Eurasia Journal of Mathematics, Science & Technology Education, 2016, **12**(7), 1925-1936
doi: 10.12973/eurasia.2016.1539a

The Development and Application of a STEAM ProgramBased on Traditional Korean Culture

Hyoungbum Kim
Chungbuk National University, KOREA
Dong-Hyun Chae
Jeonju National University of Education, KOREA

•*Received 25 June 2015*•*Revised 2 January 2016* •*Accepted 9 January 2016*

The purpose of this research was to develop a STEAM program in the context of teaching and learning a traditional Korean instrument and implement it in a high school class to determine the program's effectiveness. The STEAM program was developed through a continuous consultation process between a development team and external experts, including an "artisan of Korean music." This program was implemented for six weeks in an 11th grade science class, which consisted of twenty-six students. The twenty-six students who participated in this research study engaged in semi-structured interviews to determine how the students became aware of the STEAM program and verify the applicability of the program. The results are as follows: students recognized the meaning and necessity of STEAM education as a problem-solving procedure that resulted in increased STEAM literacy and a development of concepts through sharing opinions. Most students indicated that they would frequently make use of the knowledge they learned in the STEAM program in their science class because it allowed them to have a better understanding of the problem-solving process. Therefore, STEAM programs in science class are apt to contribute to STEAM literacy through the integration of science, technology and art as well as develop creative problem-solving abilities by introducing new ideas.

Keywords: high school, problem solving, STEAM education, traditional Korean instrument

INTRODUCTION

The recent high-paced development of science technology has led to increases in globalization, convergence, diversification, and unpredictability. As a result, future scientists will not only need to have a solid foundation in STEM education, but they will also need to develop the creative problem solving and global expertise that is

Correspondence: Dong-hyun Chae,
Department of Science Education, Jeonju National University of Education, Jeonju Jeonbuk, 55101, Korea.
E-mail: donghyun@jnue.kr

fostered through an education in the arts. The ability of Korea's students to meet these demands will determine Korea's success in the global economy. In order to ensure Korea's future prosperity, changes in education will be necessary in order to increase students' ability to solve problems in a convergent manner as well as develop strategies to merge Korean traditions and current science technology for students. The current education paradigm is changing to cultivate this convergence. With these changes, Korea has tried to enhance science, technology, engineering, arts, and mathematics (STEAM) education in elementary and secondary education. The rationale behind developing a STEAM curriculum in Korea is based on the notion of interdisciplinary education, whereby STEAM education is integrated into the curriculum. Examinations of the social, fine, physical, and liberal arts have led to an understanding of how they influence and are influenced by the studies and practices of the STEM fields (Yakman & Lee, 2012). Thus, the development of an educational framework that includes all these areas of education began in Korea with the inception of the STEAM curriculum (Yakman & Lee, 2012). With the goal of effectively instructing those who will lead the development of science and technology in the future, STEAM education aims to develop students' interest in and understanding of science and technology as well as develop their integrated thinking and problem-solving abilities (Maes, 2010).

Since the STEAM curriculum will help develop STEAM literacy and problem-solving abilities, and increase interest and understanding in science and technology in elementary and secondary school students, STEAM education is necessary to nurture the creative and convergent talent in the young people of today, who will lead future developments in science and technology (MEST, 2010). While activities of artists and research activities of scientists are different in regard to targets, means, methods, and results, they both require imagination, observation, and creativity (Kim, 2012). Kim particularly emphasized the coevolution of each of these fields, asserting that science provides methodological tools to the arts and creative art provides a model for the development of science. In this way, a convergence between art and science education effectively trains students in flexible thinking, which allows them to be innovative in either discipline (Kim, 2012). In addition, researchers have studied what impacts the preference for science amongst high school students who show high achievement in science. According to one study, the factors include: science achievement, participation in science activities, peer support, scientific ability, and strong interest in liberal arts and science (Jacobs, Finken, Griffin, & Wright, 1998).

Therefore, the current study is important, as it will provide greater understanding of the development of the STEAM program by exploring high school

State of the literature

- STEAM education aims to increase students' efficacy, confidence, and interest in science, facilitate the integrated understanding of science, technology, engineering, the arts, and mathematics, and nurture the necessary creative and convergent talent.
- The STEAM curriculum in Korea has tried to increase students' ability to solve problems in a convergent manner and to develop strategies to bring together Korean traditions and current science technology for students.
- High school age is considered a vital stage in the development of students' values and interests in STEAM literacy. Therefore, there is a need for better understanding in the development of the STEAM program and the exploration of high school students' awareness about the STEAM program based on traditional Korean culture.

Contribution of this paper to the literature

- The designed STEAM program contributes to the literature by assessing the educational effect of a STEAM program based on the theme of traditional culture that is applied within a school context.
- The STEAM program based on traditional Korean culture employed in the study informs teachers, educational researchers, and curriculum developers to implement a constructive approach in facilitating students' understanding of scientific principles, such as engineering and technology.
- The findings of this research demonstrate the importance of developing students' values and interests about Korean traditional culture and developing a STEAM program based on the theme of traditional culture.

students' attitudes toward STEAM subjects, and by examining the impact of the theme of "Korean sound" on students' STEAM content knowledge as well as awareness of STEAM content.

THEORETICAL FRAMEWORK: STEAM EDUCATION

Importance of STEAM education

STEAM includes science, technology, engineering, mathematics (STEM), and the arts. STEM education is a convergent education that advanced OECD countries have developed to nurture future talent (Yakman & Lee, 2012). STEM education stresses the importance of education that nurtures creative problem-solving skills in order to become competitive in the global era and to prepare for any future challenges (Baek et al., 2011; Christensen, Knezek, Tyler-Wood, & Gibson, 2014; Knezek, Christensen, Tyler-Wood, & Periathiruvadi, 2013; Yakman & Lee, 2012). STEAM education expands the relevance of STEM education by adding the arts (Maes, 2010). The purpose of STEAM education in Korea is not only converge the fields of science and art, but to also increase students' efficacy, confidence, and interest in science, thereby motivating students to pursue careers in science (Baek et al., 2011; Yakman & Lee, 2012). STEAM focuses on becoming globally competitive through the cultivation of expertise in science education as well as in creative problem solving, decision-making, and liberal arts knowledge (Baek et al., 2011). STEAM education has been found to increase scientific efficacy and creativity as well as maximize interest and motivation in science, which helps improve scientific competitiveness. However, there is no specific STEAM framework that focuses on nurturing convergent talent and there is little research that verifies the effects of the STEAM program. Therefore, the purpose of this research is to develop a STEAM program that uses a traditional Korean musical instrument for convergent education and implement this program in a high school class to determine its effectiveness.

Frame of reference of the STEAM program

The basic factors of STEAM are creative design and emotional touch, which provide self-initiated learning experiences based on the convergent knowledge, process, and nature of various areas related to science technology (Baek et al., 2011). As shown in Figure 1, the frame of reference of a STEAM program can be a guideline to apply STEAM to the field and basic frame of a developing program. The

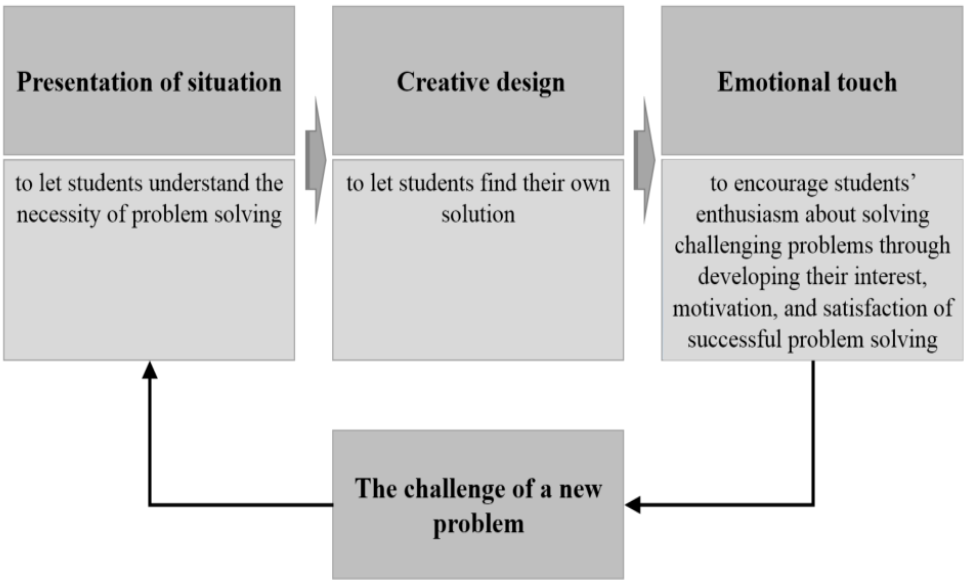

Figure 1. The frame of reference of STEAM (KOFAC, 2012)

core factors in the frame of reference of STEAM are context, creative design, and emotional touch (KOFAC, 2012).

The first step is to present a situation (Lee, 2013). It is important to let the students recognize the problem as being connected to their lives and relate it to the real world (Brown, Collins & Duguid, 1989; Lave & Wenger, 1991). The second step is creative design, which encourages students to act creatively by addressing the open-ended nature of the design (Baek et al., 2011). Specifically, the purpose of this step is to develop not only creativity but also communication skills through a cooperative learning activity (Kolodner et al., 2003) with "hands-on" and "hands-in" aspects (Baek et al., 2011). The creative design process starts with the students determining needs and values in their lives and accepting "design work" by determining which problem they will focus on as self-directed learning (Knowles, 1975) through the development of a specific and practical relationship to the learning activity. The third step, emotional touch, seeks to expand the affective domain of the educational goal, and stresses the importance of heart-on by experiencing and exploring a learning situation (Baek et al., 2011). This step also helps students develop perception, expression, and sympathy. In addition, the practical element elevates task commitment and flow by allowing students to experience the joy of discovery, which increases their interest in science learning. Maes (2010) determined that arts or liberal arts enhances students' creativity and active participation, and stimulate students to develop a creative approach to their scientific thinking that is based in imagination and emotion through the development of emotional touch.

Context, creative design, and emotional touch can be taught using three types of lessons: in-subject, related subjects, and creative experiential activities (KOFAC, 2012). The in-subject type involves teaching a main subject related to science, technology, engineering, the arts, and mathematics. The related subject type is a lesson based on a theme relating to several subjects. The creative experiential activity type restructures the whole curriculum or develops a program based on a theme (KOFAC, 2012). Especially, the STEAM program developed in this study was based on the theme of Korean traditions and enabled high school students to learn about the principles of Korean sound and explore it on their own, thereby allowing them to learn about both the scientific principles and artistic beauty of a Korean tradition. Traditional culture is an important human asset that should be preserved. In addition, traditional culture effectively combines cultural values and contemporary science, technology, and art. Through this program, students can develop an understanding of scientific principles, such as engineering and technology, through learning about their ancestors' cultural heritage and develop their creativity by exploring the beauty of Korean culture. This program is apt to cultivate STEAM literacy through scientific technology and art, and it is expected to increase students' ability to solve problems creatively by utilizing well-known scientific principles in order to synthesize new information. In addition, students will have the opportunity to experience immense satisfaction from solving a challenging problem on their own, which will increase their confidence. In addition, this research will be meaningful to Korean STEAM education in that it assesses the educational effect of a STEAM program based on the theme of traditional culture that is applied within a school context.

RESEARCH OBJECTIVES AND METHODOLOGY

This study sought to develop a STEAM program based on the theme of Korean traditional culture, apply it to a high school science class, and determine the effect of the program. Therefore the purposes of this study are as follows:

1. To develop a STEAM program based on Korean sound as a form of traditional Korean culture.
2. To explore the effect of the application of the STEAM program in the context of teaching and learning a traditional Korean instrument

Data collection

This research developed and determined the effect of a STEAM program that high school students can experience and implement themselves. The research process is shown in Figure 2.

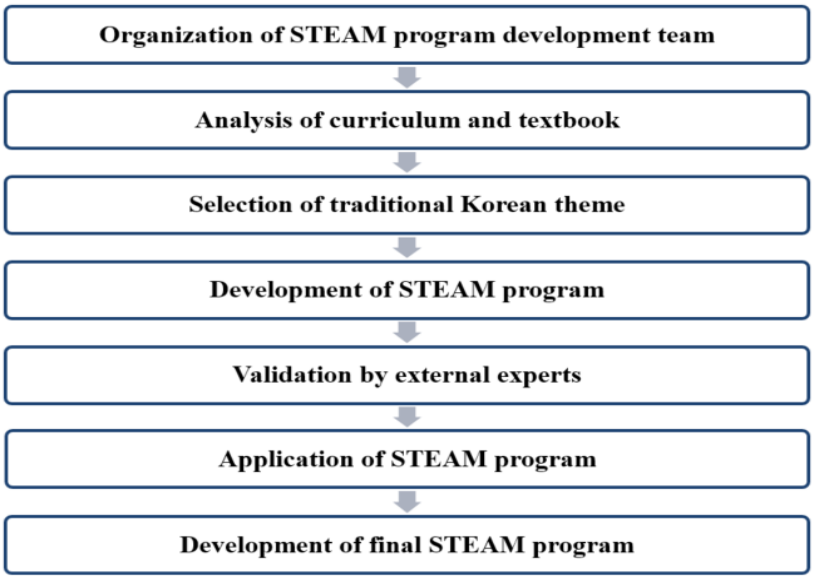

Figure 2. Program development process

For this research study, the STEAM program development team consisted of four university or college professors, one elementary school principal, four elementary school teachers, two middle school teachers, and one high school teacher. The professors taught science education and practical education, and they all had previous experience in developing a STEAM program. The principal had taught students for over thirty years and had developed a STEAM program. One of the elementary school teachers had a PhD in Elementary Science Education and another one was completing a doctoral program in gifted education. The remaining two teachers were completing their Master's degree in Gifted Education. One of the elementary school teachers had taught students for over fifteen years, two of the elementary school teachers had been teaching for either ten or fifteen years, and one of the elementary school teachers had taught for less than ten years. All of them had experience developing a STEAM curriculum focused on energy. All of the middle school teachers had between ten and fifteen years of teaching experience. One of them had a Master's degree in General Science, and had experience in developing a science inquiry program and a STEAM program. One of the high school teachers had worked as a teacher for less than five years and had been involved in STEAM program development. In order to ensure that the STEAM program was effective and that it provided students with a rigorous education, the team consisted of professors and teachers with experience in developing STEAM programs, and who were experts in related fields.

In May 2014, the team selected the theme of Korean sound because of its relevance traditional Korean culture and to the students' lives. In addition, the team considered whether science and the arts could be mixed together when choosing the theme in order to ensure an appropriate integration of science and art. After

choosing the theme, the STEAM program was developed with a lesson plan, guidance plan, and work sheet. The program was focused on teaching students easily in class through substituting the textbook by organizing the curriculum goals that students can achieve. A major component of the program was the three steps of context, creative design, and emotional touch (KOFAC, 2012).

To develop and apply the STEAM program, the development team and external expert group conducted meetings and workshops regularly as well as engaged in a process of validating the program. The expert group included an "artisan of Korean music" as an external expert. Reviews of these experts were conducted regularly, which enhanced the validity of the program and helped ensure the development of a high-quality program. This procedure enables experts to evaluate the accuracy of the research process and results because it ensures the inter-rater reliability of the study (Lincoln & Guba, 2000). The developed program was taught to second-year students in one high school class for six weeks from the first week of November to the second week of December. Also after implementing the program, the twenty-six students who participated in the research engaged in semi-structured interviews, which verified the applicability of the program.

Data analysis

The interviews of twenty-six 11th-grade students were transcribed and divided into sentences. According to research methods used in advanced research (Jeong, Kim, Chae, & Kim, 2014), the main questions sought to determine to whether the STEAM program was an engaging class for students and the usefulness of applying STEAM to science class, and were analyzed through the inductive categorization to analyse the students' answers. The interview material of the research participants were divided alphabetically and coded into major questions using a qualitative research method. In addition, the surface and implicit meanings were determined through reading the interview material and comparing the similarities and differences with other interview materials; relevant concepts were then extracted and coded according to major questions (Struss & Corbin, 1998).

RESULTS AND DISCUSSION

A high school STEAM program based on the theme of Korean sound

After the Korean sound theme was chosen, learning materials for students and teachers were developed according to the theme. This program was based on the high school science curriculum: lessons one through three focused on analyzing a short bamboo flute called a danso, lessons four through six focused on making a danso and performing a concert, and lessons seven through ten focused on developing a precise analysis of a danso and collaboratively designing a smartphone application. Twenty-six second-year high school students were divided into 4 groups of four and 2 groups of five. The main content of the STEAM program is shown in Table 1. The elements of STEAM are: science (S), technology (T), engineering (E), the arts (A), and mathematics (M).

The first stage, context, helps students recognize the learning activity as a problem that is pertinent to their lives. In other words, they play a danso and discuss the reasons why playing a danso is difficult. Also, they learn the reason why the pitch changes according to the intensity of sound, as related to the "making a sound" unit in the science textbook. As a result, students become immersed in the class activity because of the increased relevance between the presented situation and their lives.

The second stage, creative design, is the key stage of the STEAM program. This stage helps students reflect on their own creative ideas in the context of practical

Table 1. STEAM program based on the theme of Korean sound (danso)

Stage	Content	Lesson	STEAM elements
Context	-Students find out why performing danso is difficult even though they learned to play this instrument in elementary school. -Students learn that most Korean wind instruments are made of bamboo and that the sound changes according to the size and length of the instrument. -Students find out that pitch changes depending on blowing intensity when the same fingering is used.	1	S, A
Creative design	-Students measure the frequency of danso sound using a smartphone application. -Students understand the relationship between the frequency of danso sound and low or high pitch of Korean musical instruments and making a standard instrument guidance.	2	S, T, M
	-Students measure a store-bought danso. -Students understand that a certain ratio exists in the distance between holes in the instrument.	3	T, E, M
	-Students make their own danso using real bamboo. -Students design a danso that can be played easily by changing the position of the embouchure hole.	4-5	T, E, M
Emotional touch	-Students give a concert with their hand-made danso. -Students share their feedback about the best danso and the best performer.	6	S, A
Creative design	-Student groups make a danso sound principle of danso using an algorithm. -Students design a smartphone application based on the algorithm.	7-9	S, T, E, M
Emotional touch	-Students share their ideas and compare the strengths and weaknesses of each group's application design.	10	E,A

learning. To do so, they measure the frequency of the danso sound using a smartphone application, as shown in Figure 3, and they learn a creative design process to make a danso using tools after determining the change of frequency according to the distance between the holes in the instrument using vernier calipers, as seen in Figure 4. This stage allows students to not only learn but also utilize their new knowledge, thereby improving their problem-solving abilities. By motivating students to define and solve the problem themselves, students are able to become stronger creative problem-solvers.

The efect of the application of the STEAM program

The interviews with the twenty-six students were transcribed and divided into sentences and coded by main questions. This coded material was classified into an upper category through inductive categorization with similar codings. Table 2 shows how students understood the meaning of STEAM.

Students' awareness about the meaning of STEAM

As shown in Table 2, 42% of the students recognized STEAM as a "problem solving procedure using convergent thinking," 34% thought of it as an "instructional

Figure 3. Measuring the frequency of a danso with a smartphone application

Figure 4. Designing and making a danso using real bamboo

Table 2. Students' awareness of the meaning of STEAM (N=26)

No.	Students' awareness of meaning of STEAM	%
1	Problem-solving procedure using convergent thinking	42
2	An instructional procedure for knowledge generation	34
3	Finding a solution on their own in the STEAM activity	24

procedure for knowledge generation," and 24% perceived it as "finding a solution on their own in the STEAM activity."

Forty-two percent of the students regarded STEAM as a procedure of solving a problem by using solutions in connection with finding the answer of a problem, as through interaction with others and using convergent thinking, many students' solutions are used in the procedure of solving the problem. The following content is an interview content with student A.

> Student A: During the creative design discussion, I had some things to think about, so I reviewed textbooks, and asked friends and teachers about those things and was given similar answers about the sound principle of the danso. I think I could solve a problem easily through these procedures of STEAM program.

This quote shows the ways that the procedure of solving a problem using convergent thinking accords with the purpose of STEAM education, as this procedure is necessary to develop convergent and creative thinking abilities beyond specific areas of study (Baek et al., 2011; Maes, 2010).

Also, 34% of students thought that STEAM was an instructional procedure for knowledge generation through the mutual exchange of formulated opinions whichever was used with the students during the creative design and emotional

touch discussion. In other words, the procedure to apply ideas through the exchange of opinions allows students to gain new knowledge through interactions with others in the STEAM activity, therefore helping them expand on existing or generate new knowledge. This reflects the reasoning process through which knowledge acquisition occurs (Wheeler & Jones, 2008). The following content is from an interview with student B:

> Student B: In my group, no one knew how a danso worked and it would have been more easy to solve the problem if someone had knowledge related to the principle of sound. I think it was a particular experience to study this STEAM procedure by trying to apply and to find a solution based on my friends' ideas.

Lastly, 24% of students defined STEAM as a procedure of solving a problem by finding a solution on their own. The procedure of finding a solution on their own is demonstrated through the procedure of stimulating their creative science thinking, ideas, imagination, and awareness in the STEAM science class. This supports past research (Maes, 2010), which states that the arts or liberal arts help increase students' creativity and active participation in science classes. Therefore, it is clear that the arts are an important component of the STEAM program.

Students' awareness about the necessity of STEAM

As shown in Table 3, 38% of all students recognized the necessity of STEAM as it promotes the "formation of scientific concepts through the exchange of opinions," while 34% thought of it as a way of promoting the "development of advanced knowledge through problem solving." Finally, 28% perceived of it as a way of encouraging the "development of thinking skills through problem solving."

Table 3. Students' awareness of the necessity of STEAM (N=26)

No.	Students' awareness of necessity of STEAM	%
1	Formation of scientific concepts through the exchange of opinions	38
2	Development of advanced knowledge through problem solving	34
3	Development of thinking skills through problem solving	28

Thirty-eight percent of students thought that STEAM enabled greater formation of scientific concepts through the exchange of opinions. The students' awareness about the formation of scientific concepts through the sharing of opinions coincides with Maes's (2010) research, which showed that the arts should be included in education in order to bridge the gap between STEM content and the world in which we live. Converging art (i.e. creativity) and the STEM subjects allows students to develop the creativity that is needed to solve real-world problems. In addition, students learn to communicate their ideas with each other, which helps them see multiple ways of approaching a problem. The following content is from an interview with student C.

> Student C: I changed my mind about answers when I was able to understand a problem through seeing my friends' responses about questions I didn't understand about the sound principle of the danso using an algorithm. Also, during the creative design discussion I found out that there are a lot of parts that I didn't think about.

Thirty-four percent of students thought that STEAM is necessary because it develops their knowledge through problem solving. The following content from the interview with student D presents how STEAM education specifically enables the advanced knowledge:

> Student D: I was able to easily understand the content I didn't know by working on the problem and because the group members asked and taught each other about the sound principle of the danso using an algorithm we didn't understand. Also I think that we learned things about trying to solve the problem during the creative design discussion.

Twenty-eight percent of students said that STEAM is necessary because it allows students to develop critical thinking skills through problem solving. These results correspond with the aim of STEAM education (Maes, 2010), which seeks to help students develop emotional sympathy for their peers and expand their knowledge by sharing their opinions to solve problems, which can sharpens their critical thinking skills.

Usefulness of a STEAM program

As shown in Figure 5, 74% of students were interested in the STEAM program because they could participate in problem solving, solve the problem cooperatively, have fun in the process of gaining new knowledge, and learn a new concept through cooperative interactions. In particular, student E said that he used the STEAM program in his science class because it allowed him to participate in the whole problem-solving process. This shows that students are motivated by their interest in science, science efficacy, and self-confidence in the STEAM class. It corresponds with the research results that a creative design learning method is more effective than the original inquiry method in science classes (Mehalik, Doppelt, & Schunn, 2008). Furthermore, student F said that the process of solving a contemporary problem through cooperation is interesting, which is in accordance with the research showing that students can develop communication skills and appreciation for skills through cooperative "hands-on" and "hands-in" activities (Baek et al., 2011). The following are interviews with student E and F:

> Student E: It was very fun to understand a problem by ourselves and come to a solution through engaging with all the group members' opinions about and analysis of a short bamboo flute called a danso.
> Student F: It was also good when my opinions where appreciated during the creative design discussion. And I was happy to study and discuss with friends about the short bamboo flute called a danso. I thought it was a lot more creative and helpful to study cooperatively during a STEAM lesson.

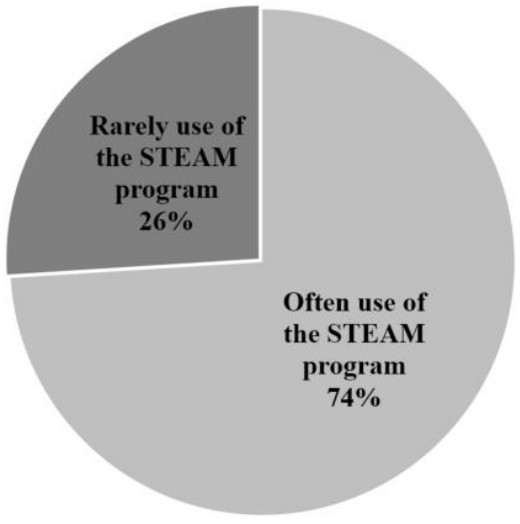

Figure 5. Comparison of usefulness of the STEAM program (N=26)

However, 26% of students indicated that they would rarely use the STEAM program because of a focus on the entrance examination preparation to university and discomfort with the strange teaching method utilized by the STEAM program. Student G thought that the term and procedural stage of STEAM program was very strange and unfamiliar, and that it was better to solve the problem using the traditional method. Thus, in order to use the STEAM program for science classes, the lesson should be conceptualized by class procedures and taught in procedural form (Baek et al., 2011). The following is content from the interview with student G:

> Student G: When the teacher gave us an orientation on how to teach the STEAM lesson, I thought that it seemed very strange and unique. So I didn't know how to solve the problem focused on developing a precise analysis of a danso and collaboratively designing a smartphone application, as it is a new approach.

CONCLUSIONS AND IMPLICATIONS

Recently, Korea has tried to increase students' interest in and understanding of science technology by adding the arts to STEM education and cultivating STEAM literacy based on science technology and problem solving. However, there is no specific STEAM framework that focuses on nurturing convergent talent and there is little research that verifies the effects of the STEAM program. Thus, the purpose of this research was to develop a STEAM program in the context of teaching and learning a traditional Korean musical instrument and implement it in a high school class to determine the program's effectiveness. As shown in this research, students recognized the STEAM science class as a "problem-solving procedure using convergent thinking," "instructional procedure for knowledge generation," and "finding a solution on their own in the STEAM activity." Students refined their imagination and awareness in the STEAM science class activity through developing their emotional touch and stimulating their creative science thinking and ideas through the reasoning process. Moreover, most participants were willing to use the STEAM program in science class often, although some students indicated that they would only use STEAM if it did not conflict with preparations for the entrance exam to university. Based on the findings of this study, the major outcome from the developed STEAM program was that students can develop a solid understanding of scientific principles as well as develop their creativity and tap into their emotions by exploring the beauty of traditional Korean culture, as seen in the danso. This means that STEAM program in the context of teaching and learning a traditional Korean musical instrument served as a network of practical divisions of varying methods, including constructions, analysis, process work, and application, as well as problem-solving. Also, this study found a strong link between the STEAM program and real-world problems. Overall, we conclude that the STEAM program increased scientific efficacy and creativity while maximizing interest and motivation in science, which helped to improve national competitiveness in the sciences. Finally, this STEAM program approach is apt to cultivate STEAM literacy through the convergence of science, technology and the arts by enhancing creative problem-solving abilities.

This research has the following limitations. It is difficult to generalize the research results because the STEAM program activity, which was based on a traditional Korean instrument in one high school, was not standardized. In addition, the study shows the results of interviews with only 26 students from one high school, and so any future research should contain a larger sample size in order to generalize the research results so that they are applicable to a significant number of high school students.

REFERENCES

Baek, Y., Park, H., Kim, Y., Noh, S., Park, J–Y., Lee, J. Han, H. (2011). STEAM education in Korea. *Journal of Learner-Centered Curriculum and Instruction*, *11*(4), 149–171.

Brown, J. S., Collins, A. S., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher*, *18*(1), 32–42.

Christensen, R., Knezek, G., Tyler-Wood, T., & Gibson, D. (2014). Longitudinal analysis of cognitive constructs fostered by STEM activities for middle school students. *Knowledge Management & E-Learning*, *6*(2), 103–122.

Jacobs, J. E., Finken, L. L., Griffin, N. L., & Wright, J. D. (1998). The career plans of science-talented rural adolescent girls. *American Educational Research Journal, 35*(4), 681–704.

Jeong, J., Kim, H., Chae, D. H., & Kim, E. (2014). The effect of a case-based reasoning instructional model on Korean high school students' awareness in climate change unit. *Eurasia Journal of Mathematics, Science & Technology Education*, *10*(5), 427–435.

Kim, H. S. (2012). A study on relation and importance of art education and STEAM education. *Journal of Korean Society of Basic Design and Art, 13*(5), 105–113.

Knezek, G., Christensen, R., Tyler-Wood, T., & Periathiruvadi, S. (2013). Impact of environmental power monitoring activities on middle school student perceptions of STEM. *Science Education International*, *24*(1), 98–123.

Knowles, M. (1975). *Self-directed learning: A guide for learners and teachers.* New York, NY: The Adult Education Company.

Kolodner, J. L., Crismond, D., Fasse, B. B., Gray, J. T., Holbrook, J., Ryan, M., & Puntambekar, S. (2003). Problem-based learning meets case-based reasoning in the middle-school science classroom: Putting a learning-by-design curriculum into practice. *Journal of Learning Sciences*, *12*(4), 495–547.

Korea Foundation for the Advancement of Science and Creativity (KOFAC). (2012). *Policy directions of STEAM education: Introductory training of KOFAC STEAM.* Seoul, Korea: Foundation for the Advancement of Science and Creativity.

Lave, L., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation.* New York, NY: Cambridge University Press.

Lee, H. (2013). *Understanding and application of STEM/STEAM education*. Seoul, Korea: Bookshill.

Lincoln, Y. S., & Guba, E. G. (2000). Paradigmatic controversies, contradictions, and emerging confluences. In N. K. Denzin & Y. S. Lincoln (Eds.), *Handbook of qualitative research* (2nd ed., pp. 163–188). Thousand Oaks, CA: Sage.

Maes, B. (2010). *Stop talking about "STEM" education! "TEAMS" is way cooler*. Retrieved from http://bertmaes.wordpress.com/2010/10/21/teams/

Ministry of Education, Science, and Technology (MEST). (2010). *The revised 2009 curriculum*. Seoul, Korea: Ministry of Education, Science and Technology.

Mehalik, M. M., Doppelt, Y., & Schunn, C. D. (2008). Middle-school science through design-based learning versus scripted inquiry: Better overall science concept learning and equity gap reduction. *Journal of Engineering Education*, *97*(1), 71–85.

Strauss, A., & Corbin, J. (1998). *Basics of qualitative research: Procedures and techniques for developing grounded theory*. Thousand Oaks, CA: Sage

Wheeler, P., & Jones, D. R. (2008). The psychology of case-based reasoning: How information produced from case-matching methods facilitates the use of statistically generated information. *Journal of Information Systems*, *22*(1), 1–25.

Yakman, G., & Lee, H. (2012). Exploring the exemplary STEAM education in the U.S. as a practical educational framework for Korea. *Journal of the Korean Association for Science Education*, *32*(6), 1072–1086.

◈◇◈