Views on the Orientation of Science in Decision-Making Revealed in Undergraduate Students' Discussion on Socio-Scientific Issues

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Abstract: The aim of this study was to identify students' views on the orientation of science and to investigate the relationship between their views and decision-making on socio-scientific issues (SSI). In this study, 27 university students attending a science course were asked to discuss four controversial issues: the Toyota recall, the green car, the global warming and swine influenza (influenza A (H1N1)). The study was comprised of two stages. At the first stage, we examined students' views on the nature of science and on the orientation of science with the open-ended questionnaire based on VNOS and VOSTS. While they held relatively similar views on the nature of science, their views on the orientation of science were distinct as pragmatic, intrinsic, communal and ethical views. At the second stage, to examine the role of their views on the orientation of science in decision-making, we selected four students who had similar views on NOS but different views on the orientation of science. The four students were selected from each group of views on the orientation of science and their decision-making processes were analyzed following grounded theory. Across SSIs, they relied upon their views on the orientation of science as the strategies for decision, though considered different perception, and causal and contextual conditions. This study indicates that understanding students' views on the orientation of science would be helpful for achieving scientific literacy for informed decision.

Key words: orientation of science, discussion, decision-making, socio-scientific issue, nature of science

1. Introduction

One of overarching goals in science education is achieving scientific literacy, which has been placed on the central area of many curricula, international reform and research outputs (DeBoer, 2000; Hodson, 2003, 2008; Hurd, 1958; Laugksch, 2000; OECD/PISA, 1998). The term implies the capability to assimilate science knowledge in media, to assess the information and to make appropriate judgment for decision-making (Hodson, 2008; OECD/PISA, 1998; Shamos, 1995). Achieving scientific literacy is strongly associated with informed decision-making (Ratcliffe & Grace, 2003).

In this vein, science education have made an effort for informed decision-making through the enhancement of science knowledge, the nature of science, moral sensitivity, risk assessment, personal experience and others (Albe, 2008; Kolstø, 2006; Lewis & Leach, 2006; Sadler, Chambers, & Zeidler, 2004; Simonneaux & Simonneaux, 2009). Among them, the nature of science (NOS) is expected to contribute to the enhancement of decision-making in socio-scientific issues (SSI), but its role is still vague. Many researchers reported that some aspects of NOS influenced the interpretation the evidence in SSI (Walker & Zeidler, 2007; Zeidler, Walker, Ackett, & Simmons, 2002) and made a difference in taking multiple reasoning (Liu, Lin, & Tsai, 2010; Schommer-Aikins & Hutter, 2002). On the contrary, Bell and Lederman (2003) challenged the assumption that NOS may influence decision-making. In their study, there was little difference of reasoning and decision-making according to the views on NOS. Others addressed that non-scientific factors such as personal experience, emotion and socio-economic reasoning were more central than NOS-related factors (Fleming, 1986a, 1986b; Langford, Marris, & O'Riordan, 1999; Schwarz, 2000; Zeidler & Schafer, 1984).In short, the role of NOS in decision-making has yet to be more

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closely investigated.

In this study, we coined the term, the orientation of science, as another factor accounting for decision-making, which has been brought from Klopfer (1971, 1976). He stressed the orientation about science's relationships with society as well as attitudes toward and interests in science when delineating the affective domain to science education. Regarding the interactions of science with society, he addressed interdependence of science, technology and society, influences of science on society, and influences of society on science. However, many students are concerned about the value of science (Jho & Song, 2011). Thus, we conceptualized the orientation of science combining his idea with the value of science, which means the stressed aspects of science such as the usefulness and honesty of science activities. The value of science is meaningful because NOS does not contain the ontological aspects and students' views on it are connected to their behavior in science classroom (Jho & Song, 2011).

The orientation of science tackles different aspects of science, which is distinguished form NOS dealt with in the previous studies. Although the orientation of science is connected to socio-cultural embeddedness, the orientation of science not only considers how science is affected by society and culture but also regards how science gives an impact to society. As well, NOS focuses more on the epistemic aspect of science empirical nature and imaginative activities of scientists (Abd-El-Khalick & Lederman, 2000; Lederman, 1992; Lederman & O'Malley, 1990), rather than the relevance to society. As well, there are some missing aspects the aim or value of science. In this vein, the orientation of science needs to be regarded more significant, in the context of decision-making in SSIs.

Thus, this study aimed to identify students' views on the orientation of science and to investigate the relationship between their views and their decision-making on SSIs. In this study, 27 pre-service teachers who attended a SSI-teaching course were asked to discuss the four controversial SSIs: the Toyota recall, green car, global warming and swine influenza. The main questions about the four issues were as listed: whether or not the recall service was reliable; whether the green car was helpful for the environmental protection; whether or not the global warming was a genuine disaster; and whether vaccination for swine influenza was perilous. Centering on four students' cases, we tried to articulate the relationship between their views on the orientation of science and their decision-makings. Although there is a limitation of a small number of participants in this study, this study would give implications for the relationship between students' views on science (NOS and the orientation of science) and their decision-making.

2. Research design

The course taught by one of the researchers was intended for students to understand the relevance of science on everyday life as well as science concepts. To raise the relevance, we encouraged students to discuss on the controversial issues in Korea, at the time. The issues tackled were totally eight but in this study we selected the results of four issues because the four were overlapped each other. Each of lessons was composed of one-hour lecture teaching science concepts and one-hour discussion. Students were asked to survey the issues one week before. As for the discussion, snowballing method was adopted (Brookfield & Preskill, 2005). The method starts from individual decision in the issue and then students have a pair discussion. Next, a group of four by combining two pairs makes a discussion, and the size of group doubles over time. Finally, the whole class members have a conversation about the issue. The students' views on NOS and the orientation of science were examined before and

after the course, and the result guaranteed the coherence of their views across the time.

This study was conducted in two stages. At the first stage, we analyzed students' views on NOS and the orientation of science. At the second stage, based on the results of the first stage, we selected four students with similar views on NOS but with different views on the orientation of science, and analyzed the role of their views on the orientation of science in decision-making across SSIs. At the first stage, this study relied upon cross-case data matrix (Miles & Huberman, 1994). Through the open-ended questionnaire, 27 students' views on NOS and on the orientation of science were identified. The questionnaire used was developed through a combination of VNOS-C (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002) and VOSTS (Aikenhead, 1992) and was given to students before and after the course. Centering on seven features of NOS (i.e., empiricism, tentativeness, theory-ladenness, socio-cultural embeddedness, imagination and creativity of science enterprise, no uniform scientific method and relationship between theory and principle), we clarified their views on NOS. Their views on the orientation of science were identified with the mutual influence between science and society and value of science. Table 1, cited from Lederman et al. (2002), shows the examples of naive and informed views on NOS.

At the second stage, we examined how their views on the orientation of science were presented in decision-making processes. In the

Table 1

Illustrative examples to assess the students' views on NOS

NOS aspect	More naive views	More informed views
Empirical	Science is something that is straightforward and is not a field of study that allows a lot of opinions, personal bias, or individual views.	Much of the development of scientific knowledge depends on observation. But observation is a function of convention. Science involves abstraction, one step of abstraction after another.
Scientific method	Science has a particular method of going about things, the scientific method.	There is no uniform method acknowledge as scientific method. Rather, an achievement is done by various reasoning and even intuition and imagination.
Tentative	Compared to philosophy and religion . . . science demands definitive . . . right and wrong answers.	Everything in science is subject to change with new evidence and interpretation of that evidence. There is nothing absolutely true.
Theories and laws	A scientific law is somewhat set in stone, proven to be true. A scientific theory is apt to change and be proven false at any time.	Scientific theories and laws are used for different purposes. While theories try to explain the world presented, laws implies the pattern between observed evidence empirically.
Creative and imaginative	A scientist only uses imagination in data collection. Since then, there is no creativity because he has to be objective.	Logic plays a large role in the scientific process, but imagination and creativity are essential for the formulation of novel ideas.
Theory-laden	Scientists reach different conclusions due to lack of data. The use of the same data would bring about the same result.	Different conclusions are possible because there may be different interpretations of the same data.
Socio-cultural influence	Science is about the facts and could not be influenced by cultures and society. Science matters and principles are the same in everywhere.	Culture influences the ideas in science. It was more than 100 years after Copernicus that his ideas were considered because religious beliefs of the church favored the geocentric model.

first stage, we categorized 27 students into four groups of views on the orientation of science (see Table 2). We selected four students from each group of view on the orientation of science, who shared similar views on NOS to sublime the effect of NOS. We focused on what role their views on the orientation of science played in decision-making (a strategy for action) to solve the phenomenon (SSI).We tried to understand their decision-making process based on grounded theory, because we regarded decision-making as a strategy and consequence to cope with the problems. According to grounded theory (Strauss & Corbin, 1990), a research vignette can be understood as six categories central phenomenon, contextual condition, causal condition, intervening condition, strategy for action and consequence. The central phenomena were the types and degrees of risks that students perceived from each of SSIs; the contextual condition was the background where the central phenomena occurred; the causal condition was the element causing the central phenomena; the intervening condition was a key to mitigate or aggravate the phenomena; the strategy for action implied students' reasoning to cope with the phenomena; and the consequence was their final decision in SSIs.

The data collection mainly relied upon the questionnaire and the transcripts. The questionnaire was developed with items from VNOS-C and VOSTS. Among the questions of VNOS-C, four questions out of ten (Question number: 4, 6, 8, 10) were chosen to assess their views on NOS. Eight questions were employed from VOSTS to examine students' views on the mutual influence between science and society and the value of science (Question number: 40421, 40131, 60211, 60311, 70212, 70411, 70711, and 90211).A total of twelve questions were modified as open-ended items to give more freedom to the respondents. Students' views on the orientation of science were examined by analyzing their responses to the questions. They answered the combined questionnaire before and after the course and their responses were checked for the consistency of their views on NOS and on the orientation of science. For validity and reliability, the researchers negotiated the relevance of questions to examine the view on the orientation of science and the nature of science, and the inter-rater reliability were.864. As for the consistence of their views, their views before the instruction were consistent with them after the instruction as much as 89 percent. In regard to coding scheme about the view on the orientation of science, we examined the inter-coder reliability and Cohen's Kappa coefficient was .614 (reliable if the value is over .600).

As another source, the students' homework and activity paper as well as the audio- and video-taped data during the discussion were gathered. To promote their participation in the discussion and to enhance understanding of their comments, we asked students to submit their ideas about the issues, as a form of homework, to be discussed before the instruction. This work was helpful to understand the meaning that they tried to explain during the discussion. As well, they were facilitated to write down their opinions on activity papers during the discussion. The activity paper was comprised of four parts: their claim and evidence, their counter-claim and evidence, their decision before and after the discussion, and note-taking during the discussion. Through the activity paper, students were encouraged to consider the evidence for their claims and counter-claims and to express their decision-making clearly. With transcribed data, activity paper and homework were used for the triangulation of data analysis. To understand their previous experience related to their decision-making, autobiographical essays were submitted before the beginning of the semester and the essays were helpful to understand personal backgrounds. The group and the classroom (whole) discussion were audio- and video-taped and transcribed.

The informants of this study were selected as an exemplary participant for their decision-making. The students were two male (Jay and Seok) and two female (Gee and Sunny).Jay had little experience about science as school subject because he took a course of liberal arts in high school. He believed that science is quite useful and makes his life better. He confessed that he was a career of hepatitis B and, when he was a secondary student, he had suffered the fracture of his left arm and stayed in a hospital for several months. For this reason, he was interested in health and took care of himself. Seok entered the natural science program at high school and had dreamed to be an engineer. He had entered at college of engineering before the pre-service teacher. He was interested in science experiments and belonged to science clubs at his high school age. Gee took liberal arts program at high school and had entered the department of political science. After the graduation, she had taught students at cram school and occasionally served as a teacher at charity institutes. Over time, she found herself enjoy teaching and finally decided to become a teacher. Similar to Gee, Sunny decided to become a teacher after the experience of volunteering teachers. She completed the instruction of art treatment and taught special children at several schools. For almost five years, she volunteered to help low-income students study. Sunny took the natural science program and graduated from the department of chemistry. At the time, she participated in research project related to pharmacy and was relatively knowledgeable about medicine.

3. Students' views on the orientation of science

According to the analysis of students' questionnaire, we identified four different views on the orientation of science as shown Table 2. Pragmatic view thought highly of usefulness of science and technology; intrinsic view supported science as a fundamental activity seeking the truth; communal view regarded science as an asset of a community; and ethical view stressed the appropriateness of science process and results.

Jay argued that science is not liable for its impact on society because science is just a tool. While he viewed science objective, he considered its application context-dependent. Science itself did not matter to him but the intention and goal of applying science was important to him. In addition, he stressed the fruitfulness of science and technology. While explaining the reason to learn science theories, he mentioned that though they are continuously changing, new findings lead to invent something useful and enrich our lives. He was concerned about a profit from science and technology with an emphasis on neutrality of science and technology. His focus was on the pragmatic value of science and his view was named as *pragmatic view*.

Jay: Many goods in the world have double

Table 2

Description and distribution of the views on the orientation of science in 27 students

Orientation of science	Description	Number of students
Pragmatic view	focuses on pragmatic value of science and technology	9
Intrinsic view	focuses on intrinsic value of science such as seeking the truth, and stresses the continuous development of science	6
Communal view	values science as a property of community	7
Ethical view	Concentrates on ethical appropriateness in the process of science	5

sides such like a knife. Even if somebody is stabbed by a knife, the knife-maker cannot be charged. As such, science is not responsible for its impact on society because science is also sort of tool··· Thus, the one who should be blamed is a user who misuses it, not the inventor.
– Questionnaire #20-1, March 5

Seok also noted that science was not responsible for its impact on society. For him, science was a fundamental discipline to seek the truth. He argued that science research should not be hindered by social background. He used a metaphor of doing research with handcuffed. In spite of the acceptance of the social influence on science research, he viewed it as an obstacle to progress science activities. It should be kept scientists studying the truth and natural phenomenon. Hereby, he emphasized the intrinsic value of science and his view was named as *intrinsic view*.

Seok: [scientists] do not have a social responsibility for their research. Scientists aim to study and find the truth. It is not their duty how to make use of the phenomenon or theories they found··· If nuclear bombs are developed through nuclear physics research, do scientists have to take responsibility for the damage by nuclear missiles? Important knowledge shall be delivered by media. Scientists are not tutors of the public and should be encouraged to keep them attending to their works. In case of the research which needs to be known to the citizens, many people will try to explain it to others.
– Questionnaire #7-2, March 5 and Questionnaire #7-1~4, June 4

Gee was much more concerned about the social impact of science. By emphasizing science-in-society, she argued that science should take into account its impact on society. Although choosing a research topic or research method is a personal tendency, the result in their research is not a personal property because science research is done within a society throughout the whole process. She also advocated that scientists have to explain their research to the public. Although media could account for science research, scientists should explain their works to the public directly because they received many supports from a society. She held *communal view* that science works in a society and is for the sake of community.

Gee: Scientists are liable for their research. This is because, from the beginning to the end, their research is done within a society where they are living··· The public's expectation and encouragement as well as administrative and financial support from the government and institutions are engaged with their research. After all, everything related to research does not belong to an individual··· Scientists have public responsibility because they have got economic support through the taxes of the citizens and support from the citizens.
– Questionnaire #24-1, 2, June 4

Similar to Gee, Sunny agreed to the social responsibility and accountability of science research. However, she stressed the ethical propriety in science research. In regard to social responsibility, she argued for a censoring group of scientist that plays a role in assessing process and result of research and criticizing the potential impact on society. As for accountability of science research, she argued for the openness to the public for the vigilance and pointed out the open-mindedness as one of important features in science ethics. However, she limited the responsibility of science as far as the research could be evaluated from moral and social perspectives. Her view on the orientation of science was named as *ethical view* that science should follow ethically appropriate procedure.

> **Sunny**: Scientists are responsible for the social impact of their research. However, the responsibility is valid when their research can be judged morally and socially. Scientists' community should play a role in discussing the proper direction of research and evaluating and criticizing the result of research in terms of its impact on society. I think that a community of scientist critics should be established to predict a social impact and to setup an appropriate goal of science research…The main duty of scientists is to conduct an accurate research following legitimate procedures.
> – Questionnaire #25-1 & 2, March 5

As summary, their views on the orientation of science could be described as listed: *pragmatic, intrinsic, communal and ethical views*. Each student was concerned about a different aspect of science: the usefulness of science; intrinsic goal of science, science as a component of a society, and the ethical appropriateness of science research. In spite of similar views on NOS, their views on the orientation of science were distinctive.

4. The role of the orientation of science in decision-making

We illustrated what roles their views on the orientation of science played in their decision-making. Centering the cases of four students, we described how their views were engaged with the decision-making process.

4.1. Jay's case: pragmatic view

In the Toyota recall, Jay regarded that the defects of automobiles were caused by short-term test. That was because the companies could not wait for a long time for profit-making. His premise was that the companies were based on profit-making. In this vein, he considered the recall as an opportunity to promote their gain, since sincere action for the recall would draw more people to purchase their items. Hence, he concluded that the recall was reliable because the companies did their best and the problem could be solved by science and technology.

> **Jay**: Actually, it is problematic that they took a short-time test. Therefore, the problems cannot but happen…. As far as I know, from a view of the companies, they do not sell a car one-off time. We are potential consumers for them. When a person purchases a car, he may become a next consumer. Therefore, it is beneficial to deliver a good appearance through recall or follow-up service, I think. They will treat the problems sincerely.
> – Transcript, Whole classroom, #009, #033, April 9

On the issue of green car, he acknowledged the context that green cars could also engender the pollution during generating electricity. Although electronic vehicles do not emit gas exhaust, thermal power plants produce the pollution during the process of electricity, he argued. However, he was optimistic about such a subsidiary pollution because he viewed there are many ways to avoid pollution such as wind, tide and the sun. Ultimately, it was conjectured that development in science would get rid of any pollution. Hence, he concluded that green car was helpful for the environmental protection.

> **Jay**: At this moment, a proportion of green-way generation such as wind, tidal force and the sun is increasing. There are some ways to produce electricity without pollution and if the new technology is developed later, destruction of the environment will be decreased. In the future, they will be more ways to produce electricity without pollution…
> – Transcript, Whole classroom, #003, April 9

As for global warming, he viewed the global warming as a natural change, by pointing out

that temperature perturbations has always emerged continuously. Even he did not attribute the phenomenon to human activities. Referring to the case of dinosaur extinction, he argued that human did not involve the extinction of species in the ancient days. Although it is true that human destroyed nature, he was not wary of the climate change because he trusted in the self-purification capacity of the Earth. He convinced that science and technology would propose a solution as science has brought about many good things to mankind.

> **Jay**: Development in science has many good points now. Science has been developed by using carbon, I think… I believe that the Earth is going to the right way…By the way, it is said that the environment is destroyed by science, due to carbon emission. Conversely, that sounds, there is a way to be corrected by science… People say that science raises the temperature but at the same time science can solve it.
> – Transcript, Whole classroom, #018 ~ #025, April 23

On the contrary, he was skeptical about the vaccination against swine influenza. He was not serious about the infection of swine influenza because there was nobody who got sick of swine influenza around him. He viewed that the atmosphere of anxiety about the disease was aggravated by the exposure of media. Instead, he was concerned about the peril of vaccines by arguing that vaccines even contained risky materials. The reliance on vaccines would not be healthy because new disease or virus could emerge. Thus, he chose the sanitation and maintain of the health instead of the inoculation.

> **Jay**: I wonder how many people have got vaccination for a severe disease.
> **All**: swine flu!
> **Jay**: In my opinion, there is nobody who did around me… In spite of many reports about fear of swine influenza, it is unrelated to my life. Among my parents, my sister and my colleagues, no one has been dead due to flu. When I saw the news that some people died, I do not feel it is real…
> Other student: Then, are you going to take vaccines after one of your friends die?
> **Jay**: As I heard, after vaccination, one can be sick like getting a cold for several days.
> – Transcript, Whole classroom, #027–#057, May 28

Except the case of swine influenza, his pragmatic view played a central role in decision-making. In the three issues, his strategy was consistent with his view on the orientation of science. He tried to solve the problem depending on the usefulness of science and technology and believed that science and technology would solve the issues because many achievements were given to us by science and technology.

However, Jay did not follow the pragmatic view in the case of the vaccination. When discussing the vaccine, he took into account personal experience. In addition to personal witness of the damage around him, he said, "there were some miraculous treatments that could not be explained medically". The argument was in line with the experience that he had received help from oriental medicines. He had suffered the fracture of his left arm and had to stay in a hospital for several months. He told that it was quite difficult to be treated and his injury got cured thanks to the herbal medicine. For this reason, he seemed to take care of himself and interested in health-related information. At least, he relied upon his knowledge about medical science in case of health-related issue.

4.2. Seok's case: intrinsic view

On the issue of the Toyota recall, Seok acknowledged the context where the error was inevitable because of the tentativeness of

technology. As well, he admitted that the recall could not be perfectly fixed. Nevertheless, he insisted the recall service since the recall would save more lives and eventually science and technology would rectify the defects.

> **Seok**: It is said that last year the operation rate [of recall] was sixty percent. It means that only sixty cars out of one hundred were properly fixed. This ensures the safety of sixty over one hundred. Therefore, I think it is worthy to be done. Sixty people out of one hundred can survive now.
> – Transcript, Whole classroom, #017, April 9

In respect to the green car, he made a similar decision to Jay. Similar to Jay, Seok admitted that green cars could cause pollution while generating electricity. However, he suggested that an intensive contamination in one place would be better than dispersed pollution by many cars, in regard to the pollution control. Even he introduced nuclear fusion as a future way of producing green energy. Even though science may cause harms to society, he argued that science should keep going to its own way and that society should not impede development of science and technology.

> **Seok**: When one thousand cars are running on the road, generating electricity in one place for thousand cars is more effective and less contaminating than dispersion of thousand cars, I heard…Korea largely depends on thermal power generation but has developed a new nuclear fusion plant called as K-STAR. In line with this, instead of nuclear fission with nuclear wastes, more electricity will be produced without pollutant by nuclear fusion… If Korea leads technology and legislation related to that, it will give us economic growth.
> – Transcript, Whole classroom, #004-006, April 19

As for global warming, he did not attribute the climate change to human enterprise, based on the insufficient evidence. He pointed out that it is insufficient to prove the causal relationship between carbon emission and temperature change. According to the study of analyzing an ice core in the Antarctic, the amount of carbon dioxide had grown after 800 years of the increase of the earth temperature. Even he claimed that scientist should be able to keep doing research since they have no charge in the global warming.

> **Seok**: When I looked up the studies related to global warming, I found that increase of the earth temperature was unrelated to carbon emission. Actually, it was reported that carbon dioxide has emitted more after the temperature increased… carbon emission increased after 800 years of the temperature increment.
> – Transcript, Whole classroom, #058-060, April 23

Based on science-related information, he insisted on the whole inoculation for swine influenza. He presupposed that, compared with the fatality of the disease, the adverse effect of vaccines was must less probable. He addressed that the whole vaccination was necessary to enhance collective immunity. Otherwise, all people would be in danger because virus spread out rapidly and became mutant easily. Once a new virus emerged, the vaccination for all people would be the best to prevent the damage. By exemplifying the case that MMR (measles, mumps and rubella), which was supposed not to emerge in the world, has been reappearing in African countries due to the low inoculation, he claimed that the denial of vaccination due to the fear of the adverse effect would be like suffering a big loss in going after a small gain.

> **Seok**: Vaccine is like an ozone layer… For example, since 1979, small pox has been eradicated by vaccine. Between 1953 and 1962, there have been 500,000 measles patients and 440 casualties in the United

States whereas only 55 cases in 2006 [thanks to vaccination]··· Avoiding immunization due to the adverse effect is like to break a butterfly on the wheel··· More important is that the damage by vaccination is much less than damage by contagious disease.
– Task, #8–7, May 28

In sum, his intrinsic view drove himself to choose a science-favored solution. He was optimistic about all the issues by suggesting that the development in science and technology would rectify the problems, similar to Jay. However, he put the priority on the development of science and technology and viewed that science should not be impeded.

4.3. Gee's case: communal view

Gee was indecisive about the safety of the recall. She anticipated that the companies would show a different attitude as the problem emerges repetitively. In the beginning, it would be solved and the companies would make an effort. But if it was repetitive, even the companies would hesitate to treat the problem and lose the reliability of customers. In addition, the assessment of the safety was linked to personal aspects. As well, the problem might not be fixed up in spite of the recall since the possibility of fixing up the faults was uncertain. As a consequence, she postponed the decision about the safety of the recall. Her concern was that the customers would be worried due to social impact of the incomplete treatment.

Gee: It is difficult to say whether reliable [about the recall] or not··· When the issue happens, maybe we can say "yes" or "no" about the company's attitude toward the recall but the same problem may emerge again despite the recall. Even though the problem is solved, customers will perceive it differently, person by person···When a problem is happening again and again, their sincere attitude will be gone. In spite of much endeavor, they will be frustrated or futile. After all, in despair, they will not do their best and not feel sorry for the problem.
– Transcript, Whole classroom, #001–#017, April 9

About the issue of green car, she acknowledged that green cars might also emit gas exhaust or pollutants as gasoline vehicles do. The existence of contaminating material notwithstanding, she argued the introduction of green cars with social needs to cope with depleting fossil fuel and climate change. She was more interested in the social need for the green cars rather than the environmental benefit of electronic vehicles.

Petroleum, fossil fuel, is a main cause of the environmental destruction. Many people worry about depletion of existing resources. For this reason, I think that the leading resource in energy market should be replaced with new one. Although green car does not emit any exhaust one hundred percent, the degree of its pollution is not much as serious as petrol car and a technique [of engine without any pollutant] will be devised in the future.
– Task, #5–24, April 19

In line with her decision-making in green cars, she viewed the global warming as a serious change. When Jay and another colleague claimed that it was natural, she admitted that the opposite argument might be plausible to some extent. However, she pointed out that a comparison between the past and the present was meaningless since the main causes were different. Moreover, the global warming has lasted for one hundred years and was caused by the abuse of nature and resources. To protect nature and save people's lives, she claimed to prepare a way for the abnormal weather change.

Gee: However, the cause is··· [The global warming] happened due to the unused energy

or the new way that has not existed before. It is meaningless to compare with the past situation. The phenomenon occurs because of something different that makes the earth more tired.
– Transcript, Whole classroom, #018-024, April 23

She was cautious about the vaccination. First, she did not guarantee the safety of vaccination based on the evidence that the effect of vaccines varied according to contextual condition like personal trait, health status, sanitation and life style. Vaccines could also bring about the adverse effect due to the toxic ingredient and attenuated virus. After all, she argued that the choice of vaccination should be left to individuals and she recommended only for vulnerable people to get vaccination instead of the whole vaccination. She focused on the way to save all people and to minimize the risk for all community.

Gee: You can be healthy without vaccination or be sick in spite of vaccination… Tested vaccines would be no problem, I think. Everybody has to make decision about health on one's own…there are many variables that can influence the effect, such as personal trait, circumstance, and others. It is unrealistic to believe a vaccine one hundred percent sure…
– Task, #8-24, May 28

Across the issues, Gee was not leaning toward yes or no entirely because of the tentative nature of the issues. Instead, her decision was likely to follow her communal view by putting her priority on the benefit of a community. Stressing "science for all mankind", she believed that science exists for society and that every work of a scientist is done in a society. For the sake of community, it was natural for her to pursuit saving lives. In this sense, she was likely to become more conservative in dealing with life-involved issues. To prevent the sacrifice of the public, she took a cautious position in the recall and the vaccination, and claimed a preparation for the environment destruction for the sake of community and many livings.

4.4. Sunny's case: ethical view

In the Toyota recall, she pointed out the company's attitude toward the recall. At the beginning, the company expressed their regret about the defects. However, they were reluctant to implement the recall service until the government commanded to do so. She addressed that the problem emerged due to their pursuit of profit because the recall needed more expenses. For this reason, she was skeptical about the effect of the recall. Due to the profit-seeking and the concealment of the truth, they would not run the recall.

Sunny: The Company delivered the apology to other countries when they decided to operate the recall in the United States. Since then, over six months, they kept repeating that there was no problem in Korea and finally began to enforce the recall after the government commanded to carry out the recall. Nevertheless, they said, "this is done for the prevention not for the repair."
– Task, #4-25, April 9

Similar to Gee, Sunny supported the use of green cars to save the Earth. She pointed out that green cars might cause the secondary pollution such as a use of heavy metals for fuel cells. Moreover, the use of electronic vehicles required to establish the international standards and stations for the recharge. Nevertheless, she agreed that it was necessary to develop recyclable resources because of the insufficient natural resources. In regard to the efficiency, green cars might not be better than gasoline engine at the time but eco-friendly system for generating electricity should be introduced.

Sunny: At the beginning, the efficiency can be

disputable. Developing recyclable energy is more significant than any other thing at this moment since underground resources such as petroleum is limited. The efficiency problem notwithstanding, from a long-term viewpoint, it should be encouraged to generate electricity in an eco-friendly way instead of thermal plants.
– Activity paper, #5-25, April 19

As for the global warming, she believed that the abnormal change has appeared due to the prolonged destruction of nature. The destruction brought on unusual change of climate such as flood, draught and hailstorm all over the world. Unlike Jay's thought that science would solve it, she emphasized the balance between nature and technology, and argued for the responsibility of mankind for their behavior.

Jay: People say that science raises the temperature but at the same time science can solve it.
Sunny: Then, we should find the way to develop with decreasing carbon emission.
Jay: Science shall find it anyway.
Sunny: No. [People] transformed nature artificially…There is a difference between leaving it alone and recognizing the problem… Even though we cannot stop [using carbon] completely, (inaudible) [we should find a way to restore the damage].
– Transcript, Whole classroom, #025-040, April 23

During the debate on swine influenza, she made an argument that both vaccination and swine influenza might damage people. She was aware that the vaccine contained some toxic materials such as benzene. As well, she reported many cases pertaining to the adverse effect of vaccination. As for the intention of inoculation, she pointed out the connection between the government and the pharmaceutical companies. During the discussion, she drew the agreement of her classmates by explaining the principle of vaccine and the process of medical treatment related to vaccines. She denied the vaccination due to the procedural problem in making vaccines.

Sunny: Mostly people think a vaccine is made from simply attenuated or dead virus. As a matter of fact, there are toxic materials such as aluminum, formaldehyde and benzene listed on the composition table… Many people do not recognize that drug makers are closely connected [with the government] as business partner. When pharmaceuticals try to reproduce vaccines or to develop new sort of vaccine, they can do anything without permission or negotiation with the government… In regard to the rate of inoculation, there is a big distinction between Korea and the United Kingdom. In this sense, I don't think inoculation is really concerned about health.
– Transcript, Whole classroom #061-067, May 28

About decision-making, she stressed her ethical view across the issue. She blamed dishonest attitude of the company and lobby of pharmaceuticals for the recall and the vaccination respectively. In the issue of vaccination, she pointed out the fundamental risk of vaccination and the political involvement of medical science in economic agents. In her homework, she criticized that advanced countries forced the third world to purchase the vaccine for swine influenza, who wanted to obtain enough vaccines. She acknowledged the need for green cars albeit they would still discharge pollutants, because of social context draining on natural resources. As well, she admitted that it is inevitable for any solution to be provisional since science and technology had a limitation.

To sum up, they were likely to consider their views on the orientation of science when making a strategy regardless of their views on the orientation of science and risk perception on

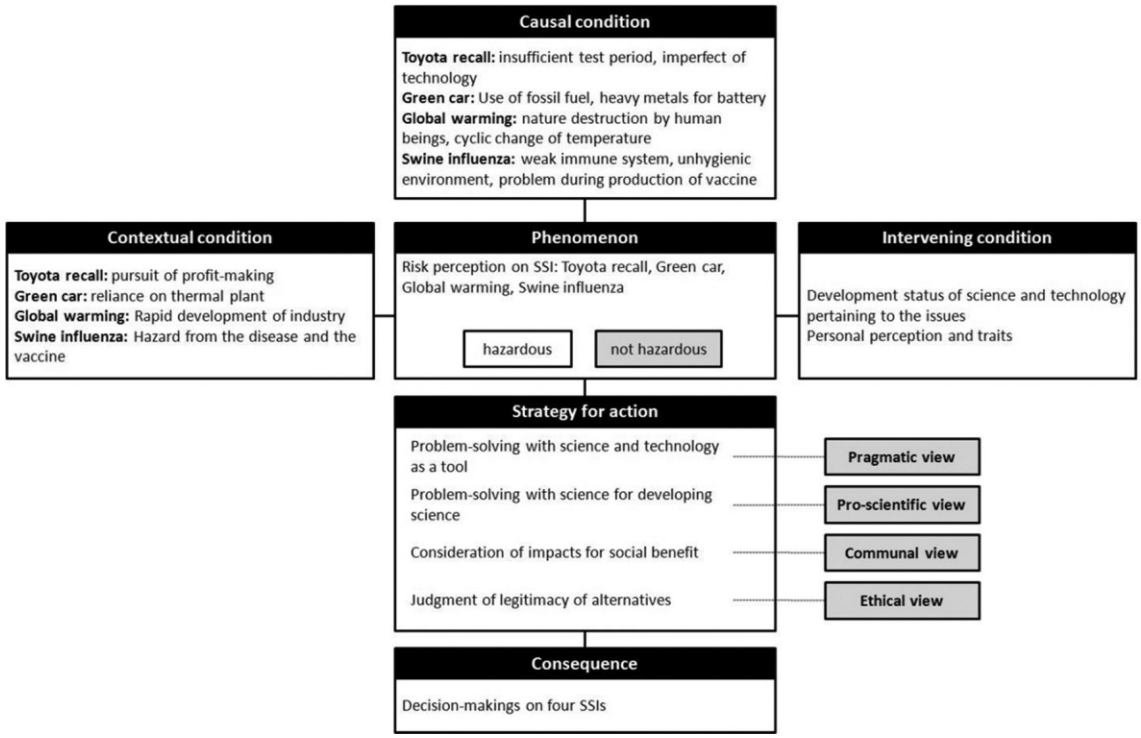

Fig. 1 *The role of the views on the orientation of science in decision-making process by grounded theory*

SSIs. Figure 1 shows how their views influence their decision-making processes, based on the analysis of data with grounded theory. They perceived the impact of the given issues in a different way. As well, they addressed many things as conditions pertaining to the issues and the conditions were unlikely to be connected with their views on the orientation of science. However, they tended to correspond with their views on the orientation of science during the process of decision-making. For example, Jay (pragmatic view) put his trust in science and technology in making decision, Seok (intrinsic view) made decision which would not impede science activities, Gee (communal view) took into account whether science would contribute to the community and Sunny (ethical view) focused on appropriateness in the process of science. In some cases, the students seemed not to follow their views on the orientation of science. Jay refused to receive vaccination even though he was a supporter for using science and technology. According to his experience, he concluded that science was not a useful tool for treatment. His past experience was considered in his decision-making.

5. Discussion and suggestions

This study aimed to identify students 'views on the orientation of science and to examine the relationship between their views and decision-making following grounded theory. First, the students held four different views on the orientation of science while they showed similar views on NOS. From the students, four participants with different views on the orientation of science were selected and we analyzed their decision-making processes on SSIs. As a result, they relied upon their views on the orientation of science as strategies for action whereas their perceived phenomena and

conditions were distinctive. As well, in some cases, students did not adapt their views in decision-makings. That was because they had personal experiences related to the issues and their experiences might affect their decision-makings. It needs to be studied how a person formed one's views on the orientation of science.

However, their views on the orientation of science were rarely linked to the contextual and causal conditions. Then, what else could affect central phenomenon and the conditions? According to the previous studies, NOS was concerned with the process of identification of the issue (Lewis & Leach, 2006). Even though views on NOS were not mainly tackled in this study, it is conjectured that the nature of science would be concerned with identifying the issue but not be directly linked to reasoning (strategy) in decision-making. In order to find out the elaborate decision-making process, the effect of different views on NOS needs to be investigated for further study.

What could influence on holding different views on the orientation of science? A small number of participants notwithstanding, the two students (Seok and Sunny) who had majored in science held distinct views. It is likely that learning science does not lead to a single view on NOS and the orientation of science. Rather, their personal experiences would be engaged with forming their views. Seok (intrinsic) spent most of time in doing experiments and Sunny (ethical view) had a bitter memory about cheating. As a consequence, Seok became more enthusiastic about doing inquiry as the essence of science whereas Sunny opened her eyes to social influence and ethical protocols of science. It needs to be studied how a person formed one's views on the orientation of science.

Several implications can be drawn from this study for science education. The orientation of science would be essential for achieving scientific literacy. One of the reasons of increasing concern in NOS is that it is regarded as an essential to scientific literacy for informed decision-making. Besides NOS elements presented in the previous studies, the orientation of science should be tackled. This study showed that it played a significant role in making strategies for action. Students' capability to deal with SSI can be improved through recognizing their views on the orientation of science and understanding diverse views on the orientation of science. However, the orientation of science is not usually taught in science class. The change of view on the orientation of science, through effective teaching of science, would bring about the more informed decision-making and better understanding of science knowledge. In line with this argument, some philosophical aspects such as the aim of science should be discussed as a part of NOS (Lederman, Nola, & Irzik, 2011).

Another implication is that when dealing with SSI, students should be taught to consider science within socio-cultural contexts instead of learning decontextualized concepts of science. In this study, their views on NOS were rarely mentioned in the process of decision-making whereas their views on the orientation of science were not. It is likely that the orientation of science was recognized through the relationship of science with surrounding contexts. That is to say, the value of science in society would be more relevant than the value of science per se. In this vein, the cross-section between science and others like culture, history and ethics needs to be considered because SSI reflects different ideas, values and beliefs.

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