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The Effect of a Climate Change Monitoring Program on Students' Knowledge and Perceptions of STEAM Education in Korea

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Korea has recently started to implement a STEM-like approach in K-12 education, titled STEAM (Science, Technology, Engineering, Arts, and Mathematics) curriculum, to educate the next generation of students to become creative innovators. As this approach has been shown to increase educational success, it is vital to prepare and develop interest in middle school students to participate in STEAM subjects-related learning opportunities. This study examined the impact of hands-on global climate change monitoring projects whose curriculum was designed based on the six structured inventive thinking (SSIT) approach that can facilitate the development of the knowledge of STEAM content and investigate the perceptions of STEAM subjects by middle school students. The participants in the study were sixty-eight grade 7 students from a middle school in Seoul, Korea. Employing a quasi-experimental research design, the participants were measured on their STEAM knowledge and perceptions before and after participation. The findings indicate that students who participated in global climate change monitoring activities reported gains in their STEAM content knowledge and showed an improvement in their perceptions of STEAM subjects. The latter finding was more pronounced for female students who had significantly higher science achievement and positive perceptions of the STEAM program than for male students. The results of this study suggest that carefully designed projects comprised of SSIT-based environmental activities can be effective in STEAM education at the middle school level.

Keywords: inventive thinking, STEAM perception, middle school, global climate change

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INTRODUCTION

The recently emerging STEAM (Science, Technology, Engineering, Arts, and Mathematics) approach in K-12 education has been expanding throughout Korea. PISA marks indicated that the level of Korean students' interests, motivations, and self-efficacy related to science learning was very low among OECD countries (OECE, 2010). In line with these results, the Ministry of Education, Science, and Technology (MEST) of Korea added the fifth domain, the Arts, to STEM and named it STEAM (Science, Technology, Engineering, Arts, and Mathematics). The rationale behind the development of STEAM curriculum in Korea is based on the notion of interdisciplinary education in which science, technology, engineering, and mathematics are integrated such as STEM. Unraveling the fields of the social, fine, physical and liberal arts led to an understanding of how they expand outwards to influence and be influenced by the studies and practices of the STEM fields (Yakman, & Lee, 2012). Thus, the development of an educational framework including all the areas of social, fine, language, liberal and physical arts began in Korea with the inception of STEAM curriculum. With the goal of effectively instructing those who will lead the development of the science and technology of the future, STEAM education aims to develop students' interest in and understanding of science and technology and to develop their integrated thinking and problem-solving abilities (Maes, 2010). Middle school is an especially crucial stage in student development when students must prepare for a rapidly changing future (George Stevenson, Thomason, & Beane, 1992). Therefore, it is vital to develop the interest of middle school students to participate in the future STEAM workforce and to prepare them for such participation. The current study is important as it will provide greater understanding in the development of STEAM education by exploring middle school students' attitudes towards STEAM subjects and examining the impact of project-based learning on students' STEAM content knowledge as well as perceptions of STEAM content. Gender differences and the implications of the findings are also discussed.

State of the literature

- STEAM learning aims to develop student interest, facilitate the integrated understanding of science, technology, engineering, arts, and mathematics, and develop problem-solving skills through real-world applications.
- The recently revised curricula in Korea emphasize that students should develop the necessary skills and ability to scientifically think about environmental issues and solve everyday problems.
- Middle school age is considered a crucial stage in the development of student interest in STEAM careers and education. Thus, there is a need for better understanding in the development of STEAM education and exploring middle school students' attitudes towards STEAM subjects.

Contribution of this paper to the literature

- The designed model contributes to the literature by examining the impact of hands-on, global climate change monitoring projects to provide greater understanding in the development of STEAM education.
- The project- and problem-based learning employed in the study informs educational researchers, teachers, and curriculum developers to implement constructive approach in facilitating student's learning of the scientific concepts related to climate change.
- The findings of this study demonstrate the importance of developing students' values and interests about the environment and developing curriculum that fosters motivation to participate in the preservation of the environment as a scientifically literature citizen in society.

CONCEPTUAL FRAMEWORK

The new STEAM education in Korea signals a significant reform in pedagogical approaches to promoting the development of scientific literacy. The curriculum revised in 2009 by MEST specifically outlines that students should develop an understanding of basic science concepts by exploring natural phenomena of earth systems with interest and curiosity. Additionally, the curriculum delineates that students should cultivate scientific competency necessary to face everyday environmental issues and develop the ability to think scientifically and solve problems creatively (MEST, 2009). The revised curriculum presents a wide range of environmental science learning that is directly related to STEAM subjects. For example, student learning may involve the development of scientific competency that can be applied to the interpretation of climate change and the understanding of the relationship between climate change and hydrospheric changes caused by human activities (MEST, 2009). To improve Korea's science and technology competitiveness, many schools have been required to support STEAM education by participating in project-based learning and scientific inquiry tasks that are interesting to students and relevant to their personal interests.

In this study, the researchers propose that the six hats thinking tool can be applied as an effective teaching strategy for implementing STEAM education. In a variety of settings, the six hats thinking tool has been found to be a useful method to create a more creative atmosphere and educate people to enact a clearer way of thinking (De Bono, 2003). When people participate in inquiry-based, or project-based learning environment, the six hats thinking tool has shown to serve as an effective method to developing solutions to the given problems (Paterson, 2006). Specifically in educational settings, the six hats thinking tool has been used to generate and explore ideas with many different groups of students. For instance, 12-14-year-old students used the thinking tool on science days to explore issues and ideas related to addressing climate change. Undergraduate students in engineering, computing, and design programs as well as postgraduates students (at the start of their Ph.D. programs) were introduced to the six hats thinking tool during industry-based, problem solving sessions (Childs & Tsai, 2010).

The six hats thinking tool may help students to look at an issue from all of its different viewpoints. The single use of a hat may elicit a type of thinking. However, the method allows students to organize the six hats in any number and in any sequence to meet their learning needs. Each of the six hats is a different color. Thus, an example of a six hats thinking sequence might be as follows: white, to elicit relevant facts and figures; green, to promote a range of creative and new ideas; yellow, to explore possible benefits of an idea and consider it with positivity and sensitivity; red, to express feelings, emotions, and intuitions about the ideas, issues, or situations; black, to identify flaws in the thinking or the ideas and to contribute a constructive option to address these flaws or errors. Additional sequences may follow to elicit further discussion and thinking. For example, the design of a sequence of green, red, yellow, and black can generate further ideas and views. Another sequence of white, green, red, and black may enable further elaboration of ideas, followed by blue to elicit reflection, understanding and meta-cognition (Childs & Tsai, 2010).

The six hats thinking principles have been used in this study to develop key thinking strategies to support the participants' learning in the STEAM project of this study. The researchers in this study used the six hats thinking principles as a framework to design the STEAM program, which adopted the Six Structured Inventive Thinking (SSIT) strategies to support the participants' creative problem-solving skills. Systematic Inventive Thinking (SIT) such the SSIT in this study is a widely accepted and validated, algorithmic approach to solving problems (Barak & Goffer, 2002). The six structured inventive thinking (SSIT) approach used in this study is shown in Figure 1. To validate the contents about the SSIT program, the researchers independently reviewed the accuracy of the research process, which was followed by collectively working together to evaluate the investigative tools of this study to come to a consensus about the design and the content of the SSIT program. The researchers from the study are the expert practitioners in K-12

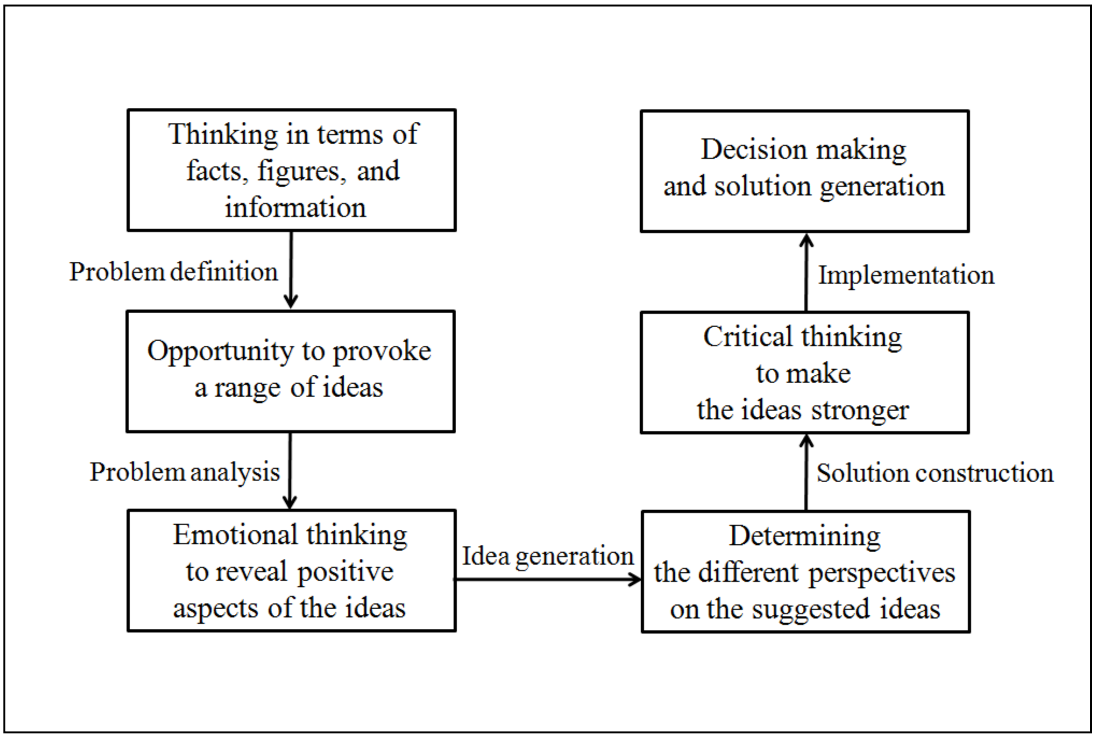

Figure 1. STEAM program of six structured inventive thinking (SSIT) strategies

education and the review process provided an inter-rater reliability of the study (Lincoln & Guba, 2000).

Effective instruction occurs when students are given the learning opportunity to demonstrate, adapt, modify, and transform new knowledge to meet the needs of new contexts and situations. To provide such learning opportunity, each SSIT strategy in this study represents a particular way of thinking. The first strategy involves thinking in terms of actions, figures, and information needed to define a problem. The main goal in this step is to attract learners' attention to the problem by presenting a problematic situation after introducing the lesson and fostering motivation for learning. In this way, the activity in the first step will result in streamlined list of verifiable facts that students can use to provide background information, and explainable theories and opinions about any technological aspect of the problem. The second strategy is to provide an opportunity for students to express a range of creative ideas and engage in problem analysis. The key activity involves searching for former cases, including past experiences of others, as a method of developing a solution to the problem. Additionally, students find clues to the solution within the problem such a process that requires the enactment of scientific reasoning using scientific knowledge. The third strategy involves thinking in terms of emotions (emotional thinking) to reveal positive aspects of the ideal process for idea generation. This means providing an opportunity for students to engage in emotional thinking and to describe the emotions or feelings provoked by each of the ideas that have been developed. In this step, the demonstration through simulations, visualizations, and modeling is a way to exemplify the ideas. Therefore, it includes guiding learners through different representations of the same phenomena through the extensive use of ideas and providing key information, including images. The fourth strategy involves exploring the different perspectives of the suggested ideas. This includes solution construction, which recognizes a good idea, and provides an opportunity for students to explore the values and benefits associated with each idea or issue that has been suggested. The activities in this step include identifying problem-solving methods and solutions by modifying concepts and principles related to the regularity found in the suggested ideas and building a hypothesis. The fifth strategy involves critical thinking to make the ideas stronger. This strategy entails finding faults and flaws to make the ideas stronger. The activities in this step include the modification of the idea to enable problem solving and verify a solution. If the idea does not appropriately solve the problem, it is modified to be more suitable until the problem is solved. Finally, the sixth strategy involves decision-making and generating a solution. This final strategy can summarize what has been achieved, or highlight the outcome, solution, or conclusion. Included in this step is the implementation of the developed design or idea. Additionally, reflection through discussion and sharing, which enact upon metacognition, is important to generate new knowledge, to promote collaborative work, and to facilitate a community of learners.

Interdisciplinary approach of SSIT

The interdisciplinary approach can be defined as a knowledge view and curriculum approach that consciously applies methodology and knowledge from more than one discipline to examine a central theme, issue, problem, topic, or experience (Jacobs, 1989). One of the typical strategies used in the interdisciplinary approach is problem-centric, which connects knowledge from several disciplines to examine real, complicated environmental problems. Science education within the new STEAM framework used in Korea requires interdisciplinary approaches across different disciplines, such as science, technology, engineering, arts, and mathematics to address the higher degree of complexity of contemporary problems (especially in regards to the global warming), which are becoming more dependent on collaboration with other disciplines to provide new applications, methods, techniques, and tools. Consequently, the success of this new interdisciplinary perspective requires new approaches, materials, and pedagogies (Jungck, Gaff, Fagen, & Labov, 2010). Solving these interdisciplinary problems will require that students go far beyond their present scientific knowledge. Thus, students must understand both the connections across disciplines and how to make those connections. Preparing future scientists without offering them exposure to and experience with engineering and technology skills will fail to produce students who are able to perform effectively in an increasingly competitive environment (Labov, Reid, Yamamoto, 2010).

The major element of the STEAM curriculum is the incorporation of project-based learning and problem-based learning. SSIT is highly relevant to the STEAM curriculum, as it is based on the constructive approach. In order to enact upon the SSIT method, students need to incorporate their current and prior scientific knowledge while continuously discovering, assimilating, and accommodating new knowledge, as well as reflecting on it and their experiences. The STEAM project thinking process can provide students with the opportunities to explore and understand the natural world as they become independent, critical, and creative thinkers. Lastly, at the core of the SSIT approach is the application of information and communication technology (ICT), which will be incorporate into the STEAM project thinking processes. These ICT skills include surfing the Internet to search for relevant information and using e-tools for communication purposes and application tools provided by Microsoft Office (MS Word, MS PowerPoint, MS Excel, etc.).

Global climate change monitoring activities

The global climate change (GCC) monitoring activities studied in this research took place within a middle school science class and focused on a specific international science crisis. According to the National Science Educations, science curriculum of middle school grades 1 through 3 of Korea was primarily designed to learn ‘The Atmosphere and Our Lives’. This topic deals with the characteristics and processes of the atmosphere. Thus, students come to learn that the atmosphere, which is an element of the earth system, has layers according to a vertical temperature profile as well as how the circulation of the atmosphere contributes to the earth's energy balance (MEST, 2009). Furthermore, students learn that human activities have affected atmospheric changes, which have in turn led to problems such as climate change, and that human activities and the atmosphere have mutual influences (MEST, 2009). Therefore, GCC monitoring activities capitalize on the interdisciplinary nature of environmental studies in order to expand the curricular space for additional opportunities to learn science and the use of educational technology, without sacrificing the curricular goals of the scientific studies curriculum. This study monitors students' involvement in the GCC activities through which they work to reach an agreement on a critical global science issue. The core of GCC monitoring activities is the introduction of problem-based scenarios. Project-based learning allows students to engage in inquiry through real world problems (Savery, 2006). Thus, it can narrow the gap between the academics and the actual practice of the profession (Verma, Dickerson, & McKinney, 2011). Activities that integrate science and mathematics, such as the standby GCC monitoring in the current study, help develop interest in both content areas (Sherrod, Dwyer, & Narayan, 2009). Such hands-on activities not only improve achievement but also develop communication, critical thinking, and problem solving (Verma et al., 2011).

This study was carried out to assess whether middle school students understand the basic processes affecting the climate, specifically the relationship between atmospheric greenhouse gas concentrations and flows of greenhouse gases into and out of the atmosphere, through the use of real-time data from the Carbon Dioxide Information Analysis Center (CDIAC). Students were given concrete analytical tasks related to broad topical issue areas (i.e., simulation of CO2 concentrations, future scenarios of global climate change) presented in the real-time data of CDIAC. The scenario developed for the current simulation focused on global warming. Students were instructed to learn about greenhouse gases and climate change prior to the simulation so that they were prepared to make appropriate "in character" responses. A rough form of the teaching-learning strategy for the GCC monitoring activities is shown in Table 1.

Research questions

Two research questions with corresponding hypotheses are addressed in this study. First, what is the effect of the GCC monitoring activities by SSIT module on the middle school students' STEAM content knowledge? The null hypothesis was the following: the GCC monitoring activities will have no effect on middle school students' STEAM content knowledge. The research hypothesis was the following: The GCC monitoring activities will have a positive effect on the middle school students' STEAM content knowledge. Second, how do male and female middle school students differ in their improvement in STEAM content knowledge and perceptions after participating in the GCC monitoring activities that follow a SSIT approach? The null hypothesis was the following: There will be no differences in the improvement of male and female students in their STEAM content knowledge and perceptions after participating in the GCC monitoring activities. The research hypothesis was the following: There will be differences in the improvement of male and female students in their STEAM content knowledge and perceptions after participating in the GCC monitoring activities. The results section will focus on answering these questions.

Table 1. Teaching-learning strategies of SSIT program for the GCC monitoring activities

SSIT module	Teaching-learning activities
Thinking in terms of facts, figures, and information	Learning about the influence of a problematic situation on global climate change - Watching a video or news material about climate change
Opportunity to provoke a range of ideas	Recognizing a problem - Providing an opportunity for students to recognize the problem of the presented problematic situation Searching for ideas - Providing an opportunity to develop ideas by writing main points necessary to solve the problem using scaffolding - Providing an opportunity for group discussion for students to think about and clarify the context of the problem
Emotional thinking to reveal positive aspects of the ideas	Problem solving - Drawing and writing down students' ideas on a worksheet Experiment with measuring carbon emission estimates - Simulation of CO_2 concentrations and future scenario of global climate change with data of CDIAC (http://cdiac.ornl.gov/trends/emis/glo.html)
Determining the different perspectives on the suggested ideas	Presenting a solution - Writing down thoughts/answers on a worksheet and giving a presentation on the principle of acceptability testing - Providing an opportunity for students to present a solution (hypothesis) through elaborating the process required
Critical thinking to make the ideas stronger	Verifying a solution - Providing students with an opportunity to verify their solutions and voice their opinions through each group's presentation
Decision making and solution generation	Making a final judgment - Developing a final judgment showing a reasonable viewpoint about global climate change monitoring activities - Applying solution to a new situation with reasonable viewpoint

RESEARCH DESIGN AND METHODS

This study employed a quasi-experimental research design because students were not randomly assigned. This study administered surveys to middle school students who did and who did not participate in the STEAM program of the six structured inventive thinking (SSIT). The middle school students from a school in Seoul, Korea participated in this study. This school has 8 classes in each grade and a class was comprised of about thirty-three students. 145 students in grade 7 were selected by randomizing sampling method from a single science teacher. The science teacher of this study participated in the entire process and development of the GCC monitoring activities program with the researchers. This approach led to a 2-factor quasi-experimental design of nonequivalent comparison (71 students from two classes of the GCC monitoring activities program by the SSIT module class (GCCM) vs. 74 students from two classes of the control (CONT)) that examined the changes in pre- and post-STEAM semantics survey responses for the GCCM group above and beyond changes exhibited by the CONT group without random assignment. The CONT group, which was comprised of students who did not choose to learn about and be trained in a SSIT module class, provided a control for time and conducted exposure to the survey items within the time period of the study. The participants in the initial administration of the STEAM semantics survey were from a middle school in Seoul of Korea. The demographic characteristics of the students are shown in Table 2. Column Ns might differ from the total sample size because some participants opted to not respond to some demographics items. The CONT group (N=74) from two classes controlled for time and repeated exposure to the survey items and was 53.2% male and 46.8% female. On the other hand, 71 students were in the GCCM group from two classes, 50.7% of who were male (N= 36) and 49.3% of

Table 2. Demographic background of the subjects

Characteristic	Overall	CONT	GCCM
Gender	N = 145	N = 74	N = 71
Male	51.1% (74)	51.4% (38)	50.7% (36)
Female	48.9% (71)	48.6% (36)	49.3% (35)
Experiences of environmental activity	N = 143	N = 74	N = 69
Yes	2.2% (3)	2.7% (2)	1.5% (1)
No	97.8% (140)	97.3%(72)	98.5% (68)
Housing type	N = 142	N = 74	N = 68
Apartment	81.7% (116)	79.7% (59)	83.8% (57)
Detached house	5.6% (8)	6.8% (5)	4.5% (3)
Multi-generational housing	10.6% (15)	10.8% (8)	10.3% (7)
Other	2.1% (3)	2.7% (2)	1.4% (1)

NOTE: $p < 0.05$

who were female (N = 35). The subjects in the two groups were considered almost equal in terms of gender ratios and levels of environmental interest (which was moderate). Among the students, 97.8% had no experience of environmental-related activities and 81.7% lived in apartments, followed by multi-generational households and single-home houses. Each survey was administered to all participants who read through and agreed to a STEAM semantics survey approved consent statement. The STEAM program of SSIT program for the GCC monitoring activities (Table 1) was run in two science classes of GCCM group for two hours per week over three months on the topic of 'The Atmosphere and Our Lives,' while two science classes of CONT group were run as business as usual, between March 26 and July 6, 2014. The GCCM group and the CONT group were surveyed in March 2014, at which point the researchers were able to document initial differences in their knowledge and perceptions of STEAM. The class in May covered the first part of the program, related to the exploration of a set of scientific facts. The latter part, regarding the exploration of value principles, was dealt with in June. The retest was conducted in July, at which point the GCCM group and the CONT group completed the second survey. Before the program, the participants were informed that an external teacher would offer them a special lecture in their science class. Nevertheless, the pupils did not know the intention or context of this research during the program.

The relevant statistical test with the greatest precision was employed. A revised survey from Knezek and Christensen's (1998) Teacher's Attitudes Toward Information Technology (TAT) questionnaire for STEM evaluation was used to measure interest in each STEAM in this study. The five most consistent adjective pairs of the ten used on the TAT were incorporated as descriptors for target statements reflecting perceptions of science, technology, engineering, arts, and mathematics. The Cronbach's α reliability coefficient ratings for the five subscales ranged from 0.71 to 0.88, which can be regarded as higher numerical values than the 0.5-0.6 of Cronbach's alpha standardized by Peterson (1994).

RESULTS AND DISCUSSIONS

In this section, we report and interpret the ratings and selections that students gave during each of the survey administrations before and after a SSIT module was taught during the GCC monitoring activities program.

Differences in students' initial beliefs and expectations

Both the GCCM group and the CONT group completed the first survey. This design allowed researchers to track the initial differences in the knowledge and perceptions of STEAM between the two groups. For the most part, the differences in students' ratings between the CONT and the GCCM groups in science, technology, engineering, arts, and mathematics prior to the GCC monitoring activities program by the SSIT module class were not statistically significant (Table 3). This showed that the GCCM group demonstrated an average level on the STEAM semantic survey as compared to the CONT group.

Changes in students beliefs and expectations

The analysis of pre-post data by independent samples t-tests from 145 middle school students revealed that the GCCM group showed a statistically significant gain in knowledge of STEAM (Table 4). As reported on the STEAM semantic survey, the analysis of the specific responses in Table 4 showed that while the students in the CONT group remained essentially constant in their responses, the GCCM group showed a marked increase in all items except for technology after the training. The perceptions of STEAM by the students in the GCCM group was more positive for the GCC monitoring activities program after the exposure to the SSIT module class. The increase was statistically significant according to the independent samples t-test comparison of pre- and post-test mean results (Table 4). Of the five areas of STEAM, four areas (science, engineering, arts, and mathematics) showed statistically significant higher values on the post-test scores when compared to the pre-test mean scores. The significant results were as follows: science ($t(143) = -6.610$, $p < .005$), engineering ($t(143) = -16.505$, $p < .000$), arts ($t(143) = -10.547$, $p < .002$), and

Table 3. Differences in ratings of students prior to the GCC monitoring activities program by SSIT module class

	Mean (Standard Deviation)		**Independent Samples t-Tests**	
	CONT (N=74)	**GCCM (N=71)**	**t**	***p***
Science	3.43 (1.325)	3.28 (1.244)	.708	.582
Technology	3.28 (1.176)	3.21 (1.204)	.390	.952
Engineering	2.14 (.941)	2.24 (.964)	-.626	.533
Arts	3.49 (1.241)	3.29 (1.185)	.943	.605
Mathematics	2.69 (.935)	2.74 (.956)	-.290	.992

NOTE: p < 0.05

Table 4. Differences in ratings of students after the GCC monitoring activities program by SSIT module class

	Mean (Standard Deviation)		**Independent Samples t-Tests**	
	CONT (N=74)	**GCCM (N=71)**	**t**	***p***
Science	3.74 (.861)	4.96 (1.298)	-6.610	.005*
Technology	3.24 (1.156)	4.81 (1.284)	-7.643	.896
Engineering	2.50 (.503)	4.71 (1.023)	-16.505	.000*
Arts	3.66 (.864)	5.53 (1.227)	-10.547	.002*
Mathematics	3.76 (.962)	4.87 (.913)	-7.043	.007*

NOTE: p < 0.05

mathematics ($t(143) = -7.043$, $p < .007$). Even though the technology item of the STEAM Semantic Survey was not statistically significant, the results show that the GCC monitoring activities program showed significant differences when compared with the group means for technology in the STEAM Semantic Survey.

Based on identifiable matched pre-post data from sixty-four middle school students in the GCC monitoring activities program, perceptions became more positive in four areas (science, engineering, arts, and mathematics) measured by the STEAM semantic survey. It was also found that students who received the GCC monitoring activities program possessed more positive perceptions of STEAM.

The first purpose of this research was to design a GCC monitoring activities program through the SSIT module class for middle school students in South Korea and investigate its effect on their knowledge and perceptions toward the GCC monitoring activities program. The effects of the GCC monitoring activities by SSIT module on middle school students' STEAM content knowledge were as follows: first, the results in this study indicate that the program helped them make sense of new values towards global climate change. Furthermore, when these findings are accompanied with the results from previous research by Sherrod et al. (2009), it can be understood that interest in both science and mathematics is further developed when activities such as the GCC monitoring of this study are integrated with both content areas. Second, the GCCM group believed more strongly than the CONT group that the math and science concepts taught in their classes were explicitly connected to engineering, $t(143) = -16.505$, $p < .001$. This showed that this gap grew for students from both groups, as there was stronger agreement among the GCCM group students and stronger disagreement among the CONT group students over time. This means that the SSIT module class, through which the GCCM group students were involved in inquiry work on real-world projects, such as the GCC monitoring activities, and were encouraged to form their own conclusions, can narrow the gap between academics and the actual practice of the profession (Savery, 2006; Verma et al., 2011).

Pre-post changes according to gender in the GCCM group

The second purpose of this research was to determine how male and female middle school students differ in their improvement in STEAM content knowledge and perceptions after participating in the GCC monitoring activities by SSIT module class. Therefore, gender-based differences in STEAM perceptions were examined for science, technology, engineering, arts, and mathematics content areas. These below results are based on detailed findings provided in Table 5. Female middle school students of the GCCM group exhibited much greater pre-post gains than their male counterparts in regards to the perceptions of science and engineering. In addition,

Table 5. Gender difference in STEAM perception gains within the GCCM group

		Male students				Female students			
		M	n	SD	ES	M	n	SD	ES
Science	Pre	3.32	34	1.75	0.28	3.46	34	1.81	0.54
	Post	3.83	34	1.89		4.47	34	1.96	
Technology	Pre	4.09	34	1.55	0.06	3.95	34	1.48	0.19
	Post	4.19	34	1.82		4.25	34	1.61	
Engineering	Pre	3.77	34	1.48	0.16	3.69	34	1.53	0.35
	Post	4.02	34	1.65		4.26	34	1.72	
Arts	Pre	4.04	34	1.32	0.13	3.98	34	1.23	0.16
	Post	4.23	34	1.57		4.19	34	1.38	
Mathematics	Pre	3.61	34	1.57	0.32	3.55	34	1.45	0.34
	Post	4.14	34	1.78		4.12	34	1.85	

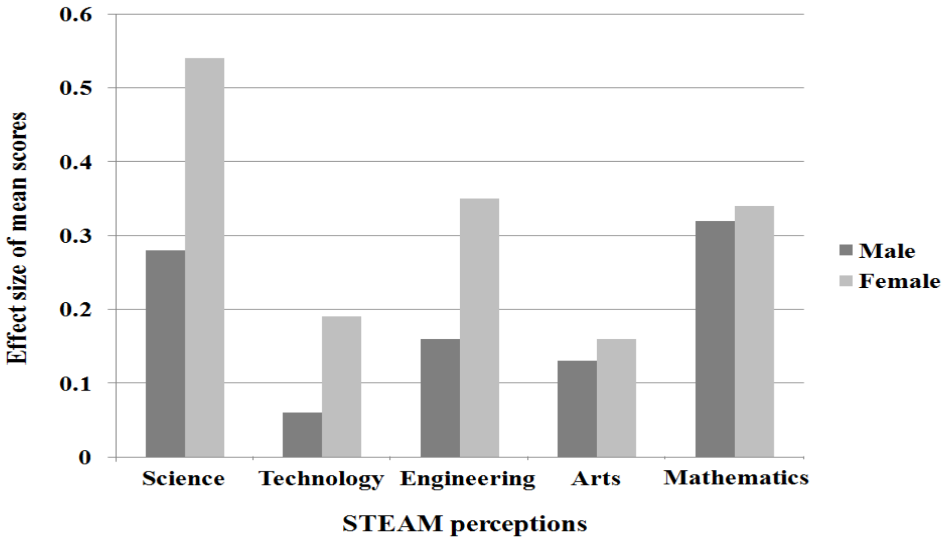

Figure 2. Gender differences in STEAM perceptions in the GCC monitoring activities

females had considerably larger gains in the perceptions of engineering and science. A comparison of the gain scores in standard deviation units (effect size, pre to post) in perceptions of STEAM by female and male students is graphically illustrated in Figure 2. The effect size (ES) was 0.49 and 0.59 for boys and girls respectively. These are considered moderate effect sizes according to the guidelines provided by Cohen (1988), which are as follows: small = 0.2, moderate = 0.5, and large = 0.8. These effect sizes are well beyond the ES = 0.3 criterion that is normally considered educationally meaningful according to established research guidelines (Bialo & Sivin-Kachala, 1996). As seen in Figure 2, the knowledge of the GCC monitoring activities of both male and female students improved. Analyses have confirmed that more positive perceptions of STEAM emerged among participants of the GCC monitoring activities in selected areas.

Finally, a comparison of the gain scores in the STEAM perceptions for female and male students showed that the female students reported the greatest increases in their perceptions of science, technology, engineering, arts, and mathematics, followed by their perceptions in engineering and science. The perceptions of females often rose dramatically to become more comparable to those of males, over the course of the GCC monitoring activities program through the SSIT module class.

DISCUSSION

Impact on the GCC monitoring activities program

According to UNESCO, environmental education should aim to foster students' values and interests about the environment and to instill motivation to actively participate in environmental protection and the improvement of individuals or society as a whole. As shown in the results of this study, the GCCM group through SSIT module believed more strongly than the CONT group that the mathematics taught in their class was explicitly connected to engineering. In addition, the major outcomes from the GCC monitoring activities included large gains in mathematics for middle school girls, with girls' perceptions generally becoming more positive during the project period to become approximately equal to that of boys. In particular, the use of mathematics in STEAM education cuts across the boundaries of other field and is the closest the world has to a common language. Therefore, the study of engineering cannot be interpreted in depth without a fundamental understanding of mathematics. More than a primary language, mathematics serves as a network of practical and theoretical divisions of varying methods, including projects, constructions, analysis, and process work, as well as results that interact with other subjects as well as stand alone as a branch of the natural science (NCTM, 2000).

Findings from the GCC monitoring activities program

During the GCC monitoring activities, the project students were brought together for several days to test the student activities and share successes and difficulties. The findings in the GCC monitoring activities program were as follows: First, the current study found positive indications that engaging students in hands-on STEAM activities promotes interest in STEAM. The GCC monitoring activities program, hands-on learning, and inquiry-based, problem-solving help students to become motivated independent learners, which is one of the main goals of education. The nature of the real-world problems that students perform in the classroom influences their perceptions of science, technology, engineering, arts, and mathematics and what they value as important to their learning. This study found a strong link between the success of the GCC monitoring activities and the use of real-world problems. The real-world problems used were not isolated issues and often required multi-disciplinary problem-solving approaches that drew on findings from STEAM disciplines. The real-world application of science through active learning projects promotes interest in STEAM. Although young students might report that science is fun and interesting, this interest might not result in motivation to choose to study STEAM areas. Therefore, the findings from the GCC monitoring activities study also indicate that a proper understanding of what real-world application in STEAM entails needs to be embedded in the STEAM curriculum. Further investigation regarding middle school students' perceptions of a STEAM career is needed.

Second, to determine the knowledge of students who participated in the GCC activities program, researchers examined a set of pre- and post-course concept maps on the topic of global climate change that were constructed by the sixty students in the GCCM group. Concept mapping presents itself as a particularly adapted assessment tool for this class since it allows for an exploration of student knowledge at a sufficient level of complexity, does not presuppose that all students have mastered exactly the same material, and has also been shown to create a more equitable assessment situation for those who have difficulty coping with test anxiety (Okebukola & Jegede, 1989). The students were instructed to construct a concept map before the course and one after the course. Prior to the construction of the pre-course concept map, the students in the GCCM group were given a 30-minute training session on concept map construction. Each student then constructed a concept map that reflected his or her thoughts (see Figure 3, an example of a participant's concept map). After the training session, each student constructed a concept map on the topic of global climate change (see Figure 4, an example of a participant's concept map). The following focus questions were given to direct the students' map construction: "what are the causes, mechanisms, consequences, and evidence of global climate change?" Students were given 40 minutes to complete each concept mapping activity.

Figure 5 indicates gains in the number of concepts before and after the GCC activities program course. These results indicate a large increase in students' knowledge regarding global climate change. There was also a noticeable change in the students' understandings of the predicted consequences, causes, mechanisms, evidence, and mitigation of global climate change. The illustration showed that one

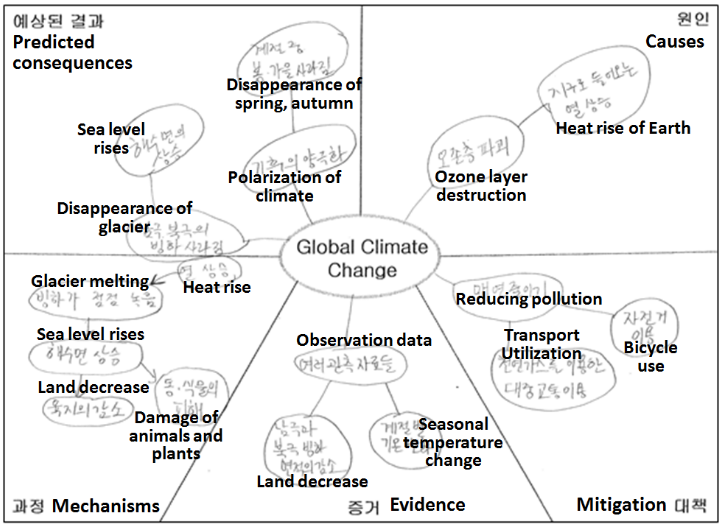

Figure 3. Pre-concept of the GCC activities program course (example of a participant's concept map)

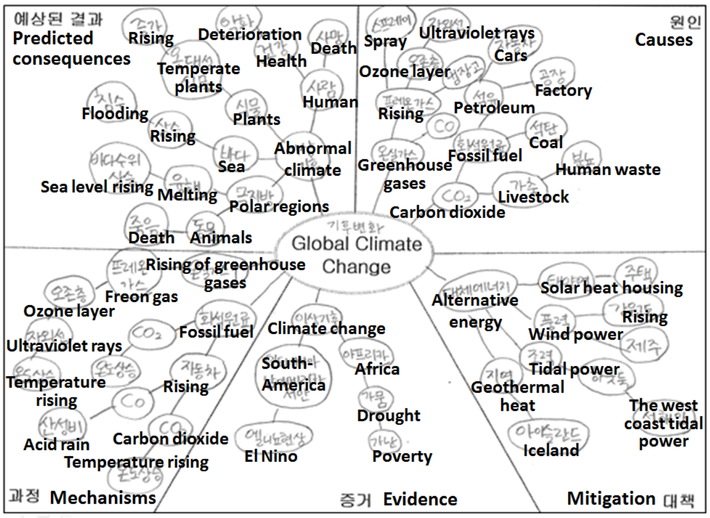

Figure 4. Post-concept of the GCC activities program course (example of a participant's concept map)

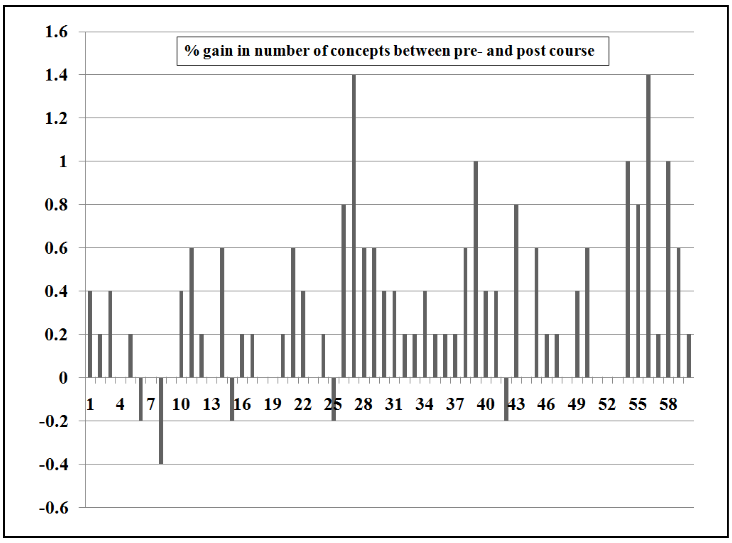

Figure 5. Gain in number of concepts between pre- and post-course results

of the students from the GCCM group had achieved a greater level of interconnectedness and cohesion in their knowledge of post-concepts about global climate change, which is compared with pre-concepts of the GCC activities program course. Therefore, this study indicates that the six structured inventive thinking (SSIT) approach can improve scientific knowledge at secondary levels by increasing students' understandings. Also, the SSIT module is in the same vein as the framework that STEAM style education follows, including a focus on transferring higher order thinking between disciplines so that students can obtain a functional literacy (Yakman, 2008).

Finally, our evaluation of students' knowledge in the GCC monitoring activities by the SSIT module class through the use of pre- and post-course provided valuable insight into STEAM taking place in the classroom.

SUMMARY AND CONCLUSIONS

The purpose of this research was to design the GCC monitoring activities program using the SSIT module for secondary school students in South Korea and to investigate its effect on their knowledge and perceptions toward STEAM. The research examined the questions: "what is the effect of the GCC monitoring activities by the SSIT module on middle school students' STEAM content knowledge and how do male and female middle school students differ in their improvement in STEAM content knowledge and perceptions after participating in the GCC monitoring activities by SSIT module class?" The major results related to each of these questions were as follows: First, as reported on the STEAM semantic survey, the perceptions of the students in the CONT group showed no change over time, but perceptions of STEAM by the students' in the GCCM group were more positive for the GCC monitoring activities program after exposure to the SSIT module class, as seen through the statistic-based testing. In addition, students taking part in the GCC monitoring activities showed a significant and meaningful gain in their STEAM content knowledge. Second, a comparison of the gain scores in STEAM perceptions for female and male students showed that female students reported more positive perceptions of science, technology, engineering, arts, and mathematics during the project period to become approximately equal with that of male students.

Based on the findings in this study, the major outcomes from the GCC monitoring activities included large gains in mathematics. This means that mathematics in STEAM content served as a network of practical divisions of varying methods, including projects, constructions, analysis, and process work, as well as the results that interact with other subjects. Also, this study found a strong link between the GCC monitoring activities and real-world problems. This also indicates that real-world applications of science through active learning projects promote interest in STEAM. In addition, the concept mapping assessment provided evidence that students experienced significant learning in the GCC monitoring activities program through knowledge enrichment, as seen through the frequencies of concepts appearing on the students' post-course maps that did not appear on their pre-course maps.

Overall, we conclude that middle school students definitely gained STEAM content knowledge during the GCC monitoring activities. More positive perceptions toward science, technology, engineering, arts, and mathematics emerged in the STEAM areas. Improvements in students' perceptions of their own STEAM tendencies appear to be an additional project outcome. Gains for the female students were especially significant. Further research is needed to confirm these findings on a broader scale. Also, a future study that could randomly assign students to conditions, while it may face serious practical challenges, would provide for greater generalizability of the experimental results.

Finally, the SSIT approach includes digital era literacy, inventive thinking, effective communication, high productivity, and spiritual and noble values. The incorporation of project-based learning and problem-based learning into the learning experience is the essence of SSIT and its objective of cultivating students' ability to engage in scientific inquiry and to discover scientific content by themselves. The SSIT stresses that engaging in scientific projects requires coordination of both knowledge and skill simultaneously. Therefore, it is necessary to develop a more successful and complicated program specialized in global climate change education, as this could lead students to put them into practice in their ordinary lives.

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APPENDIX 1

STEAM Semantics Survey

Gender: M / F

This five-part questionnaire of STEAM is designed to assess your perceptions of scientific disciplines. It should require about 5 minutes of your time. Usually it is best to respond with your first impression, without giving a question much thought. Your answers will remain confidential.

ID:____________ **School:**________	Use the assigned ID

Instructions: Choose one circle between each adjective pair to indicate how you feel about the object. **THIS IS NOT A TEST!**

To me, SCIENCE is:

1	Boring	◯,1	◯,2	◯,3	◯,4	◯,5	◯,6	◯,7	Interesting
2	Appealing	◯,1	◯,2	◯,3	◯,4	◯,5	◯,6	◯,7	Unappealing
3	Fascinating	◯,1	◯,2	◯,3	◯,4	◯,5	◯,6	◯,7	Mundane
4	Exciting	◯,1	◯,2	◯,3	◯,4	◯,5	◯,6	◯,7	Unexciting
5	Means nothing	◯,1	◯,2	◯,3	◯,4	◯,5	◯,6	◯,7	Means a lot

To me, TECHNOLOGY is:

1	Fascinating	◯,1	◯,2	◯,3	◯,4	◯,5	◯,6	◯,7	Mundane
2	Appealing	◯,1	◯,2	◯,3	◯,4	◯,5	◯,6	◯,7	Unappealing
3	Exciting	◯,1	◯,2	◯,3	◯,4	◯,5	◯,6	◯,7	Unexciting
4	Means nothing	◯,1	◯,2	◯,3	◯,4	◯,5	◯,6	◯,7	Means a lot
5	Boring	◯,1	◯,2	◯,3	◯,4	◯,5	◯,6	◯,7	Interesting

To me, ENGINEERING is:

1	Appealing	◯,1	◯,2	◯,3	◯,4	◯,5	◯,6	◯,7	Unappealing
2	Fascinating	◯,1	◯,2	◯,3	◯,4	◯,5	◯,6	◯,7	Mundane
3	Means nothing	◯,1	◯,2	◯,3	◯,4	◯,5	◯,6	◯,7	Means a lot
4	Exciting	◯,1	◯,2	◯,3	◯,4	◯,5	◯,6	◯,7	Unexciting
5	Boring	◯,1	◯,2	◯,3	◯,4	◯,5	◯,6	◯,7	Interesting

To me, ARTS is:

1	Appealing	◯,1	◯,2	◯,3	◯,4	◯,5	◯,6	◯,7	Unappealing
2	Means nothing	◯,1	◯,2	◯,3	◯,4	◯,5	◯,6	◯,7	Means a lot
3	Boring	◯,1	◯,2	◯,3	◯,4	◯,5	◯,6	◯,7	Interesting
4	Exciting	◯,1	◯,2	◯,3	◯,4	◯,5	◯,6	◯,7	Unexciting
5	Fascinating	◯,1	◯,2	◯,3	◯,4	◯,5	◯,6	◯,7	Mundane

To me, MATHEMATICS is:

1	Means nothing	◯,1	◯,2	◯,3	◯,4	◯,5	◯,6	◯,7	Means a lot
2	Boring	◯,1	◯,2	◯,3	◯,4	◯,5	◯,6	◯,7	Interesting
3	Exciting	◯,1	◯,2	◯,3	◯,4	◯,5	◯,6	◯,7	Unexciting
4	Fascinating	◯,1	◯,2	◯,3	◯,4	◯,5	◯,6	◯,7	Mundane
5	Appealing	◯,1	◯,2	◯,3	◯,4	◯,5	◯,6	◯,7	Unappealing