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The Effects of Community-Based Socioscientific Issues Program (SSI-COMM) on Promoting Students' Sense of Place and Character as Citizens

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Abstract

This study aimed to investigate how the community-based socioscientific issues program (SSI-COMM) affected middle school students' sense of place (SOP) and character development as citizens. We designed and implemented SSI-COMM on fine dust, abandoned pets, and recycling issues that were closely related to the students' local communities. SSI-COMM consisted of four phases, and in each phase, students engaged in various activities both within and outside of school. A total of 441 seventh graders participated in SSI-COMM over 8 weeks. Two questionnaires were used to measure the changes in students' SOP and character development (CVGCA) through SSI-COMM. Paired *t* test was used to compare the effects of SSI-COMM on SOP and CVGCA. In addition, hierarchical cluster analysis was conducted to identify and describe the students who showed similar patterns based on score changes in SOP and CVGCA and to create student profiles to investigate how to appropriately target those students to develop their SOP and CVGCA. The results indicated that students' SOP and CVGCA scores improved after the students participated in SSI-COMM. In detail, a 6-cluster option was determined to provide the best representation of the data measured before and after intervention (groups A to F). Although there were some differences in the pattern of score change among groups, four groups out of six groups (groups A, B, C, and D; about 69%) showed a positive change after implementing SSI-COMM. SOP scores were found to be statistically significant in all groups except group E, and CVGCA scores were statistically significant only in groups A, B, and C.

Keywords Character development · Citizenship · Community-based learning · Sense of place · Socioscientific issues

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Introduction

Ulrich Beck, in his book *Risk society: Towards a new modernity*, describes the characteristics of the modern industrial society as "risk society" (Beck, 1992). He argues that science and technology development continually produces new forms of risks—not limited to global warming, environmental pollution, health risks, etc.—to which citizens are constantly required to respond. Some risks are caused by the bifaces of science and technology (e.g., GMOs, embryo stem-cell research, and food additives), and some are brought by the growth-oriented paradigm in society (e.g., building/bridge collapse, and sinkholes). Some are unexpected and are not easily controlled by even advanced science and technology (e.g., MERS, avian influenza, and Zicca virus). Since such risks inherent in modern society are often not intuitively perceived and are largely uncertain and unpredictable, this situation raises the following questions: How do we prepare students for a risk society? What kinds of citizens do we envision for a risk society? What competencies will students as future citizens need for a risk society?

Over the past decades, scientific literacy has become "too important to leave to scientists or science educators" (Fensham, 2002, p. 9). However, there has been continuing debate among science educators regarding a consensus on the notion of scientific literacy (DeBoer, 2000; Hurd, 1998). Since it is a socially constructed concept (Laugksch, 2000), scientific literacy changes with context and time. Recently, *practice* (*action*) and *participation* have been emphasized as the main elements of scientific literacy. Hodson (2003) and Roth (Elmose & Roth, 2005; Roth, 2003; Roth & Lee, 2004) argued that science education curriculum should be oriented toward socio-political action. Sperling and Bencze (2010) also emphasized activism as one of the major elements in citizenship education and claimed that science education should be integrated with citizenship education, to cultivate responsible citizens. These progressive researchers envision citizens as proactive agents willing to participate in discourse and actions aimed at resolving issues in a manner that serves the well-being of global communities. They also emphasize "collective praxis" (Bowen & Roth, 2007; Roth & Lee, 2004) because individuals are able to better resolve the issues and to take more effective action when they are collaborating with others who have diverse set of skills and knowledge.

Therefore, a pre-requisite for developing students' civic responsibility is to provide the students with experiences of being a part of community. Authentic learning occurs contextually in relationships with the members surrounding the learners and in the places where they spend most of their time. Working in the community, students can feel connected to their community and feel responsible for addressing and resolving the community issues as community members (Catalano, Oesterle, Fleming, & Hawkins, 2004; Knapp, 2008; Stevenson et al., 2014; Tal & Abramovitch, 2013; Tytler, Symington, & Clark, 2017). As individuals get more involved in the community, they develop their identity within "community of practice" that shares certain beliefs, practices, and knowledge (Cobb & Bowers, 1999; Wenger, 1998). It indicates that the gap between learning and action has narrowed.

Powers (2004) argues that direct learning experiences within meaningful places give students a sense of attachment to the place they are in and that these experiences become the driving force for more active involvement in addressing their communities' problems, leading to action. Similarly, Morgan (2011) argues that the formation of

place attachment (PA) fosters eco-friendly behavior and responsible actions in students. Such results indicate that having the sense of place (SOP) in their community is closely related to cultivating character and values as citizens. Character and values enable individuals to act responsibly with respect to human life and allow them to show compassion for other human beings on the planet (Choi, Lee, Shin, Kim, & Krajcik, 2011; Zeidler, Berkowitz, & Bennett, 2014). Once internalized, they play a role in guiding actions, motivating attitudes toward relevant situations, and making moral judgments about oneself and others (Hodson, 2003; Zeidler, Sadler, Simmons, & Howes, 2005).

In this study, we focus on promoting students' SOP and character and values as citizens through the implementation of a community-based socioscientific issues program (SSI-COMM). SSI-COMM deals with such issues as abandoned pets, fine dust (particulate matter pollution), and recycling issues that students encounter in their community. The program draws on community organizations or resources to learning in school. The linkage with the local community is not restricted to the utilization of physical resources through simple field trips, but rather by meeting and communicating with local experts and local residents to solve community issues, in which the contribution of students to the community by taking action is emphasized. We assumed that SSI-COMM increases the SOP, and nurturing the SOP ultimately leads to character development as citizens who actually enact actions and community involvement. The guiding research questions are (1) to what extent SSI-COMM enhances middle school students' SOP and character and values as citizens and (2) what kinds of common patterns are shown in students' score changes of SOP and character and values through SSI-COMM?

Review of Literature

Community-Based Learning for Citizenship

Recently, *participation* or *political actions* are critical words in discussing the notion of scientific literacy. For example, Hodson (2003) argues that contemporary conditions demand a "politicization" of the science and technology curriculum. Hodson criticizes that current science teaching puts too much emphasis on obtaining basic knowledge and skills in achieving scientific literacy. The key objective of science education should be "to equip students with the capacity and commitment to take appropriate, responsible and effective action on matters of social, economic, environmental and moral-ethical concerns" (p. 653). Putting more emphasis on political actions, Elmose and Roth (2005) use the term, "Allgemeinbildung ("allgemein" means "general")" that "involves competence for self-determination, constructive participation in society, and solidarity toward persons limited in the competence of self-determination and participation." (p. 21).

However, the emphasis on actions and participation has hardly been actualized in the school science classroom. Birmingham and Calabrese Barton (2014) have argued that "despite attention to the role of scientific literacy for democratic participation in reform initiatives, civic action using scientific expertise continues to play minimal roles in science education" (p. 286) and presented two reasons for this: (1) science educators tend to believe that sufficient scientific understanding prompts civic engagement and actions and (2) current educational reforms focus exclusive attention on the cognitive dimension of

science learning. Other researchers (Herman, Olson, Holtz, & Colbert, 2013; Lee & Roth, 2003; Tal & Abramovitch, 2013) have also claimed that action-taking has hardly been a major focus of science learning, nor is it explicitly addressed in the science classroom.

To encourage students to take action, it is essential to provide a context for the students to leverage their scientific knowledge and skills to inform action (Birmingham & Calabrese Barton, 2014). Community-based learning can contribute to creating a social atmosphere in which students, and community members can openly communicate on issues and ultimately to improving the scientific literacy of both students and community members (Lee & Roth, 2003). The community is a meaningful learning context where students can learn about unique local history, environment, customs, and culture, by interacting with a place. The learners also form a sense of attachment to place in learning the process (Jorgensen & Stedman, 2001; Semken & Freeman, 2008; Semken, Freeman, & Watts, 2009). This process has been described by Birmingham and Calabrese Barton (2014) as "*insideness*," which is closely related to the SOP that explains the relationship between individuals and places (Jorgensen & Stedman, 2001; Kim & Yoon, 2013; Semken & Freeman, 2008; Semken et al., 2009).

A number of programs linking schools to local communities have reported positive educational effects. For example, Calabrese Barton and Tan (2010) provided opportunities for young people to participate in research and practice in the community, focusing on green energy technology issues. As a result, the students presented the increased understanding of the relationship between their urban environment and human health. Birmingham and Calabrese Barton (2014) provided low SES students the opportunity to participate in the green energy carnival for the community, emphasizing the importance of educated action experiences outside the school. They found that the students altered their relationship with science and the community by initiating dialogs with scientific knowledge. Similarly, Lim and Calabrese Barton (2010) found that low-income students developed positive attachment through the community involvement program.

Sense of Place and Character Development as Citizens

People keep building personal meanings for a particular place based on their experiences within the place. The SOP is a combined set of place meanings (Semken et al., 2009). Ardoin (2006), as shown below, defined SOP as a multidimensional concept that includes psychological, emotional, and relational elements, as well as cognitive elements.

> SOP describes the complex cognitive, affective, and evaluative relationships people develop with social and ecological communities through a variety of mechanisms. While these relationships are often believed to mature over an extended period within a specific environmental context, they can also occur in a shorter time period through an intense experience or through a strong functional dependence on a certain type of place. Alternatively, a SOP can also refer to an array of emotional relationships that enhance connections with a variety of social and ecological places (Ardoin, 2006, pp. 118–119).

Scholars have suggested somewhat different sub-elements of a SOP, but commonly included place attachment, place dependence (PD), and place identity (PI) (Jorgensen & Stedman, 2001). Place attachment (PA) means the positive emotional connection

between an individual and a particular place formulated by direct experiences (Williams & Patterson, 1999; Williams & Vaske, 2003). PD represents the perceived strength of connection that leads to a certain action. Jorgensen and Stedman (2001) distinguished PD from PA in terms that PD could be negative, depending on to what extent the place is perceived to be beneficial to achieve a certain outcome, and so could be closely related to the behavior of the actors, whereas PA focuses more on the emotional side. PI represents to what extent the individual assimilates herself with the values and cultures of a particular place (Proshansky, 1978). Whereas Jorgensen and Stedman (2001) claimed that all three components well explained the meaning of SOP, Williams and Vaske (2003) explain that SOP is a similar notion to PA and regard PD and PI as sub-elements of PA. On the other hand, Shamai (1991) suggested a seven level of scale of SOP from "not having any sense of place (0)," "knowledge of being located in a place (1)," to "sacrifice for a place (6)." This means that as SOP develops, it creates an attachment to place, shares the values and culture of the people in that place, and has a sense of identity with a place. Reaching a higher level of intimacy can lead to real action for a place, and it is also a willing sacrifice for a place. In other words, the SOP is not a mere emotion, but an impetus for problem solving.

In this respect, having SOP can be the basis for developing character as citizens. Citizens in contemporary society require a character and value system that will enable them to take responsible action for resolving socioscientific issues (SSI) (Choi et al., 2011; Zeidler et al., 2005). For a reason, Choi et al. (2011) explicitly included "character and values" as one of the major dimensions of scientific literacy and identified three sub-factors (i.e., ecological worldview, social and moral compassion, and socioscientific accountability). Once students feel connected with their community through direct experiences in the community, they are likely to have compassion for other human beings, animals, and the environment negatively affected by the development of science and technology. Furthermore, they feel the responsibility and take action to solve the problems.

For example, Bouillion and Gomez (2001) reported that students not only obtained scientific knowledge but also learned more living knowledge through working together with their community to solve the Chicago River overflowing issue. They found that students autonomously raised questions, explored the areas, and communicated with their peers and community people to figure out the problems. Cheng and Monroe (2010) found that students' experiences in nature fostered their pro-environmental attitudes and behaviors. Billig (2000) also found that students participating in the Colorado Learn and Serve program showed statistically significant changes in their community involvement and civic responsibility. These studies showed that sustainable linkage to the community, rather than a one-time community visit, could promote their SOP, and furthermore lead them to take responsible action (Stevenson et al., 2014; Tal & Abramovitch, 2013).

Methods

Participants

A total of 441 middle school students (222 males and 219 females) from eight middle schools (23 classes) in Seoul, the capital city of South Korea, participated in the SSI-

COMM programs. We designed and developed three SSI-COMM programs, and each was devoted to a specific topic—abandoned pets, Korean fine dust, and recycling—that students often encounter in their local communities. Each program was implemented in a free semester and included in-school and out-of-school activities that were designed to promote students' interests in SSI and their active participation in their communities. The free semester program lasts for a semester, during which Korean middle students "are released from the burden of examination" and in which the students follow a "school curriculum [that] is flexible and classes focus on participatory activities (e.g., debate and experiments). Students are also engaged in a variety of activities introducing careers." Most of the participating students voluntarily selected SSI-COMM program that was based on their own topic preferences; also, they showed high interest in and curiosity about, science-related community issues. A written informed consent form was obtained from each student and from his or her primary guardians before we implemented the programs with the students.

Designing and Implementing SSI-COMM

The characteristics of SSI-COMM are as follows. SSI-COMM addresses SSIs that students often encounter in their communities. Our programs were designed to urge middle school students to contribute to their local communities by raising interest in SSI that may arise in the communities, exploring and examining the issues at the local level, and cultivating character and values as citizens, throughout the whole period of the program. Specifically, the programs encouraged the students to apply and practice in everyday life what they learned about science. Additionally, SSI-COMM makes a strong connection between schools and local communities. In our programs, the students not only explored the issues in the classroom but also visited local organizations and centers and met experts who work in the related fields, as well as community residents. Figure 1 shows that SSI-COMM consists of four stages: recognition, exploration, sharing, and action-taking; in each stage, students engage in various activities both within and outside of the schools.

In the first stage, recognition, students investigate the status of the community regarding the issues with the goal of understanding the impact of the issue on their communities. They collect actual data related to the issues (e.g., airborne dust concentration provided by Air Korea) at the school and also visit relevant facilities and experts outside the school (e.g., meeting with local specialists, such as local health center officials, veterinary doctors, etc.) to become aware of the issues. In the second stage, exploration, students acquire information related to the issue. Students are encouraged to learn the basic concepts regarding the issues and search for information regarding the issues (e.g., neutering and potential diseases abandoned pets have) and to conduct scientific experiments at school (e.g., fine dust penetration experiments, dismantling a waste cell-phone), to identify the potential dangers of the issues. Instructors, teachers, and local experts assist learning if the students need scientific knowledge. In the third stage, sharing, students share what they learned in the second stage with their colleagues and their communities. For example, in schools, students share their thoughts while engaging in active discussions based on information they have learned. In the community, they meet local residents to listen to their opinions related to the issue and to inform residents about what they learned about the issues at school (e.g., risks of fine

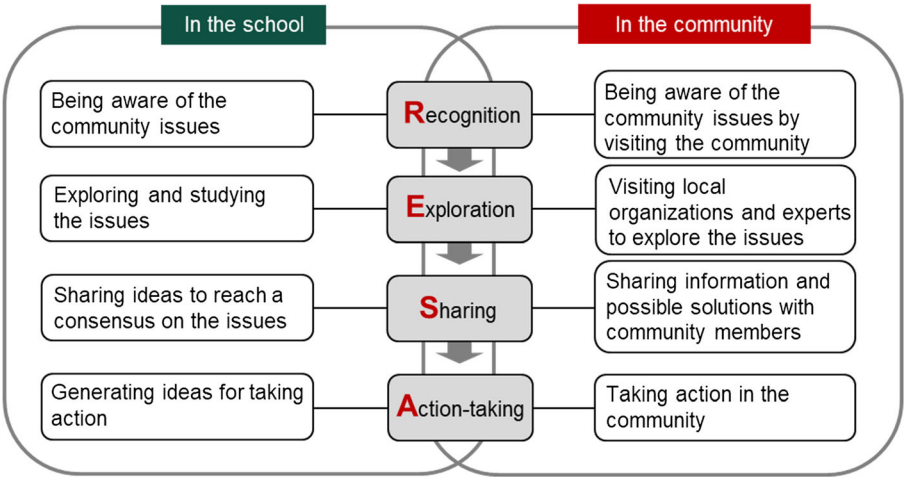

Fig. 1 The SSI-COMM model

dust). In the last stage, action-taking, students look for and implement the best solutions to the issue, considering local situations. Students should consider ways of practicing the solutions at a personal and social level, and how they can put them into practice in the community as much as possible (e.g., posters for protecting abandoned pets, or how to react to fine dust, and an exhibition of up-cycling works). In this way, SSI-COMM connects the school with the community and promotes active interaction with members of the community, which increases the sense of community and the commitment to solve the problems of the community.

This program was implemented mostly by outside instructors with the assistance of school teachers. The outside instructors had 5–24 years of teaching experiences in informal settings, including science museums. We had trained them over several weeks to fully understand the purpose, contents, and instructional methods of SSI-COMM. Some of the instructors participated in developing SSI-COMM with us. School teachers helped out-of-school activities and student management by co-teaching with the instructors. We recruited local community agency including veterinary doctors, training managers from pets' adoption center and health centers, and recycling office managers. They appreciated the purposes of SSI-COMM and agreed to participate.

In SSI-COMM, the students conducted activities in school and their community (see Electronic supplemental material). For example, the "Clear, Fine Dust!" program was designed to examine various aspects of fine dust issues that can cause serious health problems and industrial damage. First, students visited the "Air Korea" website, which showed the real-time air quality and the concentration of fine dust (PM_{10}, $PM_{2.5}$) of the local areas. Students learned the definition, size, and structure of fine dust and ultra-fine dust. Then, they visited the local Meteorological Agency and the local public health center outside the school and asked questions about the actual condition and disease symptoms that are caused by fine dust. Secondly, they conducted an experiment to compare the effectiveness of various masks, such as fine dust masks, disposable masks, and winter masks, in terms of preventing fine dust particles. Third, they created a questionnaire to ask questions of local residents, so they could determine how much they knew about the risks of fine dust. While conducting the survey, the students tried

to inform the elderly about areas in which they were vulnerable to fine dust. They also distributed soap and explained proper hand washing. Lastly, the students studied domestic and international policies on fine dust, proposed practical policy ideas, and produced informative posters and distributed them in local apartment complexes in the districts.

Data Collection

The participating students responded to the two questionnaires, before and after the program, to investigate their SOP and character and values as citizens (CVGCA). First of all, in order to measure the SOP in the community, we selected the instrument that was developed by Jorgensen and Stedman (2001). The SOP scale consists of 12 items with 5-point Likert-type scale (1 = strongly disagree, 5 = strongly agree), and scores range from 5 to 60, with higher scores reflecting greater levels of PI (4 items), PA (4 items), and PD (4 items) (see Table 1). PI refers to feelings, beliefs, or thoughts through which a person assimilates their individual beliefs, values, and goals into the values and culture of a particular place (Proshansky, 1978). PA refers to an emotional connection in which an individual has a positive bond with a particular place, which is the familiarity with and affection for the place (Altman & Low, 1992; Williams, Patterson, Roggenbuck, & Watson, 1992). PD is the degree to which a place is perceived to be beneficial to certain actions (Williams & Vaske, 2003). While PA focuses on the more emotional side, PD is closely related to the behavior of the actors. We collaboratively translated the questionnaire in Korean by considering the definitions of the original terms and avoiding literal translation to be clear and concise. We also carefully addressed the characteristics of target audiences—middle school students—to make them understand each statement clearly. This translated questionnaire was administrated to other middle school students who did not participate in SSI-COMM to check out whether any word they did not understand as well as any expression they found unacceptable. The final version of translated questionnaire was provided and the Cronbach's 훼 values proved the reliability of the instrument.

Second, students' character and values that are required for global citizens were assessed using the modified version of the instrument *Character and Values as Global Citizens Assessment* (CVGCA) that was firstly developed by Lee et al. (2013). Lee et al. (2013) identified three conceptual factors of character and values as citizens and specified those factors into sub-factors based on extensive literature analysis: ecological worldview (EW) (inter-connectedness, sustainable development), social and moral compassion (moral and ethical sensitivity, perspective-taking, empathic concerns), and socioscientific accountability (feeling of responsibility, willingness to act). They developed the CVGCA, which consists of 20 items with 5-point Likert-type scale. Some of the items were restated to represent the contents of SSI-COMM and to clarify the meaning for middle school students. These revised items were validated by three science educators and secondary school teachers. The items properly reflected the factor structure assumed in the previous study (Lee et al., 2013). Since the questionnaire was originally developed in both English (with native English speakers) and Korean, we used the revised version of Korean CVGCA for this study. The Cronbach's 훼 was .930, and the reliability of each factor was also acceptable (see Table 2).

Table 1 Reliability of Q-SOP

Factors	Items	Cronbach's α	Examples of items
Place identity (PI)	1–4	.722	1. My community says something about who I am. 2. Everything about my community is the reflection of me.
Place attachment (PA)	5–8	.848	5. I feel relaxed when I am in my community. 6. I feel happiest when I am in my community.
Place dependence (PD)	9–12	.769	9. My community is the best place for doing the things that I enjoy most. 10. For doing the things that I enjoy most no other place can compare to my community.
Sense of place (total)		.878	

Data Analysis

We used pre-test-post-test design as a quasi-experimental research to investigate the effectiveness of an SSI-COMM on middle school students' SOP and perceived character and values (CVCGA). First of all, paired *t* test was conducted to compare the students' SOP and CVGCA before and after the SSI-COMM program. We also calculated Cohen's *d* to show the effect size. Even though the items of Q-SOP and CVCGA were Likert scale, we used the parametric test because all the factors of SOP and CVGCA were considered to follow the normal distribution (i.e., skewness and kurtosis were less than the absolute value of 1) (Lubke & Muthén, 2004). Second, the cluster analysis method was used to classify the students by using score changes—before and after the SSI-COMM interventions—of their SOP and perceived character

Table 2 Reliability of the CVGCA

Factors	Items	Cronbach's 훼	Examples of items
Ecological worldview (EW)	1–4	.794	1. Since we are a part of nature, I believe the human impact on nature with science and technology will eventually come back around. 2. I believe that if we destroy nature for our benefits, it might disrupt the balance in nature and cause devastating results.
Social and moral compassion (SM)	5–13	.865	5. I can predict the social, ethical, and moral impacts that the development in science and technology might cause in my community. 6. I am interested in social/ethical issues and conflicts (e.g., installation of garbage disposal plant) caused by development in science and technology.
Socioscientific Accountability (SA)	14–20	.892	14. I can predict the social, ethical, and moral impacts that the development in science and technology might cause in my community. 15. I am interested in social/ethical issues and conflicts (e.g., installation of garbage disposal plant) caused by development in science and technology.
Total	20	.930	

and values that are required for global citizens (CVCGA). Clustering is a technique for classifying individuals into groups who have similar variables. It is used in this study for several reasons: (1) to identify and describe the students who have similar patterns based on score changes of SOP and CVGCA and (2) to create student profiles to investigate the clusters that may have needed more help and how to appropriately target those students to develop their SOP and character and values as citizens. For this study, Ward's hierarchical clustering was selected and applied using SPSS 23, since we could not pre-specify the number of clusters to be generated as required by the *k*-means approach. Thus, by distinguishing students who have similar score distributions of mean differences in the three factors of SOP and three factors of CVGCA, we investigated the common patterns of score changes in all six factors before and after SSI-COMM. Before conducting the cluster analysis, we standardized all variables by transforming each into *Z* scores. Once student groups at two points were identified, descriptive analysis and ANOVA were used to provide profiles of each type, as well as to investigate the effectiveness of SSI-COMM.

Results

Changes in Students' Sense of Place and Character and Values as Citizen

The statistical results presented that SSI-COMM was statistically significantly effective in promoting middle school students' SOP and character and values as citizens. First, as shown in Table 3, students' SOP in the community improved after the students participated in SSI-COMM. In all the three factors, PI, PA, and PD, the mean scores statistically significantly increased ($t = 8.348$, $p < .001$; $t = 6.130$, $p < .001$; $t = 6.855$, $p < .001$, respectively). The effect size of PI ($d = .398$) was relatively large compared with that of the other two factors. Table 4 shows that SSI-COMM also contributes to promoting students' character and values as citizens. Specifically, the students showed statistically significant improvement in social and moral compassion (SC) ($t = 7.559$, $p < .001$) and socioscientific accountability (SA) ($t = 6.571$, $p < .001$). In contrast, in EW, the mean score did not increase much after SSI-COMM ($t = 0.432$, $p = .666$, $d = 0.021$), although the mean score of EW was higher than those in SC and SA. The effect size in SC ($d = 0.360$) was relatively large, compared with the other two factors.

Table 3 Result of paired *t* test on the SOP scores

Factors	Pre-test		Post-test		*t*	*p*	*d*
	M	*SD*	*M*	*SD*			
Place identity (PI)	3.19	0.723	3.55	0.851	8.348	< .001	0.398
Place attachment (PA)	3.61	0.884	3.87	0.880	6.130	< .001	0.292
Place dependence (PD)	3.04	0.824	3.33	0.878	6.855	< .001	0.326
Sense of place (total)	3.28	0.679	3.58	0.763	8.674	< .001	0.413

Table 4 Result of paired *t* test on the CVGCA scores

Factors	Pre-test		Post-test		*t*	*p*	*d*
	M	*SD*	*M*	*SD*			
Ecological worldview (EW)	4.23	0.737	4.25	0.725	0.432	.666	0.021
Social and moral compassion (SM)	3.64	0.714	3.87	0.700	7.559	< .001	0.360
Socioscientific accountability (SA)	3.55	0.779	3.80	0.739	6.571	< .001	0.313
CVGCA (total)	3.73	0.664	3.92	0.645	6.648	< .001	0.317

Cluster Analysis on the Differences in SOP and CVGCA Scores

Cluster analysis was used to identify the common patterns of students' score changes of SOP and CVGCA during SSI-COMM as well as to create student profiles who may need more help in order to appropriately target them to develop SOP and CVGCA. After thoroughly examining possible options between 1 and 8 clusters, the 6-cluster option was determined to provide the best representation of the data measured before and after an intervention. Figure 2 shows the 6-cluster model. The six clusters were labeled with the name that represents the group, followed by describing and interpreting the groups on six grouping variables: mean changes on (1) place of

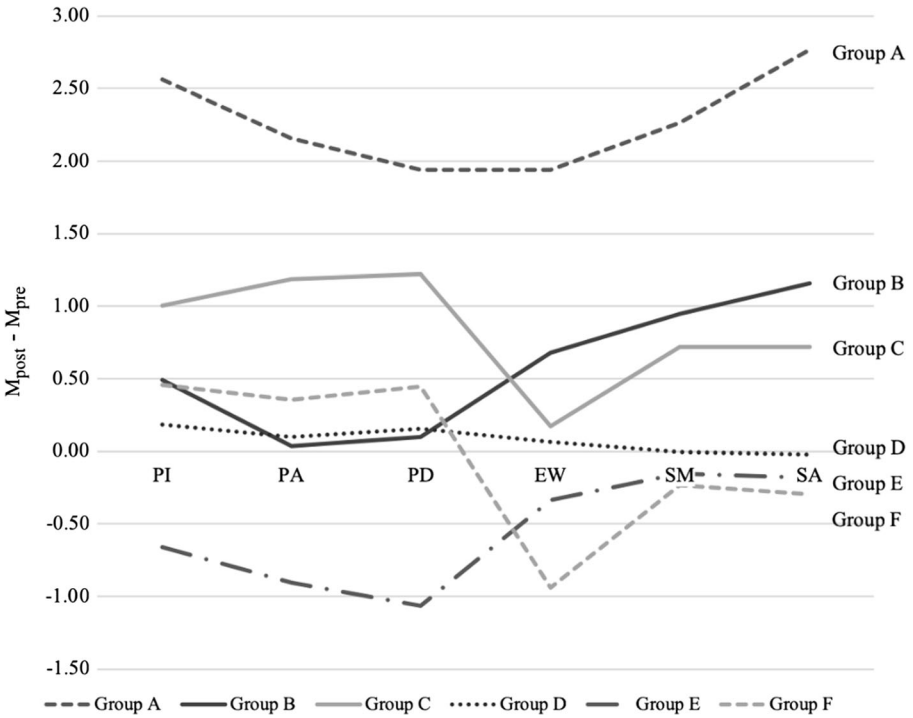

Fig. 2 Plots of mean differences on six variables (groups A–F)

identity, (2) place of attachment, (3) place of dependence, (4) ecological worldview, (5) social and moral compassion, and (6) socioscientific accountability.

Although there were some differences in the pattern of score change, four groups out of six groups (groups A, B, C, and D) showed a positive change after implementing SSI-COMM. As shown in Table 5, SOP scores were found to be statistically significant in all groups except group E, and CVGCA scores were statistically significant only in groups A, B, and C. The score change of group A was very distinctive; the range of mean difference before and after SSI-COMM was 1.94 to 2.77. Students in groups A, B, and C (about 24% in total) presented statistically significant improvements in the overall scores of SOP and CVGCA. The students in group D had statistically significant effects only on the SOP. On the other hand, the students in group E (17%) showed a statistically significant decrease in mean score in both SOP and CVGCA after participating in SSI-COMM. In group F, the mean score of SOP improved, but CVGCA scores showed a decline.

Groups with Positive Effects of SSI-COMM: Groups A–D. Four groups (about 69% of the total 441 participants) out of the six groups reported a positive effect after implementing SSI-COMM. As shown in Fig. 3, groups A, B, and C had statistically significant changes in almost all factors of SOP and CVGCA. In group A, both SOP and CVGCA scores increased significantly, while the effect size of CVGCA in group B and SOP in group C was relatively large. Group D presented a positive effect only on SOP.

Eight students in group A (2%) showed a very positive increase in both SOP and CVGCA scores through SSI-COMM (see Table 6). Before entering the program, these students scored lower than average in almost all factors; but after participating in the program, they scored significantly higher than the students in the other groups. The effect size proves this (Cohen's $d = 4.143$ in SOP, $d = 5.991$ in CVGCA). In particular, the students had a very low score on PI and SA in the pre-test, and the mean score significantly increased in the post-test and reached very high scores ($M_{PI} = 4.56$, $M_{SA} = 4.64$). It is noteworthy that although the number of these students is quite small, the students with very low SOP and CVGCA showed such a high score distribution after their participation in the program. It could be assumed that the contents of SSI-COMM were not only very attractive to them but also provided an opportunity to consider their relationship with the community and their role as citizens in investigating the community problems.

Table 5 Mean score differences on each variable in student groups

Mean differences ($M_{post} - M_{pre}$)	PI	PA	PD	EW	SM	SA
Group A ($n = 8$, 2%)	2.56	2.16	1.94	1.94	2.26	2.77
Group B ($n = 55$, 12%)	0.49	0.04	0.10	0.68	0.95	1.16
Group C ($n = 42$, 10%)	1.00	1.19	1.22	0.17	0.72	0.72
Group D ($n = 200$, 45%)	0.18	0.10	0.15	0.07	0.00	− 0.02
Group E ($n = 75$, 17%)	− 0.66	− 0.90	− 1.07	− 0.33	− 0.15	− 0.18
Group F ($n = 61$, 14%)	0.45	0.36	0.45	− 0.94	− 0.24	− 0.30

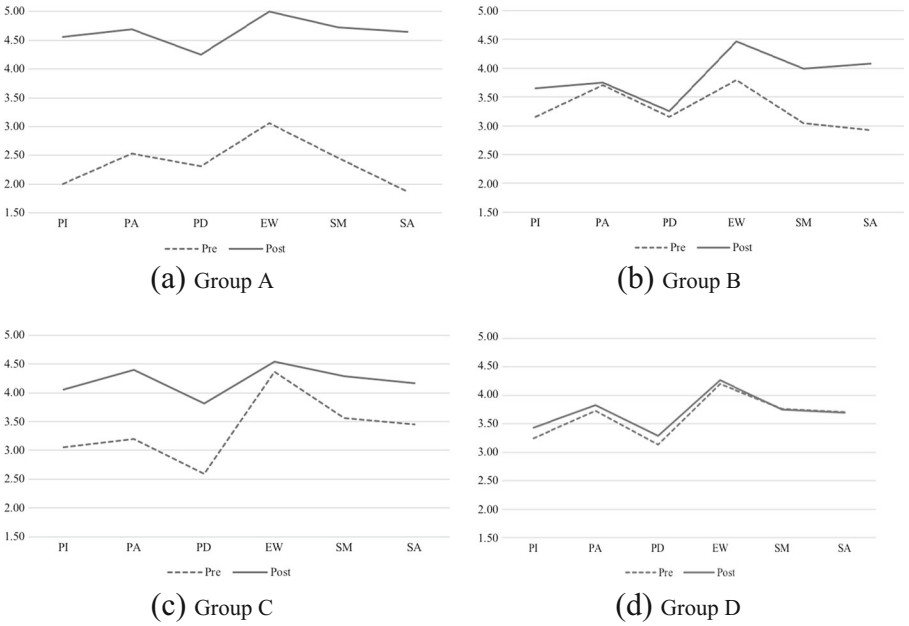

Fig. 3 Mean scores on pre-test and post-test (groups A–D)

Fifty-five students (12%) belong to group B. Before participating in SSI-COMM, their SOP score was almost average, but the CVGCA score was somewhat lower than the average. However, after participating in SSI-COMM, both SOP and CVGCA total scores significantly statistically increased (see Table 6). In particular, it is noteworthy that the improvement in CVGCA was relatively large compared with the SOP score. Only PI score statistically significantly increased in SOP, but all three factors showed significant improvement in CVGCA ($d = 2.937$). This result resonates with previous studies (e.g., Lee et al., 2013) that reported positive effects of SSI instruction on promoting character development as citizens. This has more significance in that the students were greatly improved even in their willingness to take action to resolve community issues. As the students became aware of the community issues through SSI-COMM, it seemed that they were able to recognize themselves as members of the community responsible for solving the issues. At the same time, some of the students regarded such issues as larger issues, not just limited to their community, and so felt more responsibility as citizens to take action to resolve the issues.

Group C includes 42 students (10%). For the students in group C, their SOP score was lower than the average of all the participants in the pre-test, and the CVGCA scores were almost on the average level. As shown in Table 6, group C also presented statistically significant improvement after SSI-COMM in all the factors under SOP and CVGCA. One point worth mentioning is that in contrast to group B, there was a particularly significant improvement in SOP over CVGCA. All three factors of SOP showed a large improvement by more than 1 point out of 5. In other words, the students belonging to this group formulated stronger connection with their community through SSI-COMM, and their SOP might affect their cultivation of character and values as

Table 6 Paired *t* tests on SOP and CVGCA (groups A–D)

Group	Factors	Pre		Post		*t*	*p*	*d*
		M	*SD*	*M*	*SD*			
Group A	Total sense of place (SOP)	1.99	0.626	4.46	0.733	11.719	< .001	4.143
	Place identity	2.00	0.768	4.56	1.050	8.713	< .001	3.081
	Place attachment	2.53	1.153	4.69	0.704	5.945	< .01	2.102
	Place dependence	2.31	1.237	4.25	0.707	5.136	< .01	1.816
	Total CVGCA	2.38	0.554	4.75	0.535	16.946	< .001	5.991
	Ecological worldview	3.06	1.155	5.00	0.000	4.743	< .01	1.677
	Social and moral compassion	2.46	0.575	4.72	0.595	18.014	< .001	6.369
	Socioscientific accountability	1.88	0.698	4.64	0.763	8.629	< .001	3.051
Group B	Total sense of place (SOP)	3.35	0.696	3.59	0.753	4.364	< .001	0.588
	Place identity	3.15	0.788	3.65	0.787	4.905	< .001	0.661
	Place attachment	3.71	0.866	3.75	0.897	0.606	.547	0.082
	Place dependence	3.15	0.865	3.25	0.835	1.656	.103	0.223
	Total CVGCA	3.15	0.662	4.12	0.612	21.783	< .001	2.937
	Ecological worldview	3.79	0.852	4.47	0.581	6.772	< .001	0.913
	Social and moral compassion	3.05	0.730	4.00	0.709	13.976	< .001	1.885
	Socioscientific accountability	2.93	0.745	4.08	0.848	13.254	< .001	1.787
Group C	Total sense of place (SOP)	3.01	0.619	4.09	0.704	18.479	< .001	2.134
	Place identity	3.05	0.630	4.05	0.816	10.347	< .001	1.195
	Place attachment	3.20	0.878	4.39	0.732	13.683	< .001	1.580
	Place dependence	2.59	0.763	3.82	0.900	13.231	< .001	1.528
	Total CVGCA	3.69	0.617	4.30	0.551	15.884	< .001	1.834
	Ecological worldview	4.37	0.569	4.54	0.611	2.632	< .05	0.304
	Social and moral compassion	3.56	0.671	4.28	0.593	14.941	< .001	1.725
	Socioscientific accountability	3.45	0.763	4.17	0.640	12.004	< .001	1.386
Group D	Total sense of place (SOP)	3.36	0.598	3.51	0.648	6.176	< .001	0.437
	Place identity	3.25	0.636	3.43	0.728	4.009	< .001	0.283
	Place attachment	3.73	0.779	3.83	0.778	2.904	< .01	0.205
	Place dependence	3.13	0.710	3.28	0.756	5.535	< .001	0.391
	Total CVGCA	3.83	0.577	3.84	0.594	0.245	.807	0.017
	Ecological worldview	4.21	0.713	4.27	0.684	2.337	< .05	0.165
	Social and moral compassion	3.76	0.626	3.75	0.661	− 0.175	.861	0.012
	Socioscientific accountability	3.71	0.650	3.69	0.658	− 0.659	.511	0.047

citizens. This result is in line with the previous studies showing that the improvement of SOP could promote character development.

Lastly, group D includes the largest number of students (200 students, 45%). The SOP and CVGCA mean scores were around an average of the total group and showed similar patterns between pre and post-test. Compared with groups A, B, and C, the degree of SOP and CVGCA score increases were relatively small. As shown in Table 6,

the SOP mean score in group D became statistically significantly higher, but the CVGCA scores did not show a significant difference, except for the EW factor. This result implies that SSI-COMM contributes at least to promote a SOP for a large number of students. In other words, SSI-COMM may be able to facilitate students feeling attached to their community and feeling they belong as community agents. However, their SOP does not seem to lead them enough to raise their social and moral compassion, responsibility, and willingness to take action as citizens on such SSI.

Groups with Negative Effects of SSI-COMM: Groups E and F. Figure 4 shows that groups E and F (about 31% of the total of 441 participants) showed somewhat unexpected results after the SSI-COMM implementation. In group E, both SOP and CVGCA decreased statistically significantly. In group F, SOP improved, but CVGCA showed a significant decline.

Group E has 75 students (17%). In group E, the students' SOP and CVGCA scores dropped significantly after SSI-COMM (see Table 7). The mean scores of this group were above average in the pre-test, but both scores dropped in the post-test. In particular, the SOP score decline was much greater than that of CVGCA. The changes of mean scores in social and moral compassion and socioscientific accountability under CVGCA were not statistically significant. Although care should be taken in presuming the reason of the score decline based on the given data, the content of SSI-COMM may not be relevant to the interests of the students, and so, it caused less participation. Or, by participating in the program, the students might have realized that their involvement as students could not make any difference in resolving the community issues, because the issues were too serious and pervasive. Previous study (e.g., Chang & Lee, 2010; Connell, Fien, Lee, Sykes, & Yencken, 1999) reported that when dealing with SSI, some students did not take the issues seriously, or merely quoted their own values, without any further engagement. Or some students tried to detach themselves from the issues and did not make any commitment, because they did not regard the issues as their own issues.

Sixty-one students (14%) belong to group F. Their SOP score increased after SSI-COMM, but the CVGCA score decreased inversely (see Table 7). In the pre-test, the SOP score was lower than the average, whereas the CVGCA score was slightly higher than the average. However, in the post-test, the SOP score reached average, and the CVGCA score significantly dropped below the average. Namely, the students became more aware of the community issues and felt more attached and belonging to their

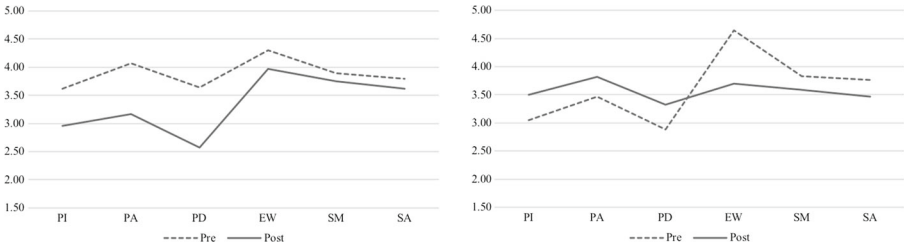

Fig. 4 Mean scores on pre-test and post-test (group E and group F)

Table 7 Paired *t* tests on SOP and CVGCA (groups E and F)

Group	Factors	Pre		Post		*t*	*p*	*d*
		M	*SD*	*M*	*SD*			
Group E	Total sense of place (SOP)	3.78	0.674	2.92	0.772	− 10.100	< .001	1.558
	Place identity	3.61	0.699	2.95	0.949	− 4.406	< .001	0.680
	Place attachment	4.07	0.914	3.17	1.025	− 6.884	< .001	1.062
	Place dependence	3.64	0.894	2.57	0.821	− 11.559	< .001	1.784
	Total CVGCA	3.94	0.537	3.74	0.658	− 2.212	< .05	0.341
	Ecological worldview	4.30	0.670	3.96	0.833	− 2.400	< .05	0.370
	Social and moral compassion	3.90	0.623	3.74	0.671	− 1.651	.106	0.255
	Socioscientific accountability	3.80	0.601	3.62	0.729	− 1.700	.097	0.262
Group F	Total sense of place (SOP)	3.13	0.633	3.49	0.728	5.012	< .001	0.642
	Place identity	3.05	0.819	3.50	0.815	4.751	< .001	0.608
	Place attachment	3.46	0.879	3.82	0.845	3.508	< .01	0.449
	Place dependence	2.88	0.748	3.33	0.883	3.673	< .01	0.470
	Total CVGCA	3.97	0.595	3.57	0.605	− 8.619	< .001	1.104
	Ecological worldview	4.64	0.471	3.70	0.692	− 13.066	< .001	1.673
	Social and moral compassion	3.83	0.675	3.59	0.652	− 4.167	< .001	0.534
	Socioscientific accountability	3.77	0.781	3.47	0.688	− 3.808	< .001	0.488

community through SSI-COMM. However, they seemed to hesitate or even avoid being more actively involved in taking responsibility for their community issues as citizens.

Conclusion and Discussion

In this study, we have designed and implemented a community-based socioscientific issues program (SSI-COMM) that makes a connection between schools and local communities. Since SSI-COMM deals with local community issues like abandoned pets, Korean fine dust, and recycling that is closely connected to their lives, most of the students voluntarily participated in the program with enjoyment from beginning to end. SSI-COMM provided the students with opportunities to use local resources, as well as to communicate with experts in local organizations and centers, and local residents. As reported in the previous studies (e.g., Birmingham & Calabrese Barton, 2014), it is crucial that students have direct experience of their community where they live, in order to increase their commitment to that community. Such experiences allow the students to be more aware of the community issues and increase their sense of community.

In implementing SSI-COMM, we first attempted to promote students' sense of place in their community, because the SOP can be a driving force to cultivate character as citizens (Morgan, 2011; Powers, 2004; Stevenson et al., 2014; Tal & Abramovitch, 2013). This study supports that SSI-COMM enhances students' SOP, including PI, place attachment, and PD. About 83% of students, except group E, showed statistically

significant improvement in SOP. Although some students showed a very low level of SOP, they gradually developed their feeling of belonging to the community, put their personal meanings to the community, shared the values and culture of the community, and obtained identity as a member of the community.

The noticeable finding is that SSI-COMM made positive impacts on the students who had the low level of SOP (groups A, C, and F). The degree of increase in SOP scores was larger than in other groups, and the students reached much higher scores in SOP. This result resonates with other studies, for example, in the study of Birmingham and Calabrese Barton (2014), students with low achievement and socioeconomic status formulated the relationship with science and their community after participating in an energy project. However, in the current classroom culture, such students hardly raise their voices and direct their own learning.

We expected that SSI-COMM would contribute to promote character and values as citizens with the increase of SOP. However, we found that the percentage of students who showed the significant increase of SOP was much higher. Only in groups A–C, both SOP and CVGCA scores increased together. It can be assumed that cultivating students' character and values as citizens takes relatively longer time and efforts. Although we need further investigation on the statistical path between SOP and CVGCA in the future studies, we believe that the improvement of students' SOP can be the basis for fostering character and values as citizens.

In terms of CVGCA scores, groups A, B, and C showed significant improvement. In particular, the degree of increase in social and moral compassion and socioscientific accountability was quite large. One noticeable thing is that SSI-COMM was very effective in promoting students' socioscientific accountability. The previous studies also reported that SSI instruction contributes to enhancing students' moral and social compassion by providing opportunities to examine diverse perspectives surrounding the given issues. Students normally engage in SSI with their personal values and experiences and so often feel compassion for people or animals suffering from the over-development of science and technology. However, only adapting discussions or debates into SSI classrooms had limitations to promote students' socioscientific accountability and actions (Bencze, 2017; Sperling & Bencze, 2010). Students' direct experiences of taking action and receiving positive feedback from their actions are crucial. As shown in Sperling and Bencze (2010), seventh graders, who conducted waste management projects in their community, gained strong feelings that even their small actions could make a meaningful impact on the well-being of self, society, and environment. The results of the present study also prove this. Through the authentic experiences of being in the community, like visiting local organizations and meetings experts and local residents, the students started to recognize that they are responsible to resolve the issues as a community member.

We also need to reconsider two groups, groups E and F, which have presented the decrease of SOP and CVGCA scores after SSI-COMM. We admit that educational programs cannot always bring positive educational results to all students. However, it would be meaningful to examine the possible reasons of the decrease. Although most of the students had chosen to participate in SSI-COMM with their own initiative, not all students continued to maintain the enthusiasm and initial interest in the program because SSI-COMM was still implemented within the structure and nature of formal school settings. Thus, it is very important for educators to let them continuously

recognize the relevance of the issues to their lives. Emphasizing personal relevance is a good approach to encourage students to naturally pay more attention to the community issues and to get more involved in their learning (Hulleman, Godes, Hendricks, & Harackiewicz, 2010).

SSI-COMM not only expands the learning space from the school to the community but also creates a learning ecosystem where diverse local resources and personnel can be parts of stakeholders in learning. Students get knowledge and information from community resources and share what they learn with community members. In other words, the knowledge that they learn in school is applied and enacted through interactions with various physical and human resources of the community. Such repetitive practice reduces the gap between knowing and doing, and so, students are able to cross the borders between school science and science they face in their everyday life (Morgan, 2011; Smith, 2002; Theobald & Curtiss, 2000).

This result invites us to revisit the current goals of science education. In the recent science curriculum reform in Korea, we newly emphasize the capability to scientifically participate and to direct their learning as life-long learners as one of the objectives in science education. However, the idea is hardly enacted in the classroom. Few programs include active interaction with the community. Cognitively oriented approaches are not enough to motivate students' willingness to participate. Students need to understand why they learn science in school by actually observing what is happening in their own community. They should feel that they belong to the community by being in the community and interacting with the people in the community. It is expected that SSI instruction adopting the concept of community-based learning can be regarded as an exemplary educational model.

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