

The pattern of risk assessment and its role in undergraduates' decision-making across socio-scientific issues

Hunkoog Jho[†], Jinwoong Song[†] & Ralph Levinson[‡]
Seoul National University, Korea[†] Institute of Education, UK[‡]

Abstract

This study aims to elucidate what risk strategies university students hold and what is the relationship between their risk strategies and their roles in discourse across socio-scientific issues. 27 first-year undergraduates in an introductory science class were asked to take part in the debate on four socio-scientific issues as listed: the Toyota recall, green car, global warming and vaccination for swine influenza. As a way of discussion, the snowballing method was implemented to encourage them to participate in discussion. The activity paper and homework submitted by the participants as well as the transcripts of group and classroom discussions were collected to be analysed. The analysis shows that there are mainly four risk strategies used in their decision-making: No loss, Minimal loss, Efficiency and Certainty strategies. It is interesting to note that the students made use of the same strategy across the issues. There were six key roles (i.e., Initiator, Critic, Knowledge provider, Coordinator, Dreamer and Follower) found in the participants' debates. There was a tendency that some roles were in charge of specific risk strategy. Students with Minimal loss strategy were taken by Initiators and Coordinators whereas Critics and Knowledge providers were taken by students with No loss strategy. Dreamers and Followers held inconsistent strategies. It seems that the risk strategy is associated with decision-making and with specific discourse roles.

Key word

socio-scientific issue, risk strategy, snowballing, decision-making, strategy and discourse role

Introduction

In the second half of the twentieth century, the socio-scientific issue (hereafter SSI) education has been introduced to school science with the emphasis on informed decision-making and STS movement. The SSI education focuses on empowering students to handle the science-related issues in their contemporary community (Driver et al., 2000; Kolstø, 2001; Zeidler et al., 2005). Many educators have been interested in tackling SSIs in the classroom. It has been reported that students' understanding of science concepts related to the issues improves through SSI instruction (Erduran et al., 2005; Osborne, 2005; Osborne et al., 2004; Zolar & Nemet, 2002). As well, students can learn the nature of science such as tentativeness and social embeddedness of science knowledge because SSI involves in some aspects of complexity, multiple perspectives, ongoing inquiry and value judgment (Abd-El-Khalick & Lederman, 2000; McComas et al., 1998; Ratcliffe & Grace, 2003; Sadler et al., 2007). Foremost, SSI instruction can enhance reasoning skill for informed decision-making (Erduran, et al., 2005; Osborne, et al., 2004; Sadler, et al., 2007). Beyond school science, a mature

sense of citizenship as critical scientific literacy (Shamos, 1995) needs to be achieved as a goal of general education.

Many scholars point out that informal reasoning plays a significant role in decision-making. Informal reasoning can be characterized as goal-dependent process engaged with generating or evaluating evidence pertaining to a claim or conclusion without logic and mathematics (Baron, 1988; Kuhn, 1991; Means & Voss, 1996). Sadler (2004) argued that informal reasoning dominates when information is less accessible or when the problems are more open-ended, debatable, complex or ill-structured. The incomplete and insufficient evidence matches up with the nature of SSI (Ratcliffe & Grace, 2003; Sadler et al., 2004). It is believed that decision-making reflects emotion, intuition and personal background as well as logical reasoning and that sometimes informal reasoning play a central role (Albe, 2008; Frewer et al., 1996; Handmer & James, 2010; Ratcliffe & Grace, 2003; Savadori et al., 2004; Setbon et al., 2005).

Risk strategy is important as a subset of informal reasoning. Kortland (1996) reported that students often make both implicit and explicit comparisons between their potential choices. Kolstø (2006) analyzed secondary students' discussion about building new power lines. He identified five types of argument according to their risk perception: the relative risk argument, the precautionary argument, the uncertainty argument, the small risk argument and the pros and cons argument. In his study, the students basically depended on the precautionary principle to avoid the potential damage. Savadori et al. (2004) reported that, in case of biotechnology issue, the public depend on potential damage or severe impact whereas professionals stress the current statistical data. In this vein, Setbon et al. (2005) showed that the public avoided consuming beef due to the fear of disease at the outbreak of the mad cow disease in 1996. It is likely that people make judgment by comparing or prioritizing the options they could choose.

More specifically, trade-offs and cut-offs are considered central in decision-making. Trade-off is characterized as the ability to consider advantages and disadvantages of multiple options whereas cut-off is to limit degree and depth of options to be searched. Many researchers claimed that students have limited ability to compare the given options and took into account of only a few aspects in their decision-making (e.g. Hogan, 1999; Hong & Chang, 2004; Ratcliffe, 1997). Seethaler and Linn (2004) also reported that students can use trade-offs but have difficulties in comparing the options. Trade-off is considered as a good point for informed decision-making. On the other hand, students utilize a cut-off level to discriminate if the options satisfy their goal (Hong & Chang, 2004). Brandstätter et al. (2006) addressed that people's examination is limited rather than exhaustive. In fact, weighing trade-offs encompasses prioritizing contradictory values (Jiménez-Aleixandre, 2002). Therefore, the ability to manage trade-offs and cut-offs among the options is necessary for informed decision-making.

The aforementioned ability related to risk strategy may be linked to argumentation. Eggert and Bögeholz (2009) analyzed students' decision-making strategies with quantitative method. Their study showed that the most elaborate strategy made use of trade-offs and prioritization of options whereas the base-level strategy took cut-off and absence of reflective thought. In a similar vein, Grace (2009) found that high quality decision-making contained justified and alternative-cared arguments. In respect to role in discourse, it is often found that there are three different roles as

promoter of thought, contributor of science knowledge and information-vigilance(Grace, 2009; Ratcliffe, 1997, 1999). Without a predominant leader, students usually swap over the roles, which is described as a *democratic team*(Gayford, 1992). By comparing merits and demerits of each option as risk strategy, appropriate decision-making accompanies with the ability to use trade-offs and cut-offs properly.

This study was designed to find out the relationship students' risk strategy in decision-making and the role of discourse on various SSIs. Student teachers who took part in an introductory science course were chosen as participants since they should be able to make informed decision to teach SSI. Totally 27 primary pre-service teachers were intended to participate in debates on various SSIs. The issues discussed were most popular and controversial in their community so that their ideas could be easily reflected and expressed. An analytic framework to identify student's risk strategy was borrowed from our previous study(Jho et al., in review), which was conducted to understand public's risk strategy about the mad-cow disease controversy on the internet in 2010. In that study, it was found that there were four risk strategies in decision-making: No loss, Minimal loss, Efficiency and Certainty strategies. No loss strategy selected a lossless solution by premising that there is a solution which does not contain any damage or risk, whereas Minimal loss strategy tried to minimize the size and possibility of damage by acknowledging that risk is involved in any choice. Regardless of comparison of the given choices, Efficiency strategy regarded the most viable one and Certainty pursued the obvious one which would not bring about unexpected result respectively. Using this framework, we tried to analyse student's risk strategy and to find out their pattern across SSIs. The four issues discussed were as following: the Toyota recall, green car, global warming and vaccination for swine influenza. More specifically, the students were asked to think about the following questions: Is the recall of automobile corporations trustworthy in terms of the safety?; Are state-of-the-art vehicles helpful to reduce the pollution?; Is climate change really happening or manipulated?; and Should vaccine for pandemic disease be taken or not? Unlike the previous study, this study was conducted in the setting of classroom oral discussion and it is assumed that specific role in discourse would influence their decision-making. In this vein, we identified the role in discourse that students played and the relationship between their roles and risk strategies. In sum, this study aimed to illustrate the idiosyncratic features of their risk strategy and discourse role in the context of classroom discussion.

Research Design

An undergraduate course, whose students were 27 prospective primary teachers, was observed in this study. One of the researchers designed and implemented the course to encourage students to participate in debates on controversial SSIs in Korea. The course was given to the students for two hours weekly. The two hours were composed of one-hour instruction to explain scientific concepts related to an issue and one-hour discussion to deal with that. Out of 27 students, ten students took the natural sciences track whereas the rest of them took the liberal arts track in their high school (Korean high school education offers two different curriculum tracks: liberal arts and natural sciences). The class consisted of six male and twenty-one female freshmen, whose age varied from

20 to 30. Their autobiographic essays were collected so as to understand their academic and socio-economic background.

To facilitate their participation in discussion, the Snowballing method was adopted (Brookfield & Preskill, 2005). This begins with thinking about the given issue individually and students make pairs and debate each other. Then, combined to another pair, a group of four people continues to discuss the issue and next, the size of discussion group doubles as eight people. Finally, the whole parties participate in the discussion and thus the way of growing discussion is like making a snowball. In order to avoid improvised debate, the participants were asked to investigate the issue about which they would talk next time as homework. During the first pair discussion and the next four-people discussion, the role exchange was done. For example, if one is sceptical about the given issue, he/she should support the issue in pair discussion and in the next phase, four-people discussion, he/she should be sceptical and since eight-people discussion, he/she can talk about the issue freely. The students were encouraged to write down their thoughts on activity paper. The activity paper is composed of four filling areas: one's claim before and after discussion and supportive and refutable evidence about one's claim. The pre-announced homework and the activity paper formed the common context between the instructor and the students, which helped the researchers to understand their terminologies better. For the triangulation of analysis (Lincoln & Guba, 1985), these data were compared to the transcribed data of eight-people and whole discussion. We collected data from audio- and video-taped discourse of students in eight-people and whole classroom discussion, their activity papers and their submitted tasks.

As an analytic tool, a qualitative methodology was adopted to mould the data into the coding framework. The analysis followed the grounded theory (Strauss & Corbin, 1990). In open coding, the taxonomy (LeCompte et al., 1993) conceptualized the data into surrounding condition, expected result and solution in various aspects of the issues such as safety, economy and society. Particularly we focused on the size of risk and probability which implied benefit and loss. The analysis method of risk strategy used in the issues was borrowed from our previous study (Jho et al., in review) and was based on the aforementioned open coding. As a supplement tool, quantitative methods were used to investigate the consistency of the participants' decision-making across the issues. Students' decision-making was coded and examined by Chi-square test between their decision-making and their risk strategy and by internal validity of their risk strategy across the issues. For example, when student A and B pose a supportive and sceptical position about the effect of the hybrid vehicle respectively, their responses were coded as 1 and 2. In terms of risk strategy, their choice among No loss, Minimal loss, Efficiency and Certainty strategies were coded from 1 to 4. Through the Chi-square test above, the coded data were examined to figure out whether the participants made use of specific strategy consistently compared with qualitative analysis. And, the result of internal validity was used to ensure the consistency of their decision-making. Finally, combined to the two different kinds of interpretation, quantitative and qualitative analysis, the research focused on revealing the feature of classroom discussion on SSIs.

Yes or no in the four socio-scientific issues

Table 1 shows pro and con in each issue: the safety of the recall, the effectiveness of green car for environmental protection, the truth about global warming and the effect of vaccination for swine influenza. As weighting up the pros (or yes) and cons (or no), the participants' arguments for and against each issue were turned out to be equally competitive.

Table 1 Claim and evidence of two contesting opinions in each issue

Issue	Opinion group	
	Yes	No
The Toyota recall	The service is reliable. <ul style="list-style-type: none"> - Recall is a chance to collect more customers by showing good attitude. - Recall can save more people. 	The service is unreliable. <ul style="list-style-type: none"> - The occurrence of problem is inevitable and it is impossible to totally fix it up. - The goal of companies is profit-making and this is against their goal.
Green car	It is helpful to protect nature. <ul style="list-style-type: none"> - Hybrid vehicles emit less gas exhaust. - Using green energy (solar, wind and tide), electricity can be generated without pollution. 	It's unhelpful for environmental protection. <ul style="list-style-type: none"> - Electronic vehicles cause pollution since electricity is generated by thermal or nuclear plants. - In spite of less exhaust, more frequent use of green cars causes the same amount of pollution as gas vehicles do.
Global warming	It is a severe disaster made by human. <ul style="list-style-type: none"> - The temperature on earth becomes drastically increasing. - Abnormal weather is reported in many places. - Icebergs in polar regions are melting. 	It is natural phenomenon. <ul style="list-style-type: none"> - The temperature changes periodically. - Carbon emission by human enterprise is a small proportion of total amount of CO₂. - The relationship between CO₂ and temperature change is unclear.
Vaccination for swine influenza	Vaccination is guaranteed to be safe. <ul style="list-style-type: none"> - Many diseases have been eradicated thanks to vaccination. - The fatality of disease is much higher than the adverse effect. 	Vaccination is also perilous. <ul style="list-style-type: none"> - The adverse effect of vaccines contains severe damage despite the rate is low. - The risk of illness is exaggerated in media and some risky materials are in vaccines.

First, students discussed the safety of the recall service by automobile companies. The group who supported the safety of the recall premised that companies would make an effort to fix up the problem since it is a chance to show a good image to customers. On the other hand, the group who was sceptical about the recall claimed that it is impossible to remove all defects and that the recall service is against their goal for profit-making. Next, the second issue was whether green cars such as electronic, hybrid and fuel cell vehicles would be helpful for the environmental protection. Some argued that use of green car would reduce carbon emission as well as air pollution whereas others claimed that green car might cause a different kind of pollution such as waste from plants and that more frequent use of green cars would cause the same amount of pollution as gasoline vehicles. Third, it was disputable whether a global warming was really happening or not. The proponents showed the evidence that abnormal weather is reported in many places and that glaciers in Polar Regions are decreasing due to the increase of temperature. The opponents doubted the

relationship between carbon emission and temperature change. They claimed that the amount of carbon emission had increased after the growth of temperature and that carbon emission by mankind takes only a small proportion of the total carbon dioxide. Last, as for vaccination for swine influenza, students were asked to choose taking vaccination or not. Some students supported that vaccine should be taken for all people to enhance the immunity because vaccines have eradicated many plagues. However, some students were wary of the adverse effect of vaccines because vaccine material contained some dangerous agents and the risk of epidemic disease was exaggerated in media. Such dichotomous choices were found all over the issues. We tried to reveal how the students made a choice based on risk strategy.

Risk-focused decision-making across the issues

Across the issues, the students' risk strategy associated with the perceived risk could be categorized into four strategies of No loss, Minimal loss, Efficiency and Certainty. There were the nature of risk, possibility, impact, opportunity cost and effect of each strategy identified. First of all, No loss strategy was distinguished from others. The most different point was that they believed there would be a way to fully avoid a risk. In other words, they perceived that there is an option which has no damage or no risk. Mostly socio-scientific issues reflected complex values and risks, but for them, it was a single risk situation and they could choose either A with risk or B without risk.

On the contrary, the rest of risk strategies acknowledged that every solution has a risk to some extent. The most frequent strategy was Minimal loss strategy to choose the least risky and most beneficial option. When taking into account both short-term and long-term effects and opportunity cost caused by their choice, they recognized that whatever they choose it may engender a risk to some extent. Next was Certainty strategy which followed the option that provided more information and treatments among the alternatives. For example, between A, which was less probable but unknown, and B, which was more dangerous but well-known, they tended to choose B. As they dealt with the problem, they focused on how they could cope with the situation that an event occurred, not the probability of an event itself. Therefore, they wanted to find out the prevention and treatment of the risk that could be made by the solution. Some followed the most viable action regardless of the comparison of the risks. This strategy is named Efficiency strategy. They regarded that the alternatives were not that distinguishable in terms of the risk. Rather than comparing the risks, they concerned about the practicality of the solution. They drew a conclusion reflecting practical merits and demerits of solutions, not simply the best solution.

One intriguing finding is Altruism strategy through which they would sacrifice themselves for the sake of community. Based on the fact that they took a risk for better gain of community, it can be seen as a subset of Minimal loss strategy. For example, in case of vaccination, some of the participants were willing to sacrifice themselves for others. This was interesting because people usually do not want to take any loss or get damaged in general (Merkhofer, 1987). They argued that they ought to take vaccination since the infection would cause elders, who have particularly weak immune system, to die of the illness. Rather than the probability of fatality itself, they concern

Table 2The category of risk strategy shown in four issues

Category	Description	Recall	Green Car	Global warming	Vaccination
No loss	Premises that there is an option without any risk and chase the option which has no loss.	<ul style="list-style-type: none"> - The company wants to fix the problem to get trust of consumers. The recall service can confer better image of them to consumers. - Profit-making is the first goal of a company. They just pretend to do (recall) but do their least because recall action brings a huge loss. 	<ul style="list-style-type: none"> - Hybrid vehicle uses less oil and by using solar cell, it can move without charging battery. - Through generating electricity by using the nature like wind, it is possible to use a car without any pollution. 	<ul style="list-style-type: none"> - The increase of the surface temperature has begun since the industrial revolution. As a result, many catastrophic changes happen. - Global warming is a fraud of developed countries to obstruct the growth of the undeveloped. The global warming is periodical change. 	<ul style="list-style-type: none"> - Through the vaccination, we can eradicate the disease. The adverse effect is negligible. - Our body can fight against most of disease. Vaccine itself contains many harmful matters and we may be in trouble by getting vaccination.
Minimal loss	Admits that risk is undeniable at any times and chooses the solution to minimize the damage by comparison of the given alternatives.	<ul style="list-style-type: none"> - Recall is the right choice from a long-term perspective but it can cause loss to companies. - In the beginning, the companies will do its best. But over time they would hesitate due to the expense. 	<ul style="list-style-type: none"> - The pollution by car exhaust can be reduced but the pollution by battery or other components exists. - Though hybrid cars emit gas exhaust slightly, that is less severe than that of fossil fuel. 	<ul style="list-style-type: none"> - Basically, the change is considered a natural cycle. But human may foster the change. - The pollution has increased by human but we are at stage of decreasing temperature and it may delay cooling the earth. 	<ul style="list-style-type: none"> - The adverse effect may hurt but it is not more serious than the disease. - If I get inoculation, I may feel pain but I will not be killed. So I will have vaccination.
Efficiency	Regards the given options as not much different things and pursues the most doable or convenient action irrespective of the risk comparison.	<ul style="list-style-type: none"> - There would be no difference whether or not recall is done. Rather than judging which case should be recalled, providing consumers with free inspection service to attract them is needed. 	<ul style="list-style-type: none"> - Pollution by one power plant is more controllable than that by thousands of cars dispersedly. - Irrespective of pollution, we should develop alternative energy to avoid depleting natural resources. 		<ul style="list-style-type: none"> - To treat patients, many labor forces are required. Rather than giving medication without vaccines, downscale of the patients by giving vaccines is better to save work force.
Certainty	Tends to take well-known risk rather than rare but veiled one considering uncertainty as a great peril.	<ul style="list-style-type: none"> - It is so difficult to find the cause of the problem. If everything is left to the company, they may cover up their faults. Hence, I cannot trust the recall. 	<ul style="list-style-type: none"> - The use of battery can cause the explosion and a lead battery may engender unknown pollution. 	<ul style="list-style-type: none"> - CO₂ is considered a main cause of global warming. But it is not sure. There is no clear answer to explain global warming. The effort to restore the nature can cause another side effect. 	<ul style="list-style-type: none"> - Vaccination can bring about unknown side effect. In spite of the risk of the disease, I will not get vaccination. - Without vaccination, I may be susceptible about infection. But it is good to me rather than afflicting the adverse effect by untested vaccines.
Altruism	Is willing to sacrifice oneself for the sake of society and put one's priority on community rather than individuals.				<ul style="list-style-type: none"> - In spite of side effect, we have to get vaccination not to transmit the disease to vulnerable people. - Even though I may suffer adverse effect, I will have immunization for elders and kids.

about the possibility of transmission of the disease to vulnerable classes such as children, disabilities and elders. Hence, they claimed to accept inoculation even though they were aware of the adverse effect of inoculation. This kind of strategy was only found in the vaccination case. In the four issues, the number of opinion group for/against an argument was nearly the same and they were often dispersed between the two extreme points, strongly agreed or disagreed. In respect to the strength of argument, the students who followed No loss strategy were apt to take the extremes as refers to Figure 1. That was because they simplified the risk strategy by concentrating on one risk among many. Hence, they were likely to choose an option from a dichotomous point of view. Even worse was the situation where incompatible values were clashed like economy and health. Minimal loss was relatively moderate than No loss because they admitted that it is inevitable to take a risk in any case. Efficiency and certainty strategies mostly took neutral position. While Efficiency tended to find out the realistic solution that could be accepted by their community, Certainty was reluctant to assert whether or not one was safe or not due to the uncertainty. Interesting is that among cautious participants with Minimal loss, some tended to go with the choice that the majority made. They wanted to examine the safety through observing other's opinion. It is likely that the choice of the majority gave the reassurance to them, alike free riders(Ratcliffe & Grace, 2003).

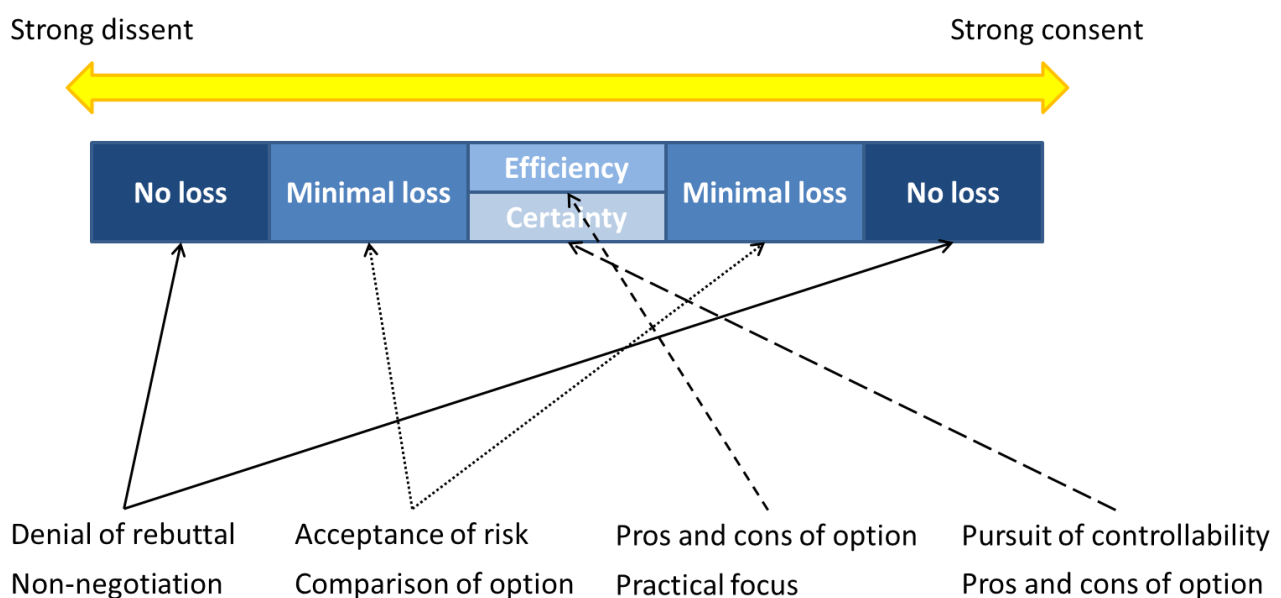


Figure 1The composition of arguments for/against the four issues

In respect to choice, the students did not agree or disagree to the issues coherently. For each issue, they had different opinion. For example, student A accepted the effect of green cars but distrusted the effect of vaccination for swine influenza. Further, their risk strategy was likely to be inconsistent with their choice. The result of Chi-square test between their choice and the risk strategy did not show any significant relationship. There was no specific strategy which was preferred in the certain

issue and the same strategy resulted in different choices. Their choice might not be linked to their risk strategy.

However, it is interesting to note that they made use of the same risk strategy across the issues. Though they did not make coherent decision over the issues, they utilized the same risk strategy that has been chosen in another issue before. The result of internal validity about coding of the risk strategy by the participants was 0.819 of Cronbach's alpha coefficient and it indicates that they adhered to use the same strategy. For example, Jay showed No loss strategy for the given issues even though he had a different choice for each issue. As for the recall issue, he considered that as a chance for a company to increase the demand by improving its image. The expense for recall was considered an investment to attract many potential customers. In his viewpoint, implementing recall service had no loss because recall itself could be solved and expense for recall would be compensated for by increase of sales volume. That was No loss strategy that he chose.

009 Jay: I think about the autonomous recall. Automobile company doesn't sell a car one-off thing. People like us are potential demand. When someone buys a car, he will be a potential consumer [for the next time] and a provider can make a demand. I think it's beneficial to plant a good image of itself in people's mind through recall and after-sale service. Therefore, they will make an effort to solve the problem if they find something defective.

- Transcript, Whole classroom #009, April 09, 2010 –

In case of green cars, the dispute was converged to the pollution by generating electricity. Since thermal power plants bring about atmospheric pollution, some argued that even electric vehicles cause the pollution to some extent. However, Jay believed that there is a way for an electronic vehicle to emit no gas exhaust by green energy.

003 Jay: I have a different idea. The way to produce electric power is shifting from fossil fuel to green something such as wind, tidal force and solar energy. There are several ways to gather [electricity] environment-friendly and it is possible to produce electricity without destruction of the environment.

- Transcript, Whole classroom #003, April 19, 2010 –

As for global warming, the debate was mainly about the impact of carbon dioxide emission on temperature change. Jay viewed that carbon dioxide does not bring the raise of the surface temperature considering the context of dinosaur extinction. He claimed that dinosaurs had been extinct without the increase of carbon dioxide. Even though it is true that human enterprise has ruined the environment, he convinced himself that it could be fixed by science and technology. For him, global warming was a natural phenomenon, not a serious change.

016 Jay: The extinction of dinosaurs was not due to burning carbons. All of you worry [about global warming] but living things may be extinct and so does mankind... There are lots

of merits thanks to development of science. I admit that the development has been done with carbons. But the earth goes to the right way.

022 So: I was told there were many abnormal changes in the past.

023 Cha: [The current global warming] is caused by what has been never done before and it is meaningless to compare the past. The phenomenon emerges because we made the earth tired.

024 Jay: But think about it. People say, excessive use of carbon due to the development of science destroy the nature. Then, conversely, there is a way to restore it with science, isn't it? If it is impossible to stop using carbon, can we treat the problems scientifically? They argue science ruined the earth but that means science can cure the problem.

025 Sun: Then we should find out the way to reduce the emission and keep growing.

026 Jay: Science will find a way.

- Transcript, Whole classroom #016-026, April 23, 2010 –

Unlike the previous cases, Jay was sceptical about the effect of vaccination. He disagreed that vaccine can prevent people from infection. He illustrated that a large amount of casualties dying of pest in the Europe were not because of the absence of vaccination but because of the unhygienic environment. Referring to the side effect of vaccination, he insisted that healthy immune system can protect our body from any disease.

043 Jay: People misunderstand that many people died of pest because they had no vaccines. However, due to the absence of drain system, there were humungous rubbish and sewage on the street at the time. That was so bad in terms of hygiene. You can guess one-thirds of people were killed not by absence of vaccine. Do you know why high heels were made? That was because women tried to avoid the dirty. The hygienic status was as bad as they had to wear high heels. That's why so many people died, as I know. It cannot be argued that vaccine eradicated those epidemics in the world.

- Transcript, Whole classroom #043, May 28, 2010 –

I am not going to be inoculated. Instead, I will keep my body healthy. I think healthy eating habits and sound mind protect me from any kind of disease... It is very difficult to cope with every disease [through vaccination]. I am going to keep my body good rather than accepting the adverse effect of all vaccines.

- Task, #8-20, May 28, 2010 –

Though Jay made decision in a different way in each issue, it can be argued that he applied the same strategy, No loss. Except the vaccination, he tried to resolve the risk by the power of science and technology. His strategy was linked to his view on science as an instrument to solve our daily problem.

However, not all of the students followed the same strategy across the issues. Six of them applied one strategy into two similar issues (they viewed them similar) and applied another strategy into

the other two issue. Cha and Yun used Minimal loss strategy in the recall and vaccination issues, whereas they used No loss strategy in green cars and global warming issues. First of all, in case of the recall, both of them viewed that concealment of the faults would give more damage to the company and that the company could not but recall the product. However, they worried that the company were unwilling to take a large expense to fix it up.

Cha: Recall is an official action. cursory inspection will get worse about its image. The companies may do their best as a chance to shape an honest image to customers. Actually, in a modern society, it becomes difficult to hide and they have no option. However, they are unlikely to take an economic expenditure to fix the problem. I cannot fully trust the service.

- Activity paper, #4-24, April 09, 2010 –

In the pollution by green cars, especially electronic vehicles, they acknowledged that the new vehicle might cause different kind of pollution to produce electric energy instead of no gas exhaust. They suggested the use of green energy to eradicate the pollution derived from electricity.

Yun: It is true that hybrid vehicle emits gas exhaust less than gasoline engine. However, if the car is driven too much with blind faith of reduction of pollution, the pollution will get worse. As well, it is possible to come about the pollution in another place. Since thermal plants make use of fossil fuel, the pollution still remains and nuclear plants give rise to the disposal issue of radioactive waste. If solar cell is used in a car, we will have no affliction from procedural contamination as well as emission issue.

- Activity paper, #5-10, April 19, 2010 –

In regard to global warming, they exemplified many natural disasters and related casualties as evidence to show that global warming is going on. Irrespective of to what extent carbon dioxide affect global warming, they contended to make an effort to reduce the gas to save more people and species.

023 Cha: [The current global warming] is caused by what has been never done before and it is meaningless to compare the past. The phenomenon emerges because we made the earth tired.

030 Yun: There may be side effects when solving a problem with science. Because science goes against the natural way of life, [it may harm] ...

043 Yun: The argument, no carbon use, is done because we get some damages. That's why we claim it. Convenience is for us and a life without damage is all for us. Why do you consider only convenience?

- Transcript, Whole classroom #023-043, April 23, 2010 –

Yun: A life is more precious than any other thing, even effectiveness. There are abundant evidence that the earth is being destroyed like rising sea levels, extinction of species and

frequent natural disaster. For example, polar bears are losing the territory where they can live. To save polar bears, we should halt greenhouse effect.

- Activity paper, #7-10, April 23, 2010 –

In case of vaccination of the epidemic, their thoughts were separated even though both acknowledged the potential risk if vaccinated. Yun regarded that the fatality of the disease is more severe than that of inoculation. Therefore she decided to take vaccination. On the other hand, Cha thought that every vaccine has the probability of the death to some extent and that she would not be immunized except for severe illnesses.

007 Yun: However, is the rate of death by the epidemic is higher than that by the adverse effect?

008 Jay: OK.

009 Seok: Unless vaccination is done, the disease which has gone can appear again.

010 Jay: I didn't mean every kind of vaccine. Like some cases where an atmosphere of fear is produced...

011 Sue: When a disease is spreading out, even though I can prevent the illness, I have to get inoculation to protect the anonymity that can be transmitted due to me.

012 Yun: It was said untested vaccine should be avoided. While testing the vaccine, there may be casualties. How should we do?

- Transcript, Whole classroom #007-012, May 28, 2010 –

Cha: A vaccination is a game of odds. One can be healthy without vaccination or be sick in spite of inoculation. In case of being sick, one can be healed, be afflicted or be killed. Every case is possible but since the inoculation prevents the illness, it is recommended... Based on scientific research, ordinary vaccines for MMR, seasonal flu and hepatitis are reported highly protective. Those are not problematic but the vaccine for epidemic which has risen drastically is not fully tested. In this case, unconditional inoculation can make some trouble...

- Task, #8-24, May 28, 2010 –

The identification of the nature of issue may be connected to their decision-making. For most of students, global warming and green car are considered scientific issues because they were unfamiliar with the principle of the brand-new vehicle and the model of heating the earth, which were not dealt with by the students. In this case, they were likely to rely on the opinion of others who were more knowledgeable than themselves or to follow their view of science. On the other hand, they referred to some social aspects in case of the recall and vaccination. They not only cited abundant science information because they were experienced about swine influenza. Some students told their own stories of how they reacted about the whole inoculation at the time. In spite of no experience about swine influenza, some students assessed the risk of the disease and vaccines based on their experience about medical treatment. That is to say, personal familiarity of the issues was linked to the identification of the issues and the identification showed a distinction

in terms of scientific arguments dealt with in debates. As well, the more the students were familiar with the given issue, the more they were likely to broaden the debate by adding more conditions and premises. The more premises and conditions were tackled, the more likely they recognized that any solution has advantages and disadvantages.

To sum up, many students took the same risk strategy even though they made a difference choice across the issues. Some of the students applied different risk strategies due to the influence of identification of the issue. This might be linked to familiarity of the issue such as personal experience. In addition, each risk strategy held a characterised position in yes or no of the four issues. In the next section, we would discuss the risk strategy and the discourse role.

The discourse role and its connection with risk-focused decision-making

In addition to use of risk strategies, in this study, we investigated students' discourse roles during the debate. It was found that there were several key roles in debates: Initiator, Knowledge provider, Critic, Coordinator, Dreamer and Follower. These could be overlapped and sometimes one person took more than one role in a debate. When following the flow of debate, an Initiator started the debate by speaking his/her comment to the group or the classroom. When the students hesitated to speak their opinions in the first time, an Initiator broke the silence and opened the debate. Then, a Critic refuted the claim and suggested his/her idea. He/she was an active participant but did not propose his/her own idea before someone began to talk. A Follower usually added some comments or evidence to Initiator or Critic. A Follower played an assisting role in supporting the same group or falsifying the opposite group. Most of Followers stayed calm during the discussion. When it was crucial to figure out whether specific information was true or not, a Knowledge provider supplied the audience with professional information as well as science knowledge. Since other students could not refute the idea of a Knowledge provider due to the lack of science knowledge, Knowledge provider's speaking terminated the dispute occasionally. As a debate was going on, students might conflict or have difficulties in clarifying their opinion. At this moment, a Coordinator presided over a meeting by summarizing other's comment or explaining others to catch up with the current topic. After some time, A Dreamer asked a question which might be off the point. Occasionally, his/her comment led the discussion to a different way. By suggesting new idea, he/she could contribute to reify the concept disputed. In a dispute, all of the roles were not found at all times and a participant often played two or three roles across the issues.

A Knowledge provider offered science knowledge to the audience. In the classroom discussion, Seok and Sunny, who majored in natural sciences, took this role. They provided science knowledge which was central to the debate. For example, Sunny argued the hazard of vaccine by explaining the ingredient of vaccine whereas Seok discerned the cause and effect of global warming by noting that melting iceberg does not change the level of water. Beyond science knowledge, information related to professional areas was given to the audience by Knowledge providers. Sunny tended to back up her claim by elucidating the process of vaccine production and the procedure of medical treatment in a hospital. Thanks to their background, the information given by them was posited as true. Besides, due to lack of professional information, other students hardly refuted their ideas. Thereby,

both of them gave comments as a Critic and they took No loss strategy by presenting the evidence which was fit for their own ideas.

061 Sunny: Mostly, it is believed vaccine is composed of attenuated or dead virus. Actually when you look up the ingredient, it contains dangerous materials such as aluminum, formaldehyde and benzene. People do not think that those can cause adverse effect.

062 Ji: How did you know that?

063 Hye: It cannot be rebuttable!

065 Sunny: Actually, there is almost zero without the compromise to the government for pharmaceutical companies to reproduce or develop a vaccine. They cannot do it without the permission.

067 Sunny: When pediatric doctors make a prescription, they should follow the guideline established by the government...

- Transcript, Whole classroom #061-067, May 28, 2010 –

The Coordinator was found in the group discussion rather than in the whole classroom discussion. They led the way for all members to speak out, encouraged them to give their comments and clarified the idea. It seems quite difficult for them to involve in the whole classroom discussion because they had to coordinate the whole discussion. It is assumed that a Coordinator is modest and our result showed that all Coordinators took use of Minimal loss strategy. Here is an example of Choi in the issue of the Toyota recall.

021 Gimmie: The recall referred here is autonomous recall before or after the accident?

022 Hye: Before the accident?

023 Gimmie: It means both, doesn't it?

024 Hyun: I think it is an important issue.

025 Choi: Then, define it as before [the accident].

058 Hyun: Recall is impossible.

059 Choi: It is impossible, what do you mean by?

060 Hyun: The crucial fault can be concealed [by the company].

061 Choi: Instead of concealing the serious one, the company tries to deal with trivial one.

070 Sue: Toyota attributed the cause of accident to component parts. In the past, a crew of theirs died of overwork but they denied. There have been serious accidents but they connived at... I am sceptical based on such an action.

071 Choi: The issue of trustworthy.

074 Hwang: What are we talking about?

075 Choi: Question 3. She said she cannot trust [in recall] but I said yes (explaining to her what's going on).

086 Hye: The primary goal of enterprise is profit-making. To gain profit, they have to get customer's trust. Then consumers are increasing. At this time, by proclaiming the recall service autonomously, they admit their faults, by themselves. From a customer

perspective, instead of covering up the problem, they try to fix it up by recall service, hmm...

087 Choi: It is possible to make profit by trust.

- Transcript, Group discussion #021-087, April 09,2010 –

Dreamers were interested in a different point which had not been discussed. Their comments occasionally led the debate to a different way. Since their questions came from the curiosity, those might be unrelated to the issue, but their ideas could imbue the audience with new insight. When talking about the Toyota recall, Cho wondered how the customers would respond if domestic companies committed a crucial flaw. His question fostered to think about the difference of trustiness by customers and financial impact of the recall on domestic companies. Dreamers had not followed single strategy, instead they change their strategy and decision-making at all times.

019 Marie: I think I can trust the recall...

021 Cha: Due to the iterated problems, that makes me distrust the service...

022 Seok: I think a company with a good service will survive...

023 Cho: I just want to know, we try to introduce the recall system from foreign countries. In the domestic market, I wonder how the consumers think about that. If ask to replace old parts with new ones, then people say 'wow' but if say "oh, there's a problem and please visit to exchange the part", then would they say "Oh, that company is so reliable that they can acknowledge their faults honestly" or "That makes me visit again and again and it's quite annoying"?

(They started to talk about the response of domestic customers and the impact of the recall on domestic economy)

- Transcript, Whole classroom #019-023, April 9, 2010 –

Followers had a large proportion of the students and took inconsistent choices over the issues. They had their own opinions but did not want to speak them loud. Among them, active group with No loss strategy added some comments to their supporting group whereas cautious group with Minimal loss wanted to delay their decision until they find out the consequence of other solution.

Table 3 The relationship between the role in discourse and risk strategy in socio-scientific issues

Role (unit: number)	Description	Main strategy
Initiator (4)	Icebreaker, starts discussion by speaking out comments first	Minimal loss
Critic (4)	illustrates opposing claim and evidence	No loss
Knowledge provider (2)	Supplies others with professional knowledge related to issues	No loss
Dreamer (2)	Leads a discussion to the different way by raising a question or comment irrelevant	Efficiency
Coordinator (2)	Balances the chance to speak out and summarizes other's comments	Minimal loss
Follower (13)	Does not participate in discussion explicitly	Diverse

Among the roles, three of them can be found in Grace (2009)'s study. He investigated students' decision-making related to conservation of biodiversity. His finding was that there were three key roles in high quality groups as listed: promoter of thought, contributor of science content knowledge and information-vigilance. These are similar to Initiator, Knowledge provider and Critic respectively. However, a contributor of science knowledge (Knowledge provider) in our study offered not only science content knowledge but also professional information. As well, information-vigilance was in accord with a Knowledge provider and a Critic. In addition, Critics promoted it as promoter of thought did. In addition, Coordinators, Dreamers and Followers did not match up with Grace's three roles. As for a Coordinator, Grace (2009) stated that in high-quality decision-making, the members did not play only one role but swapped over roles without a predominant leader as *democratic teams* (Gayford, 1992). But, in this research, a Coordinator encouraged silent Followers to present their comments. Even though the participants may not be high-quality opinion group, a coordinator played an active role in encouraging colleagues to participate in discussion and promoting the debate.

The combination of the role in discourse with risk strategy provides us with more specific understanding how they make decision. There was a tendency that the same people were likely to take the same roles and strategies. The four Initiators chose Minimal loss strategy. They did not suggest their idea strongly. Instead, they introduced their claim and evidence within two or three sentences. Strong debaters (No loss strategy) did not play an initiating role because they could face with outnumbering opposition if they raised their voice from the beginning. Uncertainty strategy seemed difficult to be the first since they were unclear about risks of the given options. The Initiator should know the point of discussion and have relatively moderate position to get more support. After all, Minimal loss strategy was most appropriate to open the discussion. Initiators were not consistent Minimal loss chasers but might take No loss in another issue. Conversely, Critics were all strong debaters who followed No loss strategy. The Critics not only pointed out fallacies and contesting evidence of the given claim but also defended themselves from continuous rebuttal. Sometimes, they relied on personal experience and emotion, which seemed irrational.

Concluding remarks

The one of the most significant findings in this study is that though their decisions made across the issues were different, the risk strategies used were consistent across the issues. The result posits that the risk strategy has to be highly regarded as a key role in decision-making. In science education research, most of studies dealing with SSI have concentrated on the reasoning level or conceptual understanding (Erduran, et al., 2005; Grace, 2009; Osborne, et al., 2004; Oulton et al., 2004; Sadler, et al., 2007; Sadler, et al., 2004), whereas there have not been paid much attention to risk strategy and decision-making itself (Kolstø, 2006; Savadori, et al., 2004; Wynne, 2002). It would be fruitful to shape the whole picture to explain one's decision-making if the role of student's risk strategy in interpreting the given information is studied.

Lewis and Leach (2006) concludes that conceptual understanding infuses the formation of identifying the issue and the identification affects their decision-making. However, according to the

result of our study, it may be that they have the same strategy regardless of increasing information about the issue and the strategy infuses the analysis of the given information. Without consideration of their risk strategy, the effort to improve students' reasoning would be somewhat aimless. For instance, Jay believed that he did not have to take a risk by relying on the immune body. The increased information of the illness notwithstanding, he stubbornly refused vaccination. It is true that he might get some sick or pain by the infection like mild fever unless he is immunized. But he did not consider that as a risk or loss. The risk issue is not ontological but epistemological (Irwin, 2003; Irwin & Michael, 2003; Irwin & Wynne, 1996). Therefore, simple knowledge acquisition does not improve the ability to make decision unlike Lewis and Leach's emphasis on conceptual understanding(2006). Many comments of value engagement in SSI decision-making support the idea proposed in our study (Fowler et al., 2008; Grace, 2009; Levinson, 2006, 2008; Oulton, et al., 2004; Ratcliffe & Grace, 2003; Sadler, et al., 2004; Zeidler, 2003; Zeidler et al., 2002). With respect to the role in debate related to SSI, here it is argued that the specific role in debate is connected to the risk strategy. In this study, there were six key roles in promoting the discussion. The Minimal loss takes charge of opening the debate as an initiator and a strong debater among No loss strategy participates in the debate to criticize the first given argument. A Coordinator is one of those who keep neutral in decision-making by minimal loss. Knowledge provider can be a No loss user if he/she attends the debate to terminate the disputable argument by suggesting detailed professional ideas. Dreamers adopt inconsistently strategies case by case and Followers contain every kind of risk strategy. Though it is difficult to generalize the induced pattern, it is likely that the strategy influences the role taken in discourse. It implicates that we need to encourage students to take a different role to provide them with an opportunity to have a different strategy. As well, it should be studied how each role in discourse contribute to the other students' decision-making or a whole classroom discussion.

As a further study, the view of science should be investigated. It is argued that understanding the nature of science affects student's understanding of science contents and identification of the issue (Lewis & Leach, 2006; Sadler, et al., 2004; Zeidler, et al., 2002). In this study, student Jay and others believed that the damage could be avoided thanks to science and technology. The idea is related to his pragmatic view on science. In order to understand why the participants reached the different conclusion in spite of the same strategy, the role of their views of science in decision-making is worthy to be researched. And, it is found that Dreamers and Knowledge Providers led the debate in a different way. By analysing the discourse pattern in relation to the role of discourse and strategy, we may figure out whether a specific discourse pattern influence their decision-making and risk strategy on SSI.

References

- Abd-El-Khalick, F., & Lederman, N. G. (2000). Improving science teachers' conceptions of nature of science: a critical review of the literature. *International Journal of Science Education*, 22(7), 665-701.

- Albe, V. (2008). When scientific knowledge, daily life experience, epistemological and social considerations intersect: students' argumentation in group discussions on a socio-scientific issue. *Research In Science Education*, 38, 67-90.
- Baron, J. (1988). *Thinking and deciding*. Cambridge, U.K.: Cambridge University Press.
- Brandstätter, E., Gigerenzer, G., & Hertwig, R. (2006). The priority heuristic: making choices without trade-offs. *Psychological Review*, 113(2), 409-432.
- Brookfield, S., & Preskill, S. (2005). *Discussion as a way of teaching: tools and techniques for democratic classroom*. San Francisco: Jossey-Bass.
- Driver, R., Newton, P., & Osborne, J. (2000). Establishing the norms of scientific argument in the classroom. *Science Education*, 84(3), 287-312.
- Eggert, S., & Bögeholz, S. (2009). Students' use of decision-making strategies with regard to socioscientific issues: an application of the Rasch partial credit model. *Science Education*, 94(2), 1-29.
- Erduran, S., Osborne, J., & Simon, S. (2005). The role of argumentation in developing scientific literacy. In K. Boersma, M. Goedhart, O. De Jong & H. Eijkelhof (Eds.), *Research and the quality of science education* (pp. 381-394). Dordrecht, The Netherlands: Springer.
- Fowler, S. R., Zeidler, D. L., & Sadler, T. D. (2008). Moral sensitivity in the context of socioscientific issues in high school science students. *International Journal of Science Education*, 31(2), 279-296.
- Frewer, L. J., Howard, C., Hedderley, D., & Shepherd, R. (1996). What determines trust in information about food-related risks? underlying psychological constructs. *Risk Analysis*, 16(4), 473-486.
- Gayford, C. (1992). Patterns of group behaviour in open-ended problem solving in science classes of 15-year-old students in England. *International Journal of Science Education*, 14(1), 41-50.
- Grace, M. (2009). Developing high quality decision-making discussions about biological conservation in a normal classroom setting. *International Journal of Science Education*, 31(4), 551-570.
- Handmer, J., & James, P. (2010). Trust us and be scared: the changing nature of contemporary risk. *Global Society*, 21(1), 119-130.
- Hogan, K. (1999). Thinking aloud together: a test of an intervention to foster students' collaborative scientific reasoning. *Journal of Research in Science Teaching*, 36(10), 1085-1109.
- Hong, J.-L., & Chang, N.-K. (2004). Analysis of Korean high school students' decision-making processes in solving a problem involving biological knowledge. *Research In Science Education*, 34, 97-111.
- Irwin, A. (2003). *Citizen science: a study of people, expertise and sustainable development*. London, U.K.: Routledge.
- Irwin, A., & Michael, M. (2003). *Science, social theory and public knowledge* Buckingham, U.K.: Open University Press.
- Irwin, A., & Wynne, B. (1996). *Misunderstanding science? : the public reconstruction of science and technology*. New York: Cambridge University Press.
- Jho, H., Song, J., & Levinson, R. (in review). Strategies found in public's decision-making confronted with a risk-oriented issue: a case study of Bovine Spongiform Encephalopathy (BSE) on a Korean web board. *Public Understanding of Science*.
- Jiménez-Aleixandre, M.-P. (2002). Knowledge producers or knowledge consumers? Argumentation and decision making about environmental management. *International Journal of Science Education*, 24(11), 1171-1190.

- Kolstø, S. D. (2001). Scientific literacy for citizenship: tools for dealing with the science dimension of controversial socioscientific issues. *Science Education*, 85(3), 291-310.
- Kolstø, S. D. (2006). Patterns in students' argumentation confronted with a risk-focused socio-scientific issue. *International Journal of Science Education*, 28(14), 1689-1716.
- Kortland, K. (1996). An STS case study about students' decision making on the waste issue. *Science Education*, 80(6), 673-689.
- Kuhn, D. (1991). *The skills of argument*. Cambridge, U.K.: Cambridge University Press.
- LeCompte, M. D., Preissle, J., & Tesch, R. (1993). *Ethnography and qualitative design in educational research*. San Diego: Academic Press.
- Levinson, R. (2006). Towards a theoretical framework for teaching controversial socio-scientific issues. *International Journal of Science Education*, 28(10), 1201-1224.
- Levinson, R. (2008). Promoting the role of the personal narrative in teaching. *Science & Education*, 17(8-9), 855-871.
- Lewis, J., & Leach, J. (2006). Discussion of socio-scientific issue: the role of science knowledge. *International Journal of Science Education*, 28(11), 1267-1287.
- Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic inquiry*. Newbury Park, CA: Sage Publications.
- McComas, W. F., Clough, M. P., & Almazroa, H. (1998). The role and character of the nature of science. In W. F. McComas (Ed.), *The nature of science in science education: rationales and strategies* (pp. 3-40). Dordrecht: Netherlands: Kluwer Academic Publishers.
- Means, M. L., & Voss, J. F. (1996). Who reasons well? two studies of informal reasoning among children of different grade, ability, and knowledge levels. *Cognition and instruction*, 14(2), 139-178.
- Merkhofer, M. W. (1987). *Decision science and social risk management: a comparative evaluation of cost-benefit analysis, decision analysis, and other formal decision-aiding approaches*. Dordrecht, The Netherlands: D. Reidel Publishing Company.
- Osborne, J. (2005). The role of argument in science education. In K. Boersma, M. Goedhart, O. De Jong & H. Eijkelhof (Eds.), *Research and the quality of science education* (pp. 367-380). Dordrecht, The Netherlands: Springer.
- Osborne, J., Erduran, S., & Simon, S. (2004). Enhancing the quality of argumentation in school science. *Journal of Research in Science Teaching*, 41(10), 994-1020.
- Oulton, C., Dillon, J., & Grace, M. (2004). Reconceptualizing the teaching of controversial issues. *International Journal of Science Education*, 26(4), 411-423.
- Ratcliffe, M. (1997). Pupil decision-making about socio-scientific issues within the science curriculum. *International Journal of Science Education*, 19(2), 167-182.
- Ratcliffe, M. (1999). Exploring aspects of scientific literacy in the classroom - evidence based decision-making. In O. De Jong, K. Kortland, A. J. Waarlo & J. Buddingh (Eds.), *Bridging the gap between theory and practice: what research says to the science teacher* (pp. 51-67). Hatfield, UK: International Council for Association for Science Education.
- Ratcliffe, M., & Grace, M. (2003). *Science education for citizenship: teaching socio-scientific issues*. Philadelphia, PA: Open University Press.
- Sadler, T. D. (2004). Informal reasoning regarding socioscientific issues: a critical review of research. *Journal of Research in Science Teaching*, 41(5), 513-536.
- Sadler, T. D., Barab, S. A., & Scott, B. (2007). What do students gain by engaging in socioscientific inquiry. *Research In Science Education*, 37.
- Sadler, T. D., Chambers, W., & Zeidler, D. L. (2004). Student conceptualization of the nature of science in response to a socioscientific issue. *International Journal of Science Education*, 26(4), 387-409.

- Savadori, L., Savio, S., Nicotra, E., & Rumiati, R. (2004). Expert and public perception of risk from biotechnology. *Risk Analysis*, 24(5), 1289-1299.
- Seethaler, S., & Linn, M. (2004). Genetically modified food in perspective: an inquiry-based curriculum to help middle school students make sense of tradeoffs. *International Journal of Science Education*, 26(14), 1765-1785.
- Setbon, M., Raude, J., Fischler, C., & Flahault, A. (2005). Risk perception of the "mad cow disease" in France: determinants and consequences. *Risk Analysis*, 25(4), 813-826.
- Shamos, M. H. (1995). *The myth of scientific literacy*. New Brunswick, NJ: Rutgers University Press.
- Strauss, A. L., & Corbin, J. M. (1990). *Basics of qualitative research: grounded theory procedures and techniques*. Newbury Park, CA: Sage Publications, Inc.
- Wynne, B. (2002). Risk and environment as legitimacy discourses of technology: reflexivity inside out? *Current Sociology*, 50(3), 459-477.
- Zeidler, D. L. (Ed.). (2003). *The role of moral reasoning on socioscientific issues and discourse in science education*. Dordrecht, The Netherlands: Kluwer Academic Publishers.
- Zeidler, D. L., Sadler, T. D., Simmons, M. L., & Howes, E. V. (2005). Beyond STS: a research-based framework for socioscientific issues education. *Science Education*, 89(3), 357-377.
- Zeidler, D. L., Walker, K. A., Ackett, W. A., & Simmons, M. L. (2002). Tangled up in views: beliefs in the nature of science and responses to socioscientific dilemmas. *Science Education*, 86(3), 343-367.
- Zolar, A., & Nemet, F. (2002). Fostering students' knowledge and argumentation skills through dilemmas in human genetics. *Journal of Research in Science Teaching*, 39(1), 35-62.