only students in School B could be in Group 3, there was no students belonging to Group 3. So, the mean score differences among the three groups (0, 1, 2) were compared with analysis of variance (ANOVA). The results are shown in Figure 5-7 (error bars show 95% confidence intervals). The results indicated that the main effect between groups was non-significant (F (2, 205) = 1.78, *ns*). In the multiple comparisons by the Holm method, no significant difference was found between any groups. Also, 95% confidence interval of all three groups were higher than 3 (*no change*). Therefore, it can be inferred that there was a positive change without strongly relying on prior interest.

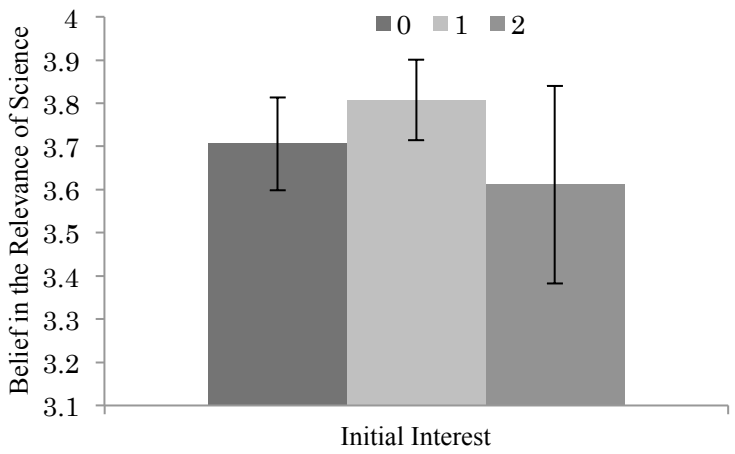


Figure 5-7. ANOVA results.

5.4. Discussion

5.4.1. To whom are SLASH effective?

The present study shows the following as the effects of SLASH. First, despite choosing two different schools in students' ability, we could not observe a difference in the amount of change in their belief. Both schools showed positive change. In other words, SLASH can expect some degree of effect not depending on academic ability, both in middle and advanced schools. This will be certain evidence that such interventions have a positive effect on beliefs with being independent of academic ability.

Secondly, this positive effect can be expected for students with poor academic performances measured by SLASH. The following are free descriptions of students whose SLASH points were lower than the average.

"I realized that science influences our lives largely. I want to learn about science further and know how science is relevant to our lives." (School A, a girl)

"I thought that chemistry is related to many things in our lives." (School A, a girl)

Thirdly, this effect is not strongly restricted by gender. This is a novel finding since preceding studies revealed that current science education is gender-biased (e.g., Tytler, 2014). According to Tytler, topics that girls are more interested in than boys are not included in the current curriculum contents in general. This reflects the notion that science is a masculine subject (Osborne, Simon, & Collins, 2003). Also, Inoue & Ikeda (2008) suggested that more girls than boys struggle to find the relevancy of science. Therefore, the fact that the effect of SLASH was not determined by gender is favorable at this point.

Fourth, even if initially not interested, SLASH could have positive effect on such students' belief. Following descriptions gives us to interpret why this happened.

"I felt that there are various kinds of academic disciplines with this trial (= SLASH). In addition, I have got interested in science and want to study." (School B, a boy)

"I answered the questions of each topic based on the amount of materials that I had never used so far and the talk of the university people. The contents of the material were difficult, so it took me some time to understand it with repeated reading. This trial became a good opportunity because I could get an image of what people are doing in the university." (School A, a boy)

What is inferred from these descriptions is that there are many unknown academic disciplines for high school students and even if not interested in the topics initially, it is possible for students to become interested in them and find relevance of science with those disciplines by using SLASH. In other words, SLASH cannot only change the beliefs in the relevance of science, but also have a role of career education as it includes the viewpoint of high school/university articulation.

Another interpretation of this result is that civic topics of SLASH (global

warming and genetically modified organisms) influenced students positively who were not interested in the academic topics. In this interpretation, unlike the previous explanation, SLASH did not have a role of career education, but influenced through students' awareness as a future citizen. It is beyond the capacity of this study to submit established interpretation for why the initial interest did not produce significant differences on the belief in the relevance of science. Whichever interpretation is reasonable, however, the result indicates that SLASH will be beneficial for wider students in terms of their interest.

5.4.2. Limitation of SLASH.

While SLASH may have the promising effects described above, it was not effective for all students. The free description from School B students revealed that when students had already known the topics contents, positive effect could not be expected even though the students had prior interest in them.

In addition, while the overall positive change of belief in the relevance of science (percentage of students who selected 4 or 5) was as high as nearly 70%, 5 (*strongly agree*) was selected by only 10% students in average (see Figure 5-5). The rest about 60% students selected 4 (*somewhat agree*). So there was not so much difference compared with the intervention developed in Hitomi & Kobayashi (2012; 2014). However, this fact does not deny the effectiveness of SLASH. As pointed out by McLeod (1992), beliefs are developed over a relatively long period of time. In the situation where interventions are not fully developed, it would be difficult to sustain favorable beliefs in the long term. Therefore, developing multifaceted and multilateral approaches is desirable. It would be the most appropriate way at this moment to employ SLASH, Hitomi & Kobayashi's modules, and other materials comprehensively to enable students to recognize the relevance of science.

5.4.3. Implications for future study.

In this study, for high school students in a humanities track, SLASH was developed with the aim of positively changing the beliefs in the relevance of science. It is suggested that SLASH affect pupils in a wide range. As Goto, Nakanishi, & Kano (2018) and Kano et al. (2013) mentioned, it is difficult to invite people with low interest in science into science communication events. The developed SLASH is expected to change this situation in the future. In particular, it is noteworthy finding that the positive influence of SLASH is not strongly bound with content comprehension of SLASH,

gender, and initial interest. However, there are some limitations in this study.

Firstly, this study measured the belief in the relevance of science only in the post survey without pre survey. Since the intervention was a short period in one 50 minutes lesson, the author asked the change of belief in the questionnaire considering the burden on the students. This has a disadvantage, however, that we could not identify the students' initial status. While informal interview for the teachers before this trial reported that lots of students had lost their motivation to learn science, this point needs to be examined with pre survey.

Second, how long the change in this belief last is a research question to be inquired. Since questionnaire survey was conducted immediately after the intervention, it was not possible to mention long-term effects.

Thirdly, it was not possible to specify whether the change in the belief is the influence of watching clips or answering questions. While students' free description showed that they could engage in the contents owing to drill-type interventions, this influence remains unclear.

Fourth, this intervention could not employ a comparative study design. Therefore, it is impossible to mention clearly about the effectiveness of SLASH in comparison with other intervention such as Kobayashi & Hitomi (2012).

In the future study, whether it is possible to influence the students who had positive beliefs beforehand and how long the positive change in the belief persists will be required to examine. In addition, through comparative studies, we can obtain further suggestions for how to improve SLASH and whether SLASH is more effective than other intervention. Furthermore, whether this changed belief will enhance interest in science should be examined for tackling the Flight from Science.

Notes. The content of this chapter is under peer-review process.
Naganuma, S. & Matsushita, K. (under review). Development and Evaluation of Science Learning Aids for Students in a Humanities track. Educational Technology Research.

Chapter 6. Conclusion

In this chapter, the major findings and limitations of the investigations in Chapter 2-5 are discussed collectively to address the research questions that framed the work in this dissertation. The main implications that arise from these studies for practice and future studies will also be presented.

6.1. Main Findings

The main findings relevant to the six key questions presented in Chapter 1 are summarized as follows.

1) **What is the current situation of adults' civic scientific literacy (CSL) in Japan?** (Chapter 2)

ACSEL assessed the three competencies assessed: *Using Scientific Evidence* (USE), *Explaining Scientific Inquiry* (ESI), and *Making Decisions* (MD). Results from 401 Japanese citizens (66.6% female; ages 20-69) were reported here. The most novel results were that most Japanese citizens just raised only one objective reason or emotional reasons to support their decision on trans-scientific issues dealt with in ACSEL. Only a few percent of participants could give at least two objective reasons to support their decisions. These results deserve careful attention since reliable scientific knowledge on trans-scientific questions is often not available (Kobayashi, 2007; Todayaya, 2011; Weinberg, 1972). If most people represent their opinions on single objective information with uncertainty, their opinions will change easily in response to emergence of new or alternative information. This will result in the confusion in the society. We need citizens who can raise at least two objective reasons on trans-scientific questions.

2) **Does a new instrument (ACSEL) satisfy allowable level of the reliability and validity?** (Chapter 2)

The reliability and validity of ACSEL were examined in Chapter 2. Cronbach's α coefficient indicated that the two competencies—USE competency and ESI competency—had allowable internal reliability while the MD competency showed low value, which is unacceptable in general. This low value might reflect the notion that the MD competency is domain-specific rather than generic. This result cautions that we

should not view the MD competency as generalized one in this study.

The validity was examined in a pilot study for the graduate students and contents check by experts. We can say, through this process, that surface validity and content validity of ACSEL were checked. However, other types of validity such as concurrent validity and consequential validity were not checked in this study. In this sense, validity of ACSEL can be further investigated

３） **What demographic factors influence CSL?** (Chapter 2)

The author examined whether demographic variables (gender, age, and educational background) determined CSL in ACSEL. In general, these variables did not produce significant differences. Only educational background influenced the ESI competency slightly.

４） **Do the nature of science teaching, interest in science at high school level, and scientific knowledge determine CSL?** (Chapter 3)

Chapter 3 explored whether the nature of science teaching and interest in science at the high school level and scientific knowledge influence adults' CSL in a retrospective way with multiple regression analysis. The result showed that hands-on activities and scientific knowledge did influence all the three competencies in CSL significantly. Moreover, this study highlights the importance of interest in science for the MD competency. On the other hand, the other three promising teaching approaches (interactive teaching, student investigations, and use of applications) had either no significant impact or even significant negative impact.

５） **What is promising and feasible approaches to increase interest in science?** (Chapter 4)

In Chapter 4, the author focused on interest in science that would enhance the MD competency, supported by the results from Chapter 2 and 3. Previous studies in Japan on interest in science from elementary to secondary school level were reviewed. Through this comprehensive review, the author abstracted six determinants as follows: teacher, parents, teaching methods, informal experience, difficulty of science, and relevance of science. Considering the social situation and working environments of teachers, the author concluded that focusing on relevance of science is a promising and

feasible approach to enhance interest in seience.

6) **To whom are the new learning aids (SLASH) effective in order to change the belief in the relevance of science, one of the key factors to increase interest in science?** (Chapter 5)

Backed up by the conclusion in Chapter 4, the author developed Science Learning Aids (SLASH), for high school students in a humanities track who hardly recognized the relevance of science. SLASH is a supplementary material with various questions, and contextualizes how the science relates to the situation in a university or a civic life in the future. The data from 208 high school students was analyzed, focusing on the "belief in the relevance of science." The results showed SLASH could have positive impacts for broad scope of students regardless of school, SLASH points, gender, and initial interest. This changed belief is expected to enhance students' interest in science in the future.

6.2. General Conclusions

In this study, the author started evaluating CSL corresponding to the era of trans-science by using a new assessment tool, ACSEL (Chapter 2). In this research, the author evaluated the three competencies (USE, ESI, and MD), which had not been evaluated so far, for adults over 20 years old. As a result, it became clear that most citizens were making decisions based only on their emotions or only on one uncertain scientific evidence for trans-science issues. These trans-scientific questions are new in that experts and citizens need to work together to reach solutions. As Todayama (2011) mentioned, citizens need to propose multifaceted framing with respect to society, politics, ethics, responsibility and credibility, while respecting scientific risk evaluation. Given such capabilities are necessary, the current situation is unlikely to satisfy these demands. Therefore, it was judged that there is a problem in terms of the MD competency. Then, what kind of intervention can be effective to improve this MD competency? In Chapter 3, in order to answer this question, some factors were examined by multiple regression analysis. As a result, it was suggested that improving interest in science, enabling students to learn basic scientific knowledge, and increasing opportunities for hands-on activities are effective for improving the MD competency. Of these, how to improve the interest in science has been long debated in Japan since

around the 1990s. It is an "old new problem" that has not been solved yet. Therefore, in order to obtain suggestions as to how to improve the interest in science, the author has extensively reviewed over 20 years of researches in Japan. Major determinants abstracted from these literatures were categorized into six: *parents, teachers, teaching methods, informal experiences, difficulty of science, and relevance of science*. The results suggested that the approach to enable students to recognize relevance of science is effective (Chapter 4). Standing on this conclusion, in Chapter 5, Science Learning Aid for Students in a Humanities track (SLASH) was developed and its effect was examined. It was suggested that SLASH can be effective in changing the belief in the relevancy of science for a wide range of students without being strongly restricted by science achievement, gender, and initial interest.

Based on the results above, for improving CSL of adults from long-term viewpoints, the following suggestions can be obtained. In high school education, SLASH can positively change the belief in the relevance of science of high school students, which will lead to an increase in interest in science. With this interest, they can access and understand various information when making decisions on trans-scientific issues after becoming an adult. This will result in enhancing the MD competency in CSL. The results of this study, however, do not always guarantee such a long-term formation process for CSL. Section 6.4. describes this point in detail.

6.3. Original Contributions of the Present Study

The significance of this study is, firstly, its focus on adults' scientific ability, who have not been focused so far compared with school children. The assessment the author implemented that employs authentic assessment theory is pioneering in the field of scientific literacy research for adults. It cautions against overdependence on Miller's Oxford Scale to assess CSL.

Secondly, the present study provides the basic information for the status of CSL in Japanese general citizens. These data inform us how competent Japanese adults are in CSL.

Thirdly, the analysis of connecting the adults' CSL with the high school days' attitudes or experiences can be applied to other studies in the future in that it examines long-lasting influences of high school learning.. This approach stands on the position that educational outcomes sometimes appear in some later time.

In the fourth point, the author presented a promising approach to enhance interest in science considering feasibility. Since Flight from Science has been discussed for about 30 years, academic significance of this contribution will be high in that this approach can be sustainable.

Finally, the author would like to remind our readers of the fact that this study has developed learning aids, SLASH, as artifacts to bridge two tracks (a science track and a humanities one), which is a unique division seen in Japanese educational system.

6.4. Future Prospect

The following issues remain unsolved in this dissertation. First of all, there is a limitation to make a judgment on the sufficiency of CSL scores. In this study, we concluded that current situation of the MD scores are under satisfaction, considering the unavailableness of scientific knowledge on the trans-scientific questions. However, we could not judge whether the other two competencies were sufficient. In the PISA survey, we can compare Japanese students' literacy scores (reading literacy, mathematical literacy, scientific literacy) with the OECD average scores but such comparison was not made in this study. Such comparison will provide us further suggestions for CSL of Japanese adults.

Secondly, the validity was also insufficiently examined in this study. For example, we can name *Cornell Critical Thinking Tests* as an acceptable measure to critical thinking ability. Examining concurrent validity using such similar scales will be necessary in the future.

Third, clear causality was not identified. Since the author could not adopt the longitudinal research design this time, the causality was judged by using multiple regression analysis and theoretical and logical explanations. Moreover, in order to verify the validity of the long-term formation process as drawn in 6.2., it is necessary to compare CSL of two groups of adults—those who use SLASH and those who do not in high school level. In the present study, due to time constraints, such comparison has not been done.

Fourth, the variance explanation for the competencies ranged from 10 to 20%. It is necessary to examine more variables and models that can improve the variance. For example, the author attempted to make models from the viewpoint of science education

in this study, but we can include the “civic” aspects of CSL in the future study. Factors such as “political consciousness” can also be included in the models to improve its variance explanation.

Fifth, in Chapter 5, while we saw the improvement of belief in the relevance of science, the author cannot present empirical evidence that this change of belief will also lead to an increase in interest in science. It is necessary to clarify this from a long-term perspective.

I hope this research will be helpful for future development of science education research.

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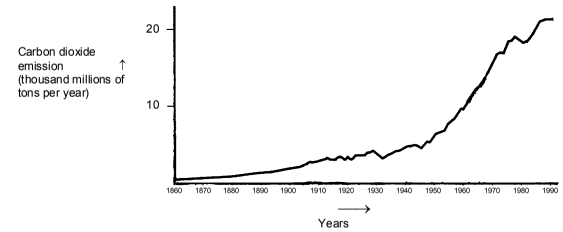
Appendix A. Assessment of Civic Scientific Literacy (ACSEL)

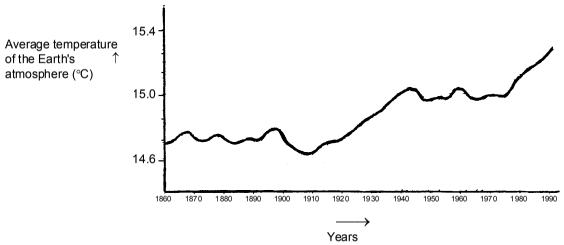
Greenhouse Effect

In newspapers and periodicals the increased carbon dioxide emission is often stated as the main source of the temperature rise in the twentieth century.

A student named Taro (boy's name) becomes interested in the possible relationship between the average temperature of the Earth's atmosphere and the carbon dioxide emission on the Earth.

In a library he comes across the following two graphs.





Taro concludes from these two graphs that it is certain that the increase in the average temperature of the Earth's atmosphere is due to the increase in the carbon dioxide emission.

Q1. What is it about the graphs that supports Taro's conclusion?

Q2. Another student, Hanako (girl's name), disagrees with Taro's conclusion. She compares the two graphs and says that some parts of the graphs do not support his conclusion. Give an example of a part of the graphs that does not support Taro's conclusion. Explain your answer.

Q3. As we saw, opinions about whether greenhouse effect is a cause of global warming or not differ among people.

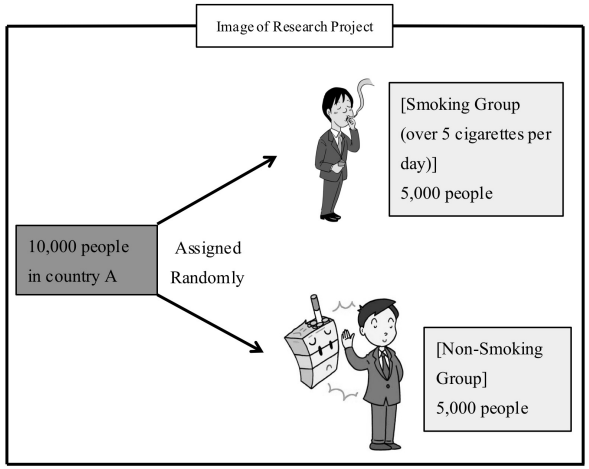
Then, are you agree or disagree with reducing carbon dioxide as a strategy against global warming? State your position and give reasons as many as possible to support your opinion.

Smoking and Lung Cancer

Lung cancer located on higher level of mortality factor in many countries. Some researches insist that smoking lead to lung cancer. On the other hand, others argue their relationship or causal-link is less convincing.

In a country A, therefore, a large-scale research was planned targeting 10,000 people. Below is the image of this research plan. In this project, participants will be divided into two groups randomly. Therefore, those who smoke may be assigned in non-smoking group in which participants are banned smoking.

Some expected this research to be scientifically significant, while public complained that this research had several serious problems. As a result, this research project needed to be reconsidered.



Q1. In the initial research project, what result was expected by researchers which demonstrates the hypothesis that smoking causes lung cancer?

Q2. In this research project, researchers were thinking that it was clearly indicated that smoking causes lung cancer through comparison of two groups. Why do you think did they think so?

Q3. As stated above, public complained that this research had several serious problems. Then what were their criticisms? Raise at most two possible criticisms.

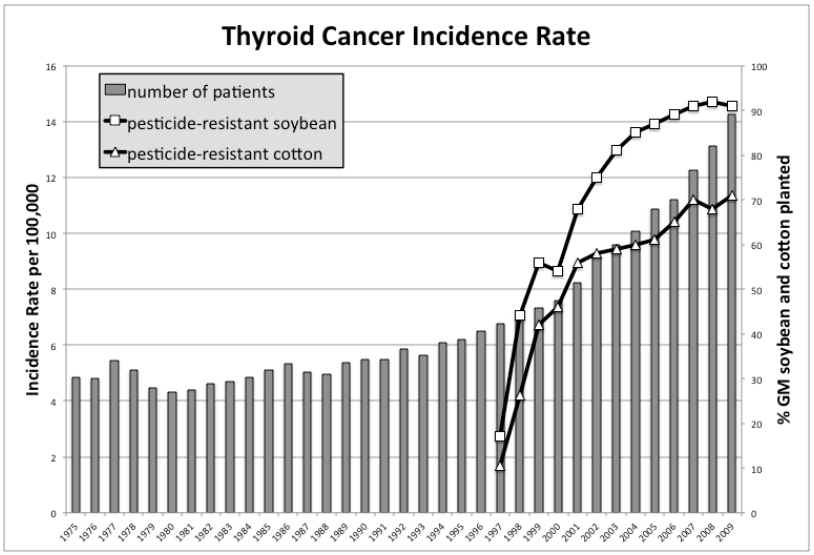
Q4. In your town, under slogan of "Town of Health and Longevity," banning smoking both indoor and outdoor will be taken into policy in order to reduce lung cancer risk. However, as we saw, opinions about whether smoking is a cause of lung cancer or not differ among scientists.

Then, are you agree or disagree with banning smoking as a strategy against the risk of lung cancer? State your position and give reasons as many as possible to support your opinion.

Genetically Modified Organisms

Genetically modified technology means to extract gene from cells of the organism, and incorporate it into plants' gene to make plants have new property. By using this technology, it is expected that organisms can have property that producers or consumers hope to. This organism is called "Genetically Modified Organisms."

There are two standpoints concerning genetically modified organisms. Some people insist that we have to promote it since it will bring many advantages for producers or consumers. Others question the safety of it and show prudent attitude toward its use. Then, people who are prudent give the graph below as the basis of their supporter.



Q1. In this graph, pesticide-resistant soybean and pesticide-resistant cotton are genetically modified organisms. With pesticide-resistance, a particular pesticide does not work to wither.

Then, what is it about the graphs that supports conclusion of those who are prudent?

Q2. Against this conclusion from those who are prudent, those who promote refute them indicating the limitation of the graph. What do you think is it?

Q3. As we saw, opinions about whether genetically modified organisms are safe or not does not match.

Then, are you agree or disagree with the sales of genetically modified organisms? State your position and give reasons as many as possible to support your opinion.

(This graph was created with the public domain data from http://www.ers.usda.gov/data-products/adoption-of-genetically-engineered-crops-in-the-us/recent-trends-in-ge-adoption.aspx#.UWkbfivtcRc and http://seer.cancer.gov/csr/1975_2009_pops09/download_csr_datafile.php/sect_26_table.05.csv)

Appendix B. Rubric for Greenhouse Effect

Score	GE1 [USE]	Examples	Score	GE2 [USE]	Examples	Score	GE3 [DM]	Examples (pro)	Examples (con)
3			*3*			*3*	State more than two objective or persuasive reasons beyond emotional reasons	***"There is a few evidences that can deny the effect of carbon dixide on warming. Also, it is significant to take such a strategy in this international society in terms of cooperation.***	***"Because carbon dioxide cannot be said the cause of grobal warming, and strategies to reduce it might force people to change their life dramatically.***
2	Refers to the increase of both temperature and carbon dioxide emission, or positive relationship between the two.	***"As the emissions increased, the temperaure increased."***	*2*	Refers to one particularr part of the graphs in which the curves are not both decreasing or both climbing and gives the corresponding explanation.	***"In 1900-1910 carbon dioxide was increasning, whilst the temperature was going down."***	*2*	State one objective or persuasive reason beyond emotional reasons.	***"We face not only grobal warming but also other human-caused damage to natural world, so it is impotant to respond and take action for these. "***	***"As the above discussion shows, carbon dioxide is not identified as a cause of grobal warming."***
1	Refers to the increase of either temperature or carbon dioxide emission.	***"The temperature increased."***	*1*	Mentions a correct period, without any explanation. Or mentions the differnces without refering a specific period.	***"1930-1933." "At same places the temperature rises even if the emission decreases."***	*1*	State unconvincing reasons, especially emotionlal reasons.	***"I would like to do what I can do for the future."***	***"I don' t want to change my present life."***
0	Unrelated answers		*0*	Unrelated answers		*0*	Unrelated answers		

Note. USE = Using Scientific Evidence, ESI = Explaining Scientific Inquiry, MD = Making Decisions

Appendix C. Rubric for Smoking and Lung Cancer

Score	SLC1 [USE]	Examples	Score	SLC2 [ESI]	Examples	Score	SLC3 [ESI]	Examples	Score	SLC4 [MD]	Exapmles (pro)	Examples (con)
3			*3*	State that scientific inquiry to identify causual-link requires control group to control other variables.	**"Because we can equalize factors other than smoking."**	*3*	State at least two reasons that scientific inquiry will be restricted in terms of social side: cost, ethics, human rights, risk, damade to sorroundings.	***"This will damage human rights and cost much."***	*3*	State more than two objective or persuasive reasons beyond emotional reasons.	***"It is true that manner of smokers is not good and banning smoking will lead to improve the environment and sanitation of our town. "***	***"It is not revealed what effects smoking has on lung cancer and this new agenda takes away too much freedom of smokers."***
							State one possible shortcoming inside the research project and one social restrict.	***"Air pollution or stress which will affect the outcome are not considered, and ethically, it is problematic to make people smoke against their will."***				
2	State that more people with lung cancer will be seen in smoking group than in non smoking group.	***"We will recognize more patients in smoking group than in non smoking group."***	*2*	State that scientific inquiry requires control group while the reason for this is not mentioned.	**"We can detect the influence of tobacco clearly through comaprison."**	*2*	State only one reason. Or state two reasons but it lacks social perspectives.	***"Air pollution or stress will affect the outcome, too."***	*2*	State one objective or persuasive reason beyond emotional reasons.	***"Because some smokers' manner is not so good."***	***"Tobacco is said to decrease the stress of smoker."***
1	Focusing on only one group.	***"A rate of incidence of lung cancer is high in smoking group."***	*1*	Not state the reason why comparison is required.	**"Because tobacco contains harmful substances."**	*1*	Try to state related answers but cannot reach valid level or remain ambiguous.	***"The conditions before this research project are different."***	*1*	State unconvincing reasons, especially emotionlal reasons.	***"Because I dislike dobacco."***	***"Because I like to smoke tobacco."***
	Compare two groups without explicitly mentioning which group will have more patients.	***"We can see the difference of number of patients."***		Misunderstand the reason of comparison.	**"To keep enough number."**							
	State unrealistic results.	***"All people will become lung cancer in smoking group."***										
0	Unrelated answers		*0*	Unrelated answers		*0*	Unrelated answers		*0*	Unrelated answers		

Note. USE = Using Scientific Evidence, ESI = Explaining Scientific Inquiry, MD = Making Decisions

Appendix D. Rubric for Genetically Modified Organisms

Score	GMO1 [USE]	Examples	Score	GMO2 [ESI]	Examples	Score	GMO3 [MD]	Examples (pro)	Examples (con)
3			*3*	State that we cannot identify the cuasual-link only from the given graph.	***"From this graph, we cannot insist causal-link of genetically modified organism on Tyroid cancer."***	*3*	State more than two objective or persuasive reasons beyond emotional reasons.	***"Production of crops will be increased and consumer can take nutrition more efficiently."***	***"It is true that people will be afraid of its risk and discussion about if human should operate gene or not seems not enough."***
2	State that both genetically modified organisms and patients of Tyroid cancer are increasing.	***"Two genetically modified organisms are increasing while patients of Tyroid cancer are going up."***	*2*	State possible but insufficinent counterargument in terms of causual-link.	***"Other variables like gene will be the cause of Tyroid cancer, too."***	*2*	State one objective or persuasive reason beyond emotional reasons.	***"It will lead to solve the food lack problem."***	***"We have to wait future reseaches if this will affect or not future generations' health."***
1	State only either genetically modified organisms or patiensts of Tyroid cancer.	***"The number of patients with Tyroid cancer is increasing."***	*1*	Not essential answers though attempts to answer is seen.	***"The number of patients is still low."***	*1*	State unconvincing reasons, especially emotionlal reasons.	***"I don't care."***	***"Natural things is better."***
0	Unrelated answers		*0*	Unrelated answers		*0*	Unrelated answers		

Note. USE = Using Scientific Evidence, ESI = Explaining Scientific Inquiry, MD = Making Decisions