How Seventh-Grade Students Experience the Complexity of Socioscientific Issues Through Decision Making on the Autonomous Vehicle Issue

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Abstract

This study investigates what perspectives younger students considered and how they experienced the complexity of multiple perspectives about autonomous vehicle issues. Over the course of 6 weeks, 28 seventh-grade Korean students participated in role-play and group discussion to understand different perspectives on the issue. We qualitatively analyzed students’ positions toward these issues before and after the class and their perspectives in group decision making. The results indicate that students showed anxiety toward artificial intelligence systems, thus opposing it. They also explained where their concerns about the new technology arose to justify their views and opposition. We also found different patterns when students experienced uneasiness and conflicts in a group decision-making process. The patterns can be classified as (1) exploring multiple perspectives for decision making and (2) experiencing conflicts...
in working toward group consensus. Implementations for incorporating diverse perspectives into teaching strategies are discussed.

초록

본 연구는 중학생들이 자율주행차 이슈에 대한 논의를 진행하는 과정에서 고려한 관점들이 무엇인지 탐색하고, 자율주행차 이슈를 둘러싼 여러 입장들이 지난 복잡성을 경험하였는지 조사하는 것을 목적으로 한다. 중학교 1학년 학생 28명을 대상으로 6주 동안 SSI 수업을 진행하였고, 수업은 그룹 토의를 중심으로 이루어졌으며 각 그룹은 자율주행차 이슈와 관계된 특정 집단의 역할을 맡아 토의를 진행하였다. 수업 이후 학생들의 자율주행차 이슈에 대한 개인 입장의 변화를 알아보았고, 각 그룹이 이슈에 대해 합의하여 도출된 최종 의사결정을 분석하였다. 연구 결과, 학생들은 AI 기술에 대해 불안해하며 도입을 반대하는 입장이 우세한 것으로 나타났다. 또한, 학생들이 자율주행차 이슈에 대한 그룹 의사결정 과정에서 나타나는 두 가지 다른 경향성을 발견하였다. 그 경향성은 첫째, 의사결정에 대한 다양한 관점을 탐색하는 것과, 둘째, 그룹 합의를 위해 노력하는 과정에서 갈등을 경험하는 것으로 나타났다. 연구 결과를 바탕으로, SSI 교수에 있어서 다양한 관점을 통합하는 방안에 대해 논의하였다.

Keywords

ssi-based argumentation – socioscientific issues (ssi) – complexity of ssi decision making – autonomous cars – middle school student

1 Introduction

1.1 Educational Challenges in a New Technology Era

The development of science and technology is rapidly changing how we think and live our lives today. In particular, the development of artificial intelligence (AI) technology is leading us to think about the future of intelligence, knowledge, and problem solving in a society differently. It pushes boundaries of people’s imagination and action in everyday lives. As an example, AI-based autonomous cars or driverless cars can change how humans think about and act on transportation and how transport systems function in society. AI-based autonomous cars have already been introduced for future transportation and labor markets worldwide. For example, Google, at the forefront of autonomous vehicle development, is actively testing autonomous driving vehicles (Markoff, 2010). Korea is not an exception from this worldwide
discourse on AI technology. In Korea, automobile companies and associated organizations have been testing and applying temporary operation of autonomous vehicles in certain regions (Yang, Kim, & Kwon, 2017). Recently, public perceptions of autonomous vehicles have been studied in the US, UK, and Australia. Research findings have revealed that people have high expectations for the benefits of autonomous cars (Schoettle & Sivak, 2014), express their willingness to pay for autonomous cars (Hulse, Xie, & Galea, 2018), and strongly believe that autonomous vehicles would improve traffic safety (Begg, 2014; as cited in Penmetsa, Adanu, Wood, Wang, & Jones, 2019). Although it is likely that implementing autonomous vehicle technology will soon come true, there are also concerns about its impact in people's everyday life and society in general. People have expressed concerns about problems of safety and stability of AI systems in autonomous vehicles (Shin, Ha, & Lee, 2018; Schoettle & Sivak, 2014). Young students tend to perceive AI technology as frightening or as “depending on users” (Park & Shin, 2017). Kim and Kim (2018) also reported that preservice teachers frequently mention concerns about job losses and negative effects of AI. Although people can recognize the benefits and abundance of future science and technology such as AI, they also have concerns about risks and conflicts of AI and have anxiety associated with it.

With the social expectations and changes associated with AI technology, countries around the world have been giving attention to implementing educational changes to foster future generations’ preparation for the AI era. For example, in the United States, the Educational Advances in Artificial Intelligence symposium focusing on AI in society was held in November 2019, and the AI4K12 initiative symposium was held with the support of the National Science Foundation to discuss AI education for students. Germany is also actively implementing AI-related education for students. In Berlin-Brandenburg, for example, the subject of AI and human interaction is integrated with other subjects to educate students (Chung et al., 2017). In Korea, understanding roles and implementation of AI in society is also introduced as an important component of future education in the 2015 revised curriculum (Jeong et al., 2015). The objective of this study was to determine how AI technology issues, specifically the issue of autonomous cars, could be implemented in a socioscientific issues (SSI)-based teaching approach in science education.

1.2 SSI Approach for Current Science and Technology
Supporting students to understand and engage with timely issues in the society is a part of cultivating students’ scientific literacy (Aikenhead, 2006; Holbrook & Rannikmae, 2007). The SSI approach can promote engagement of students in understanding, examining, and reflecting the complexity of science knowledge and practice in the personal, social, cultural, and political domains.
Such engagement is critical for developing scientific literacy for citizens (e.g., Roberts & Bybee, 2014; Zeidler, Sadler, Simmons, & Howes, 2005). SSI s are characterized by open-ended and debatable problems with different perspectives and solutions (Sadler & Zeidler, 2005). To make decisions about SSI, it is necessary to understand the complexity and multitude of people’s knowledge, perspectives, and values engaged in the process of evaluating, negotiating, and justifying claims (Romine, Sadler, Dauer, & Kinslow, 2020; Sadler, Chambers, & Zeidler, 2004). Sadler, Barab, and Scott (2007) emphasized that analyzing SSI s from multiple perspectives and understanding the concern of various stakeholders is one of competences necessary for making decisions about SSI s. Through complex SSI cases, students can learn to be open to diverse values associated with science and technology issues in the decision-making process, provide evidence and reasons for their decisions, listen to others’ opinions, and persuasively make the case for their own decisions (Geddis, 1991).

Once qualitative descriptions of multiple perspective-taking competence were provided by Sadler et al. (2007), the importance of understanding others’ viewpoints in the context of SSI has been emphasized by several studies. For example, Kahn and Zeidler (2019) suggested socioscientific perspective taking (SSPT) through a conceptual analysis and distinguished perspective-taking from a simple opinion or position. Newton and Zeidler (2020) also developed and implemented an SSI instruction using perspective reading and writing interventions. According to the study’s findings, SSI instruction should make a conscious effort to encourage students to consider a wider range of perspectives.

As the importance of perspective taking has been emphasized, recent studies have focused on how to examine the extent to which students can improve their understanding of other’s viewpoints through SSI learning. For example, Sadler and colleagues developed instruments to quantitatively measure students’ multiple perspective-taking competence and reported that long-term SSI interventions with larger sample sizes could have an impact on students’ multiple perspective taking (Romine et al., 2017; Romine et al., 2020; Sadler, Klosterman, & Topcu, 2011). Other recent studies (Byrne, Ideland, Malmberg, & Grace, 2014; Lim & Jung, 2013; Sutter, Dauer, Krezinger, Schubert, & Forbes, 2019; Rose & Barton, 2012) have adopted qualitative approaches to understand young students’ SSI decision-making processes. For example, Byrne et al. (2014) revealed how 9- and 10-year-old students negotiate a complex environmental SSI, focusing on the repertories they used. By analyzing students’ conversations, researchers explained that students could develop their arguments based on a wide range of repertories, including both their everyday experiences and science and technology repertories. They also revealed that students used more diverse repertories even when they were involved in conflicts in
group discussions, which might have made students aware of the complexity of SSIs. Young students' decision making on SSIs in these previous studies was mainly focused on environmental issues (i.e., climate change, energy issues, and power production) and biotechnology-related topics. However, little discussion has been done about the complexity of students’ decision-making processes and tendencies.

1.3 **SSI-Based Argumentation**

SSI-based argumentation in classrooms can be introduced to explore diverse perspectives in SSI decision making through rationality and by introducing a variety of knowledge as it can generate more possibilities for morally correct decision making within deliberative democracy (Erduran & Kaya, 2016). According to Erduran and Kaya (2016), the notion of deliberative democracy should be preceded by authentic deliberation. They explained that argumentation for deliberative democracy aims to produce understanding and respect toward opposing views and thinking with evidence and justification rather than sharing simple opinions. The aim of argumentation for deliberative democracy is also to develop a greater chance for shared consensus rather than forcefully reaching a consensus. According to Sadler et al. (2007), it is possible to avoid reaching naïve conclusions through understanding the complex nature of SSIs from multiple perspectives. Thus, in this study, we take argumentation as a tool to help students understand the complexity of diverse perspectives in SSI decision making through group discussion.

In argumentation approaches, students learn to interpret and analyze information and evidence related to issues and communicate different perspectives on such issues (Erduran & Jiménez-Aleixandre, 2008; Zeidler & Keefer, 2003). In SSI-based argumentation, moral, ethical, and individual values make learning through argumentation more challenging (Sadler & Zeidler, 2005). When encountering diverse perspectives and values in collaborative problem solving and argumentation, students have difficulties in refuting other students' remarks (Cavagnetto, Hand, & Norton-Meier, 2010), being aware of their own values and engaging in internalized decision making through those values (Chang & Lee, 2010; Ju & Lee, 2013), and being open to and accepting others' claims with evidence opposed to their own claims (Evagorou et al., 2012). To help students learning about – and through – argumentation, teachers' strategic plans on argumentation are critical (Kim, Nam, Kim, & Noh, 2018). Previous studies (e.g., Simonneaux, 2001) have reported that group-argumentation activities such as discussions can improve the quality of reasoning.

In this study, we used a role-playing activity as a teaching strategy for SSI-based argumentation to provide students opportunities to explore diverse perspectives with information and evidence available (Agell, Soria, & Carrió,
In a role-play activity, students are encouraged to actively participate in classroom discussions; learn other people's situations, perspectives, and actions in the roles; and develop empathy for them (Belova, Eilks, & Feieraben, 2015; McSharry & Jones, 2000). By engaging students in the dynamic perspectives and situations of different roles, role-play can promote students' critical reflection on ideas and situations they encounter outside the classroom (Belova et al., 2015). For example, Agell et al. (2014) used the role-playing activity to help students defend different positions and reflect on students' personal opinions in decision making about an SSI in the context of biomedicine. Their results showed that students actively took part in discussions and made use of new information after role-playing activities. Garrecht, Reiss, and Harms (2021) also used role-playing activities in a teaching unit to enable students to explore different perspectives. These studies demonstrated that using role-playing activities is an effective way to introduce students to the complexities of SSIs.

1.4 Research Questions

This study's aim was to explore what perspectives middle school students consider and how they experience the complexity of multiple perspectives during group discussions about autonomous vehicle issues. By using a role-playing activity as an SSI-based argumentation approach, we encouraged students to experience the complexity of working with diverse perspectives in SSI decision making and argumentation. The specific research questions of this study were:

1. What perspectives about autonomous cars did middle school students consider during group argumentation?
2. How did they experience the complexity of diverse perspectives in their decision making?

2 Research Methods

2.1 Participants

Participants of this study were 28 seventh-grade students (20 boys, 8 girls) attending a public middle school in Seoul, Korea. Students' achievement, socioeconomic status, and academic interests were higher than the national average standard. All students participated voluntarily in a science class that was one of their elective classes as part of the free-semester system in Korea. Since 2013, this system has been implemented in all middle schools in Korea. Classes are flexibly operated by teachers for one semester to motivate students'
learning with interest and creativity. Teachers can choose current topics outside of the prescribed school curriculum. This approach emphasizes student-led activities such as discussion, hands-on activities, presentation, and so on. (MOE, 2015). The class, called Science Story, was centered on students’ group discussion, focusing on two themes: genetic manipulation and AI technology. One of the researchers was in charge of whole program class, while the other participated in the group discussion sessions and assisted the student discussion process.

2.2 Design of the Science Class

The class was held for 6 weeks with six class sessions. The design of this class featured SSI-based instruction (Sadler, Foulk, & Friedrichsen, 2016). For example, we encouraged students to argue by having them face the real-world problem of autonomous car issues and led students to participate through group discussions. The main activity of the class was role playing in groups. Each group took the roles of five different stakeholders with conflicting perspectives on autonomous car issues. Role play is a widely accepted strategy for introducing and exploring the various sides of a dilemma in science education (Howes & Cruz, 2009). Students were able to gain different perspectives by discussing autonomous vehicle issues from the point of view of each group’s role and then listening to the thoughts of other groups. In the first and second classes, we introduced the purpose and organization of the course and the structure of argumentation. Students had a preliminary discussion about the need for flu vaccinations to understand and experience how to effectively foster group discussion. During the discussion about this topic, students learned about the complexity of science and technology in society and practiced argumentation-based discussion regarding SSI. The students and teacher discussed how to justify their ideas based on using information as evidence to strengthen their claims during the discussion.

In this study, various information on autonomous vehicles was provided to students. Students also researched this topic on their own to justify their claims. From the third class, students participated in argumentative discourse on the topic of AI technology. Various activities included brainstorming, mind mapping, video watching, article reading, and individual reflection in writing and group discussion. We developed and presented a problem scenario featuring autonomous vehicle issues to students (see Appendix 1). Role-play activities began from the fourth class. We introduced several stakeholders related to the scenario in order to generate complexity of issues for students’ discussions. Eight groups (groups A–H, 3–4 students for each group) were formed. We introduced five different stakeholders: a truck drivers’ association
(Groups B, F, and H), general drivers (Groups A and G), scientists and engineers (Group E), a logistics company (Group C), and national policymakers (Group D). Each group of students randomly took a specific role. They discussed and developed their ideas. They then made a final decision on the issue through group discussion.

According to Agell et al. (2014), role-playing activity is an effective way to introduce students to the complexities of an SSI. After introducing the problem scenario, the teacher briefly introduced each stakeholder related to the issue and students developed further arguments for and against the adapting of autonomous cars in our country. In the fifth class, we presented each group reading supplements containing additional information about the issue. Reading materials were made by researchers based on knowledge and information about autonomous cars retrieved from various internet newspaper sources. These reading materials included subjects such as global trends of autonomous vehicles, AI technology for autonomous vehicles, social and economic benefits from autonomous vehicles, environmental benefits of autonomous vehicles, and cases of accidents involving autonomous vehicles. With additional reading materials, students continued to explore in depth other aspects of autonomous vehicle issues. After each group had come to a consensus on the issue, they had a group poster presentation. Overall, students had two small group discussions and one presentation regarding the AI issue. Details of the process are shown in Table 1.

2.3 Data Collection and Analysis

Data collection and analysis were conducted in three phases. In the first phase, we explored how individual opinions on autonomous vehicles had changed after group discussions and argumentation. Students were asked to fill out a worksheet with their personal positions about autonomous vehicle issues in the beginning of the course. After the course, we asked them to write down whether there was any change in their initial opinion on the issue. In addition, each student was required to write a reflective essay in order to get a better understanding of their thoughts on the issue. As prompts for reflective writing, the following questions were used: “What are the factors that influenced your final opinion on the issue?” “Has your perspective changed after group discussion? If so, why?” and “What difficulties did you experience during group discussion?” We compared individual positions of students before and after the class and counted the number of instances in which students’ opinions changed or did not change. We also classified the reasons their opinions had changed, if applicable.
In the second phase, we focused on students’ group decision-making processes to understand the extent to which students considered multiple perspectives during decision making. Artifacts from group activities, such as activity sheets, audio/video data from group discussions, and presentation poster materials, were collected. We used the thematic coding method (Braun & Clarke, 2006). First, we transcribed all collected data and continually read transcripts, comparing transcribed data to check whether common characteristics appeared saturated. We then generated initial codes for perspectives in students’ decision-making processes. Thirty-three codes were developed at this stage, such as “accidents caused by defects in technology,” “high initial cost for purchasing autonomous vehicles,” and “discomfort and fear for new technology.” We then grouped similar codes together by categorizing them as pros and cons. We selected key themes that described perspectives that students considered in decision making. Three themes emerged in this stage: economic perspectives, benefits and uncertainties of science and technology development, and social perspectives.

In the third phase, the position presented in the final group decision-making activity sheet and evidence used for it were classified based on analysis results of the second phase. We analyzed what kind of evidence the students used
in the decision processes during their group discussions to make their final decisions. The frequency of each perspective used was checked. Whether they considered other viewpoints in addition to their own was also determined. Three different cases were found. We then formed focus groups (Groups A, B, C, and F) to obtain group cases that clearly revealed the three cases. We then interviewed them to gain a thorough understanding of students’ discussions. A focus-group interview was also conducted by asking for students’ detailed opinions based on their group and individual worksheets and materials. We tried to understand how students attempted to reach a consensus and investigate the complexity of their decision-making process. We identified tendencies in conflicts that arose during students’ group discussions, difficulties that students encountered, changes in their opinions, and reasons for such changes. We then selected several episodes that showed these tendencies clearly and examined how students’ perspectives, positions, and statements were intertwined with others during group discussions.

For the trustworthiness of the study (Lincoln & Guba, 1985), the three researchers in this study met regularly both offline and online to determine and reconfirm the analysis process for developing and coding themes, continually adding and modifying themes by comparing points in the data (Flick, 2006; Williams & Moser, 2019). One of the researchers planned and arranged the class through constant discussion with other researchers, and during the student discussion session, she observed the students with one other researcher and collected data together. We also used various data sources, including audio/video data, interview materials, and worksheets, to analyze students’ discussions.

3 Results and Discussion

3.1 Students’ Perceptions of Autonomous Vehicles Before and After the Class

In the beginning of discussion, nine students answered that they supported the adoption of autonomous vehicles in our country and 13 students said they opposed it. In the beginning, the number of students opposed to the use of autonomous cars in our country were slightly higher than the number of students who agreed. Students who supported the use of autonomous cars cited advancement of the country’s economy and fewer car accidents as reasons from the information they searched. For example, Cho, a student in Group C, argued in favor of autonomous cars, saying, “The autonomous car is convenient
and has many advantages because it can be used by many people who cannot drive.” The students who objected to the use of autonomous vehicles in our country, on the other hand, mentioned the danger and safety of autonomous vehicles. For example, Lim, a student from Group F, argued against the use of autonomous cars, stating that “since blind faith in the latest technology may injure people due to errors, sufficient practices are required.” At the end of the class, there were five students who supported the usage of autonomous vehicles, whereas 17 students indicated they against their use and six students did not answer on their viewpoint. Some students changed their minds during the class, and afterward more students opposed the use of autonomous cars. Table 2 provides an overview of changes in students’ viewpoints. In terms of how their final position changed after taking classes, 13 students did not change their positions, while nine students did. At the end, eight students continued to support it, four students changed from their previous support to opposition, and nine continued to oppose it. Most of these changes were made by students who initially supported autonomous vehicles but later opposed them. After the discussion, only one student changed positions from being opposed to being supported.

### 3.2 Perspectives in Students’ Decision Making on Autonomous Vehicle Issues

Based on overall changes in students’ opinions, we looked closely into their dialogues during group argumentation to determine what perspectives induced students to agree or disagree. Students presented 58 grounds for their final decision, with 20 in favor and 38 against. We grouped these 58 grounds together with similar meanings and presented them in 10 different justifications. Table 3 shows the perspectives that students considered regarding the final decision making about the autonomous car issue.
### Table 3: Students’ positions and justifications on autonomous vehicle issues after the class

<table>
<thead>
<tr>
<th>Position</th>
<th>Justification</th>
<th>Number of students</th>
<th>Examples of the students’ comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supported</td>
<td>Enhanced economic efficiency</td>
<td>9</td>
<td>“Overcrowding is reduced, resulting in fuel and time savings.”&lt;br&gt;“Autonomous car saves time figuring out where to go.”&lt;br&gt;“Autonomous car is fast and efficient.”</td>
</tr>
<tr>
<td>Supported</td>
<td>Car accidents are less likely to occur</td>
<td>5</td>
<td>“Autonomous cars have the potential to be safer.”&lt;br&gt;“The risk of accidents is lower because they follow traffic laws more closely. There is indeed a decrease in the number of fatal accidents.”</td>
</tr>
<tr>
<td>Supported</td>
<td>Enhanced driver convenience</td>
<td>3</td>
<td>“You can pass the time while driving.”</td>
</tr>
<tr>
<td>Supported</td>
<td>Possibilities for improving technology</td>
<td>3</td>
<td>“There will be no progress if it is regulated as risky.”&lt;br&gt;“The possibility of expanding the system develops.”</td>
</tr>
<tr>
<td>Opposed</td>
<td>The insecurity of technology</td>
<td>11</td>
<td>“With imperfect technology, an accident can occur.”&lt;br&gt;“The machine may malfunction. There are no such things as complete safety.”</td>
</tr>
<tr>
<td>Opposed</td>
<td>Ethical and legal concerns</td>
<td>10</td>
<td>“Hacking may result in casualties.”&lt;br&gt;“There is no law dictating where responsibility should be assigned in the event of an accident.”</td>
</tr>
<tr>
<td>Opposed</td>
<td>Loss of driver’s job</td>
<td>7</td>
<td>“A lot of people will lose their jobs.”&lt;br&gt;“The driver’s role is eliminated”</td>
</tr>
<tr>
<td>Opposed</td>
<td>Expensive R&amp;D costs</td>
<td>4</td>
<td>“Cars are pricey. Economic loss when the system is implemented in practice.”</td>
</tr>
<tr>
<td>Opposed</td>
<td>Difficulties in AI management</td>
<td>4</td>
<td>“It is difficult to respond to an emergency like a human.”</td>
</tr>
<tr>
<td>Opposed</td>
<td>Fear and distrust for new technology</td>
<td>2</td>
<td>“There is apprehension about new technology.”&lt;br&gt;“There is a risk of accidents or crimes while driving in all age groups.”</td>
</tr>
</tbody>
</table>
3.2.1 Economic Perspectives
During students’ discussions, frequently emphasized were economic values and issues related to autonomous vehicles such as profits, job markets, convenience, ease of use, and research and development costs. Students pointed out that a new autonomous vehicle system could make human life more convenient, save time, and improve work efficiency. For example, students in Group C (a logistics company) agreed to the implementation of autonomous vehicles in society. Initially, they were concerned about the high cost of introducing autonomous vehicles, but later agreed because commercialization of autonomous vehicles would be more profitable for their company. We extracted keywords for positive economic perspectives such as “economic development,” “higher work efficiency,” and “reduced driver labor costs.” Students also mentioned concerns about implementation such as “drivers’ jobs disappearing,” “high costs,” and “expenses for R&D” as negative economic perspectives. Students who were opposed to autonomous vehicles pointed out the following disadvantages: (1) drivers’ jobs would be threatened and (2) the initial cost of introducing an autonomous vehicle system would be too high. The following conversation was from the first discussion in Group B which took the position of truck drivers.

Cheong: Guys, we’re the head of the truck drivers’ association. We have to be against the autonomous system because there are so many cases where truck drivers have lost their jobs after AI systems are introduced.
Yoo: Yes, I agree.
Cheong: So, for now, is there any way to put off the adoption of an autonomous-vehicle system?

During group discussion, they were most concerned about the loss of drivers’ jobs. Cheong continued to say that they should oppose the implementation of autonomous vehicles and insisted on finding a way to slow the introduction of AI in general. Students in another group also opposed autonomous vehicles because of the burden of cost, saying that “autonomous vehicles are expensive to buy.” Whether they opposed or supported the implementation of autonomous vehicles, students placed emphasis on economic issues.

3.2.2 Benefits and Uncertainties of Science and Technology Development
Students were aware of the uncertainty of new science and technology, along with values of developing science and technology for society in the future. During group discussions, students expressed their expectations and enthusiasm for new technology, mentioning current practices and future possibilities
for AI-based robots in the workforce and society. However, they also shared a fear of imperfect new technology, mentioning “technology defects,” “system-error possibilities,” “difficulty of AI management,” and “inconvenience and fear with new technology.” Students explained that there were still uncertainties with the new technology, saying that “the current autonomous vehicle system has a technical limit and the risk of accidents.” The following is an excerpt from Lee’s individual reflection writing:

At first, I thought autonomous vehicles would be convenient and good. However, after I talked with my group, I changed my mind. This was because autonomous vehicles could not avoid or recognize unexpected natural disasters or dangerous situations as quickly as humans. Science and technology play an important role in improving the quality of our civilization and our lives. However, the latest science and technology, which has not yet been proven, will definitely introduce some errors and should not be released to the customer until it is perfect.

Lee, a student in Group A, changed his mind after he learned that an imperfect system could lead to accidents. In this excerpt, he was well aware of possible risks in adopting unproven new technology. His group took on a general driver’s position. Their final decision was against the adoption of autonomous vehicles. In their discussion, they focused more on the present situation, referring to examples of past accidents showing “risk of malfunction” and “system hacking or intentional manipulation.”

On the other hand, some students emphasized benefits of new technology even when it has not been proven to be perfect. We extracted keywords illustrating such themes as “expectations of new technology” and “possibilities for improving technology.” The following is from Cho’s interview. Her group took on the role of a logistics company.

I found several disadvantages of autonomous vehicles. These should be addressed. At the present time, autonomous vehicles cannot be fully aware of things, which could lead to accidents. However, I don’t think that we should discard autonomous vehicles due to problems. I think we should invest more time in technology so that we make the technology more perfect. I think that we can make up for it.

Cho was aware of the risk of autonomous vehicles. She was focused more on the possibility of the development of AI technology and its value for the future. She further pointed out that it was necessary to continuously develop
unsecured science and technology so that it could become secure. Even if students addressed the insecurity of autonomous vehicles, they believed that new science and technology could bring economic and social benefits in the future. Thus, they believed that there was a need to keep developing the technology.

3.2.3 Social Ethical Perspectives
Students also considered social and ethical aspects, mentioning positive perspectives of personal and social wellbeing regarding autonomous vehicle implementation. The extracted main keyword was “drivers’ welfare.” Students in Group F (truck drivers’ association) stated their concerns about job loss and salary deduction with the system coming into implementation. They also addressed busy lifestyles in society. The following excerpt is from their conversation:

Teacher: What’s the reason for objection? Would you agree [to adopt autonomous vehicles] even if your salary would be declining?
Lim: There is no clear evidence that salaries would decline. A truck driver could more easily pursue personal activities for pleasure than ever before.
Teacher: Oh, I see. So, money is not everything, right?
Chae: Time is more precious than money.

As the chief advantage of autonomous vehicles, Lim mentioned that drivers could use time more freely than before. They anticipated that drivers’ personal activities would increase if autonomous vehicles were adopted and that such leisure time would release drivers from their heavy work duties and provide better lives. The above conversation implied that they were also aware of the advantage of autonomous vehicles for developing human wellbeing, even though Group F was against the autonomous vehicle system in their final decision.

Students also frequently discussed ethical issues related to accidents involving autonomous cars. Main extracted keywords were “lack of responsibility for accidents” and “lack of laws related to accidents.” The following excerpt is from Group C’s discussion:

Kim: How can we be responsible when an accident occurs due to a system error in autonomous vehicles?
Cho: That’s a good question.
Kim: If, for the victim’s family, an autonomous vehicle was 100% responsible for the accident … and if an accident occurred, it was the fault of
this autonomous vehicle system, then this could represent a big mistake of the company, too.

Oh: I got it. So, basically, the cause of the accident is actually a system error, but people could say that the accident is the logistics company’s responsibility?

Kim: Yes, because we (the logistic company) put the autonomous vehicle system in rather than hiring people (drivers).

Oh: (Writing) When an accident occurs. Or we can say that “an accident is caused by a system error.”

Kim: And people do not know why the accident occurred.

Oh: Right. (Continuing to write) If a system error occurs and causes an accident, then the responsibility ...

Kim: What is the term exactly?

Oh: Accountability for the accident.

Students discussed the unclear accountability for car accidents involving autonomous vehicles. As Kim mentioned at first, students mentioned system errors in autonomous vehicles as the primary cause of accidents. When it comes to responsibilities for the accident, however, students could not clearly say whose fault it would be as they were aware of positions intertwined with the accident: those of victims, the driver, the carmaker, and the logistics company. This indicated that students were aware of social and ethical aspects that needed to be considered in future decision making when implementing AI-based autonomous cars in everyday lives.

3.3 How Students Experience Complexity of Diverse Perspectives through Group Discussions

Engaging students in exploring and reflecting on various positions on autonomous cars in group discussions was to help them experience the complexity of decision making. To understand how diverse perspectives on autonomous cars and their roles could influence their decision making, we examined what perspectives students considered in their final decision-making process during group discussions. We particularly looked at presentation reports for the final decision and coded how frequently each perspective was discussed and which perspectives were given more weight for their final decisions. Figure 1 shows the final position of each group on the autonomous vehicle issue and the frequency of justification supporting their final position based on Table 3. Two groups (Groups C and E) stated that they supported the use of autonomous vehicles, whereas five groups (Groups A, D, F, G, and H) opposed it in their final reports. Group B took a neutral stance on this issue.
As shown in Figure 1, some groups (Groups A, D, G, and H) mainly took one-sided perspectives to support their positions while some groups (Groups C, E, and F) explored both perspectives to develop their final arguments. For instance, students in Group H used only opposing perspectives to develop their final positions whereas students in Group E discussed three supporting and two opposing perspectives for their final position. Students in Group B expressed a neutral position, experiencing conflicts among perspectives between their personal position and their role's position. Details of their decision-making process are shown below.

3.3.1 Exploring Multiple Perspectives for Decision Making
In group discussions before making a final decision, certain patterns were observed. First, students explored and discussed both pros and cons of their roles and explained how these perspectives could be beneficial or harmful for their position. These groups deliberated on multiple perspectives and reflected on them to produce reasonable decisions. Rather than using their own beliefs and specific positions from their roles, students in Groups C, E, and F took
particular caution to make information-based decisions. Here are some examples of Group C (the logistics company position):

Kim: Let's think about the advantages first.
Cho: The cost of labor – I mean, the cost of hiring a driver – goes down?
...
Kim: When that time comes ... What do we call it?
Park: Popularization?
Cho: When everyone can use them [autonomous vehicles].
Kim: Yes, that's it.
Cho: [Writing] The driver's employment cost is greatly reduced?
Kim: When autonomous vehicles become popular, the company does not need to hire people, thus saving a lot of money.
...
Kim: Next, let's talk about disadvantages. Some companies may not successfully invest in autonomous cars.
Cho: They can't afford to pay for them.
Kim: Right, when autonomous cars first come out, they will be much more expensive because they are not yet universalized.
Cho: [Writing] Prices of autonomous vehicles will be so high that they can damage a company's management.
Oh: But the industry (of autonomous cars) has begun to succeed, little by little.
Cho: Right, other companies can succeed too.

As shown above, these students did not immediately frame their argument in either support or opposition. Rather, they investigated relevant issues and information thoroughly and broadly, considering what benefits or risks autonomous vehicles might bring to people's lives. They explored multiple perspectives of autonomous vehicles and agreed that the company's economic benefits would be greater. Thus, they were in favor of autonomous vehicles. They also discussed several ethical and legal issues surrounding autonomous vehicles. However, they considered such issues unavoidable aspects in a society during the constant development of new science and technology. For instance, during the focus group interview, Kim said: “because autonomous cars can't fully recognize surroundings yet, car accidents can occur – but I don't think we should abandon the technology because of such problems. I see more potential for development.” They searched for as much information and evidence as possible to ground their claims. They compared their reasons with their own and others’ roles. They also constructed counterarguments based on opposite perspectives to strengthen their own claims in their final decision.
Another pattern was that several groups (Groups A, D, G, and H) of students tended to look into only the information that supported their role’s position. During group discussions, students built their arguments around the assigned roles’ point of view and interpreted ideas and information from reading materials to support their own roles and claims, which were clearly shown in their final decisions. The following conversation from Group A (general driver group) below supported this. Kang and Ko were in favor of autonomous cars before they were assigned the role of general drivers. However, when they were asked to represent general drivers, they only expressed concerns about autonomous vehicles in traffic.

Kang: Well then, people here, my group, are those who still drive their own cars, just normal driving people.
Teacher: Right, driving regular cars, not using autonomous vehicles.
Kang: So ... let’s suppose that you are driving, and you see an autonomous car next to you. How would you feel? I think you will be uneasy.
Teacher: That could be uncomfortable. Keep going.
Kang: I think it’s awkward. There is a car next to me, but there is no one inside. And I do not think driving will be completely safe with autonomous cars.
Ko: Okay, we all have a negative opinion now.

When they were situated in the condition that they were driving regular cars on the road by themselves, they came to pay attention to the safety of the system. Kang opposed the implementation of autonomous vehicles because their safety had not been guaranteed. He searched for more information to represent ordinary drivers’ viewpoint and used it as evidence to support their group claim. Group A continued to discuss accidents caused by autonomous vehicles before reaching their final consensus. Students in other groups (Groups D, G, and H) also demonstrated this tendency in their final decision-making process. They examined one-sided information during their group discussion and reached a consensus.

3.3.2 Experiencing Conflicts in Working Toward Group Consensus
Students encountered conflicts in decision making between their personal beliefs and the roles they had to represent, recognizing diverse perspectives around issues of implementing autonomous cars in society. With such conflicts, some students explored the advantages and disadvantages of autonomous vehicles while some students decided to examine only the perspectives of their own roles to make their final decisions. Some students could not make decisions because of such conflicts. Students in Group B (truck drivers)
struggled with their final decision making. They were unable to set their priorities with any one position. Thus, they came up with a neutral stance to compromise their points of view. They felt uncomfortable because the viewpoint of the assigned role contradicted their own. They could not ignore their own viewpoints, that is, supporting the implementation of autonomous cars. Thus, it was difficult for them to work on the given role. They even argued with their team members during the decision-making process. Here are some examples.

Cheong: Why am I against autonomous vehicles? Because AI takes away the jobs of our truck drivers.
Park: Right.
Yoo: But once autonomous vehicles are widespread, we won't need any truck drivers. Then we will need people to make the new system. I mean, even if our jobs disappear, there would be new jobs created, such as making autonomous vehicles.... So, the job market is not going to be shrinking. Now, AI is being added in making cars. The industry will be upgraded even more. So, if you think about it from the economic perspective, it's better to lose our jobs because the whole economy is getting better.
Cheong: Then how will we (truck drivers) make a living?
Park: Right. I mean, what can we do for a living?
Shin: There will never be job loss because of autonomous vehicles. Because ...
Yoo: Right, there could be more jobs. We have the technology to make ordinary cars, but now we are talking about autonomous cars. So, we need to have more manpower to add AI systems to existing cars.

From the above conversation, Yoo and Shin refuted Cheong's claim that jobs would disappear. They continuously showed positive attitudes toward autonomous cars, suggesting that new jobs would be created. Yoo even told the teacher that he did not want to represent the truck driver's situation, saying that he was “not a real truck driver.” Shin also supported Yoo's opinions. Their debates continued in the final group discussion.

Teacher: What is your group’s opinion?
Cheong: We are absolutely against autonomous vehicles. There's no other option than that.
Yoo: But I'm actually in favor of autonomous cars.
Teacher: Your group represents truck drivers, right?
Yoo: Yes. But I'm not a real truck driver, so I don't know well.... So, I really don't know what position I should take. I just wish I was not in such a situation.
Yoo consistently stated that he would support the use of autonomous cars. With conflicts and confusion, students as a group were unable to reach an agreement. Eventually, the teacher suggested that they could consider it from the perspective of middle school students rather than as truck drivers because some of them were experiencing conflicts with their beliefs and values. They agreed to make a conditional approval and continued their discussion: “It’s premature because technology for autonomous vehicles is not perfect now, but it could possibly be introduced in 10 years after the technology is fully developed.”

4 Conclusion and Implications

This study explored what perspectives Korean middle-school students paid attention to and how they experienced the complexity of multiple perspectives during group discussions about autonomous vehicle issues. The following discussions were generated based on the research findings.

4.1 Need for Having Students Experience Complexity of SSI Decision-Making Process

The research results indicate that middle school students were aware of various perspectives about autonomous vehicles. They applied their perspectives to their decision making through group discussions. In this study, AI-related autonomous vehicle issues were chosen to provide students opportunities to experience and understand the complexity and ambiguity of current science and technology and various aspects involved in a decision-making process. Students’ decision-making processes were based on various values and perspectives, such as economic development and losses, social and ethical aspects, and benefits and uncertainties of science and technology in lifeworld implementation and practice. This finding was consistent with previous studies on middle school students’ decision making about SSI’s (Capkinoglu, Yilmaz, & Leblebicioglu, 2020; Sutter et al., 2019). Exploring and understanding diverse perspectives did not always lead them to change their positions about autonomous cars. More than half of students did not change their initial positions about the autonomous car issue after class or group discussions. Previous studies have shown that middle school students do not easily change their ideas or decisions on SSI’s even with contrasting evidence (e.g., Emery et al., 2017). Thus, the findings of this study are not new or surprising. However, making students change their position was not the priority of the SSI decision-making process in this study. We were interested in understanding how students developed evidence-based claims based on the complexity of diverse perspectives intertwined in the issue.
In their decision-making processes, more students tended to oppose AI system-based autonomous cars rather than support them. Students expressed their discomfort by mentioning uncertainties of science and technology (i.e., lack of safety assurances, potential for system hacking, and general anxiety about new technology) and explained these were evidence that AI-based autonomous cars at the current level would not work. Students believed that, thus, such cars should not be implemented in our society. These results partly correspond with previous research findings on students’ perceptions of AI. For example, according to Shin et al. (2018), students had negative perceptions on AI systems as either an “enemy” or a “servant.” The researchers pointed out that such students’ fears or imaginations were vague and unsubstantial, which could be a serious barrier to understanding the principles and applications of an AI system. They could also hinder the development of rational value-judgment abilities. In this study, students also expressed their anxiety and fears about autonomous cars, thus opposing their implementation, although they explained where their concerns and distrust arose about this new technology after exploring available information and diverse perspectives of stakeholders in society. They were concerned about problems with autonomous vehicles such as the stability and safety of the system. However, some saw that such problems could be solved if science and technology can be further advanced. Because the current level of AI technology is not ready to be implemented in society, they opposed it. Although students were concerned about job losses due to the technology, they also thought about how to cope with such problems creatively. They could explicitly explain their fears and anxiety toward AI systems rather than vague threats to human society. Students’ hopes for and anxiety about autonomous cars in diverse perspectives were expressed and explained throughout the decision-making process.

4.2 Teaching Strategies for Inviting Diverse Perspectives

It is critical to provide an appropriate teaching strategy for students to consider multiple perspectives that are intertwined in SSI issues during a decision-making process. This study employed a role-playing activity in argumentative contexts to encourage students to explore multiple perspectives and others’ positions that could be different from their own. By exploring different viewpoints and values from diverse social members, they also experienced uneasiness and conflicts in their decision-making process. Sometimes as they switched roles back and forth or from their own to others’, they noted that their positions and value-judgements were also challenged and changing. They told us why they needed to “listen to” others to understand how others experienced
certain issues. Through the practice of role-playing argumentation, students realized the need for understanding and communicating with others to reach fair decisions based on available information and evidence. Developing students’ understanding and willingness to respect others’ perspectives can be critical outcomes of learning through argumentation for deliberative democracy (Erduran & Kaya, 2016). Students explored and understood diversity and difference in knowledge, values, and experience regarding the practice of science and technology. They were encouraged to respect others’ perspectives during dialogues and decision making.

We believe the process of understanding the complexity of diverse positions of different members of society and the process of learning how to communicate across differences are more important in SSI-based argumentation than reaching one conclusion or changing their points of view. As there were many unknown factors in the area of autonomous cars and safety concerns outweighing benefits, many students did not change their stance, that is, their opposition to its implementation. Yet, the complexity of the perspectives, values, and roles of others that they represented led them into some degree of conflict in their decision making. They coped with these conflicts among diverse positions differently. Some students categorized available information into advantages and disadvantage in order to understand their roles and determine their final positions. Some only focused on their assigned roles, purposefully choosing evidence that could support their positions. Some students could not ignore their confusion or conflict in their given roles, as those roles clashed with their own values. They could engage in an active discussion only after the teacher told them that it was okay to take a neutral position instead of taking a particular role. Students expressed difficulties in making decisions for certain groups, especially when roles they took were different from their own personal beliefs and values. Inviting students to think about diverse ideas and positions in different roles by randomly assigning roles provided students opportunities to experience complex and conflicting perspectives. It was a meaningful approach to enhance their dialogical deliberative decision-making skills by embedding the role-play in SSI-based argumentative contexts.

4.3 Limitation and Future Directions

There is a limitation to generalizing from this study because of the limited number of participants (28 students). Even though sampling was limited to a one school in a single country, the perspectives of a select group of students could be examined in depth in this study. From the results, we found that students made decisions on a current SSI issue by examining various
perspectives, including social, scientific, and economic perspectives. But in this study, instead of focusing on the actual scientific content related to the topic, students focused on the ambivalence that comes with new scientific and technical advances. This may have been because, in this study there was no teaching or usage of scientific and technological knowledge related to autonomous cars. Explicitly encouraging students’ use of scientific knowledge in the discussion process, we believe, would improve the future study.

As an SSI-related study, we believe it is significant because we explored how young students make decisions about an SSI by utilizing recent issues about autonomous vehicles, which have not been well covered in SSI research. Furthermore, we feel that role-playing activities can be used as a teaching strategy in the future to support teachers and researchers who develop SSI classes and related research.

The findings of this study emphasize the importance for democratic dialogues of understanding the complexity of decision making through argumentation, not just for reaching a final conclusion as an end product. Educational focus can be given to how students collectively explore and negotiate diverse perspectives intertwined in issues. As SSI-based argumentation is critical for developing scientific literacy for citizenship, teachers need to develop and examine various strategies to help students learn to participate in democratic processes of argumentation and communication for decision making. In this regard, this study presented one particular strategy to encourage students to experience and understand the complexity of science and technology in society today.

**Abbreviations**

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>AI</td>
<td>Artificial Intelligence</td>
</tr>
<tr>
<td>AI4K12</td>
<td>Artificial Intelligence for K-12</td>
</tr>
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<td>SSI</td>
<td>Socio-Scientific Issues</td>
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**Ethical Considerations**

The data reported in this study does not require human subjects' approval. The data was generated from a regular class organized by the school system. The academic use of data had been agreed upon by the students and their parents. No data was collected or reported on that will risk students' safety, identity, and confidentiality in this study.
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References


Appendix 1

The Scenario
Should We Adopt Autonomous Vehicles in Our Country?

Autonomous vehicles are operating on real roads in the US and Europe (e.g., Germany). There are two million truck drivers in Europe, where 75% of logistics rely on roads. Truck traffic is expected to continue increasing in the future. Truck drivers in Europe cannot drive more than five hours per shift. Therefore, most trucks have two drivers. From a logistics company’s point of view, reducing the number of employees by laying off both drivers from each shift can save more than half of current operational costs. When several autonomous trucks are simultaneously deployed, they automatically generate and control their speeds coordinated through Wi-Fi communications. Only one operator is needed in order to control several trucks. Because the processing speed of AI is much faster than any human, vehicles can drive closer together and more safely. Autonomous trucks’ software can react 25 times faster than a human driver does. Ultimately, it is possible to save five to fifteen% of the fuel. The cost of implementing an autonomous vehicle system does not seem to be a problem at present. Unlike ordinary cars, trucks can be sold at higher prices even when they are used or preowned ones.