Science and Technology Trends
Policy Trajectories and Initiatives in STEM Education

STEAM Education in Korea: Current Policies and Future Directions

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1. Introduction

In the era of the Fourth Industrial Revolution, in which artificial intelligence is continuously in development and jobs evolve at a rapid pace, creative human resources are needed in order to create new jobs and solve future problems. With changes emerging in the economy, society, culture, and the ecological environment, education for future generations must advance, as well. The World Economic Forum (2016) presented the key skills required for the Fourth Industrial Revolution by 2020, such as complex problem solving, critical thinking, and creativity. While identifying the skills required for students to succeed in work, life, and as citizens of the world, Partnership for 21st Century Skills (P21) focused on the 4Cs: Critical thinking, Communication, Collaboration, and Creativity (http://www.p21.org).

The Korean government has continually driven STEAM (Science, Technology, Engineering, Arts, and Mathematics) education policy since announcing "The second basic plan to foster and support human resources in science and technology (2011-2015)," which includes STEAM education (The Korean Ministry of Education, Science and Technology, 2011). As the most representative national institution for STEAM education, as well as science, mathematics, and software education, the Korea Foundation for the Advancement of Science and Creativity (KOFAC) has managed systematic STEAM education programs at the national level. To help STEAM education become more well established, KOFAC cultivates and supports leading groups, reinforces teachers' capabilities, develops and distributes content, promotes interactive and exploratory activities for students, and institutionalizes and builds infrastructure (see Figure 1).

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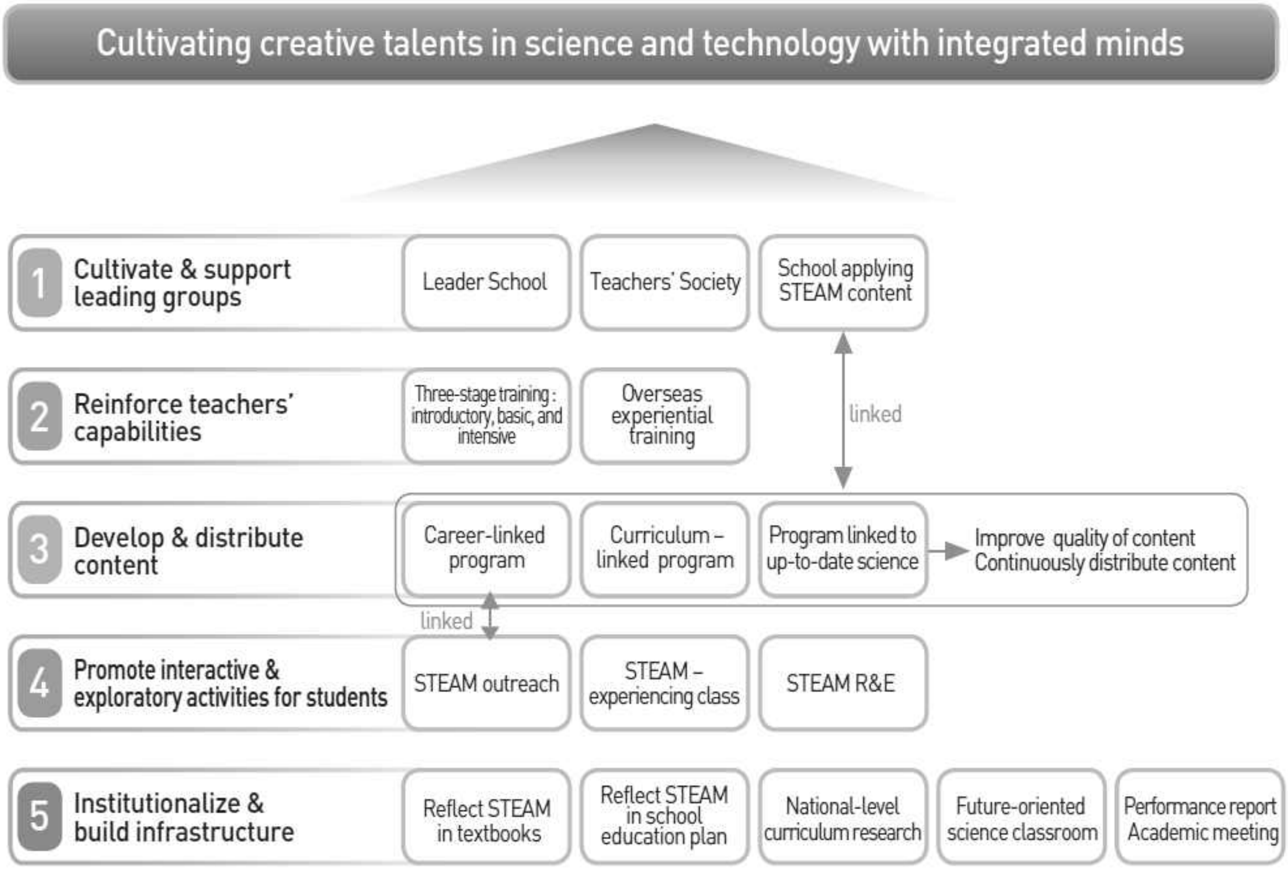
Figure 1. The structure of STEAM education programs managed by KOFAC

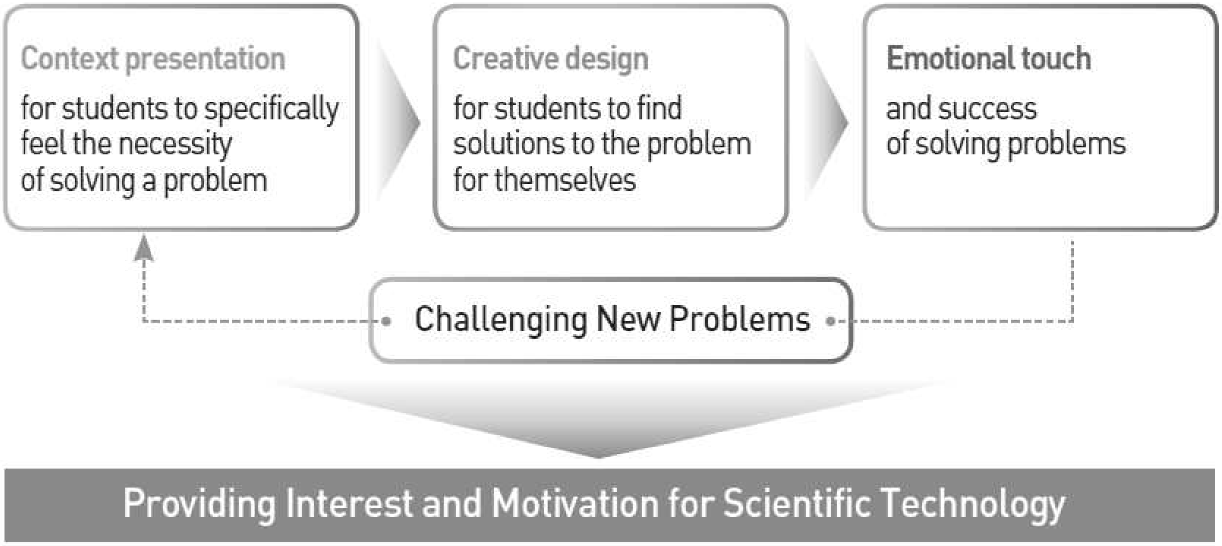


Source: Korea Foundation for the Advancement of Science and Creativity, 2016 (p.45)

The *Learning Standards Framework of STEAM Classes* has been developed so that it can be utilized to design classes that meet the goals of STEAM education. The framework consists of the following three steps: Context presentation, Creative design, and Emotional touch. A description for each step is given in Figure 2. It is recommended that STEAM classes be conducted based on this framework.

Korea's new national curriculum, '2015 Revised Curriculum,' aims to cultivate creative talents with integrative thinking and problem solving. STEAM education will thus continue to be emphasized as an educational strategy for future generations. It is, therefore, meaningful to look into STEAM education policy put forward thus far and to propose the next step based on what has already been established. In this report, an outline is presented on the current policy of STEAM education in Korea based on the three elements of education: the teacher who teaches, the student who learns, and the educational content that mediates the teaching and learning (Shin, 2005), future directions for STEAM education are then suggested.

Figure 2. Learning standards framework of STEAM classes



Source: Korea Foundation for the Advancement of Science and Creativity, 2016 (p.25)

2. STEAM Professional Development for Teachers

Teachers' capabilities in practicing STEAM education are of great importance. According to research conducted to investigate the current status of STEAM education by analyzing online survey responses collected from 56.8% (N = 6,473) of elementary, middle, and high schools in Korea, it was found that 48.3% (N = 3,127) of the responding schools conducted STEAM education (Park *et al.*, 2016). Assuming that schools not participating in the survey do not implement STEAM education, it can be understood that approximately 27.1% of all schools in the country have conducted STEAM education classes (see Table 1). This research discovered that the most important factor in implementing STEAM education was the 'voluntary efforts of teachers,' and the main reason for not implementing STEAM education was difficulties in drawing a consensus from teachers regarding STEAM education. This result indicates that the role of teachers is very important in the implementation of STEAM education.

Table 1. The number of schools that implement STEAM education

no.(%)

School Level	Total schools	Responding schools	Implementing STEAM	Not Implementing STEAM	Implementing STEAM/Total
Elementary	5,978	3,362 (100.0)	1,838 (54.7)	1,524 (45.3)	1,838/5,978 (30.8)
Middle	3,204	1,831 (100.0)	879 (48.0)	952 (52.0)	879/3,204 (27.4)
High	2,344	1,280 (100.0)	410 (32.0)	870 (68.0)	410/2,344 (17.5)
Total	11,526	6,473 (100.0)	3,127 (48.3)	3,346 (51.7)	3,127/11,526 (27.1)

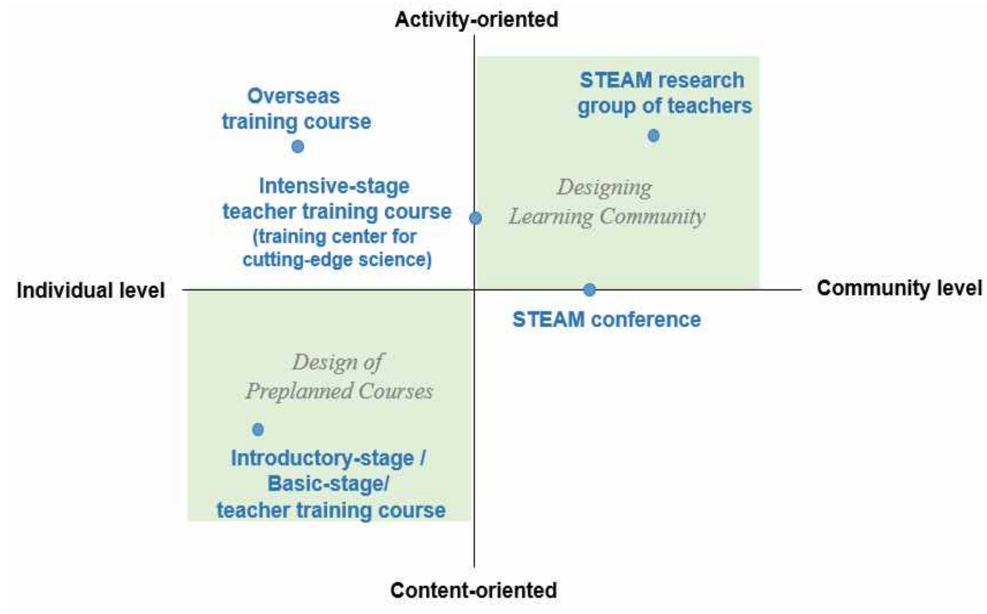
Source: Park *et al.*, 2016

To support STEAM professional development for teachers, three steps of teacher training programs are currently being operated. ‘Introductory training’ focuses on helping teachers understand the concepts, policies, and representative content of STEAM education. ‘Basic Training’ involves a 15-hour online program centered on sharing best practices, such as how to organize STEAM education suitable for the school curriculum or how to implement STEAM education for after-school programs. ‘Intensive Training,’ a mixture of online and offline programs, has the purpose of improving teachers’ capabilities to develop and implement their own educational materials for STEAM classes. The 60-hour training program includes fieldwork, as participants attend the Teacher Training Center for Cutting-edge Science and STEAM fairs, as well as group activities in developing classroom-applicable STEAM educational materials.

In spite of these great efforts made to train STEAM teachers, many teachers have difficulty in selecting appropriate topics, integrating two or more subjects, developing educational materials, and evaluating classes (Noh & Paik, 2014; Lee & Shin, 2014). Jho, Hong, and Song (2016) categorized in-service training programs for STEAM education in Korea, including three steps of teacher training programs, by adopting Ryn and Cowan’s (1996) framework with two dimensions of knowledge and learning (see Figure 3). Knowledge construction is separated into the individual level and the community level, while learning construction is categorized as content-oriented and activity-oriented. This research asserted that teacher training programs for STEAM education should focus on designing a learning community that is activity-oriented at the community level (top right plane of Figure 3) to foster sustainable professional development.

Considering this assertion, STEAM research groups of teachers, made up of experienced teachers and experts in relevant fields, work together to develop and apply STEAM educational materials, serving as a good model for sustaining STEAM professional development. Furthermore, according to the report surveying teachers’ needs for STEAM education, what STEAM teachers reported most often was the need for support for teacher communities in terms of learning and research (KOFAC, 2013).

Figure 3. Mapping in-service training programs of STEAM education in Korea



Source: Jho, Hong, & Song, 2016

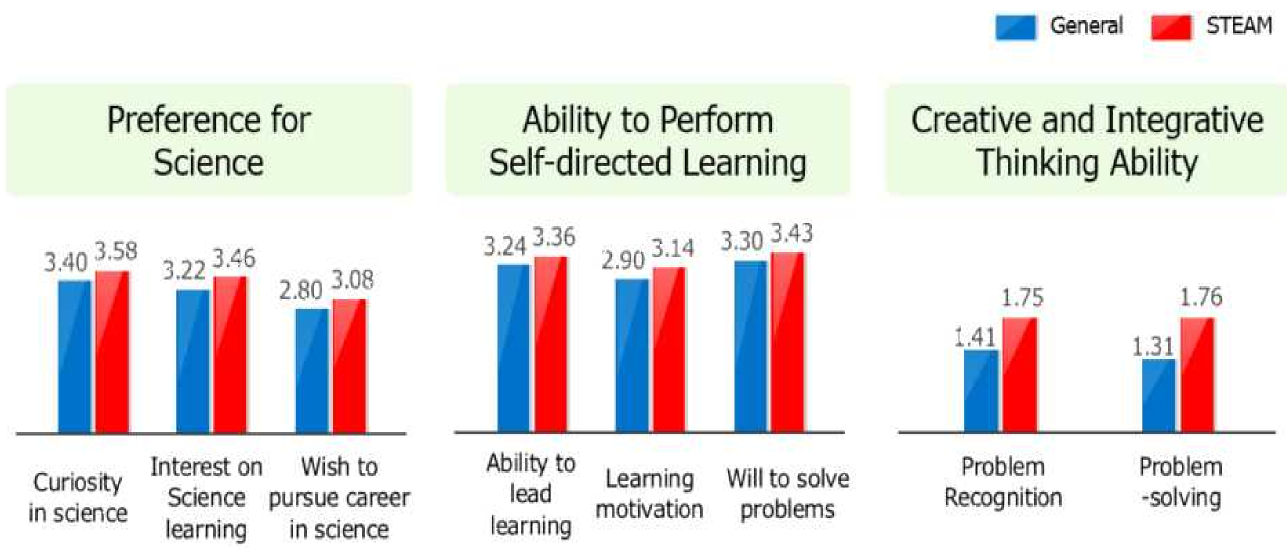
3. Improving Students' Science Preferences, Self-directed Learning, and Creative and Integrative Thinking Abilities

STEAM education began with the expectation that it could solve some of the problems associated with students' studies in science and mathematics. According to international evaluation programs, such as TIMSS (Trends in International Mathematics and Science Study) and PISA (Program for International Student Assessment), Korean students demonstrated high performance but very low interest in the subjects of science and mathematics. In addition, the lessons and evaluations, which focused on concepts and knowledge relating to science and mathematics, led to decreased interest for learners.

According to a study on the effects of STEAM education, conducted by KOFAC (2013), students who participated in STEAM classes showed higher 'science preference' than students who did not participate. This trend has been revealed in all detailed areas: *Curiosity in science, Interest in science learning, Embracing the values of science, Belief in learning science, Will to perform science-related tasks, and Wish to pursue a career in science.* The students who experienced STEAM classes also showed higher levels in terms of 'Ability to perform self-directed learning,' composed of *Ability to lead learning, Cognitive strategy, Learning motivation, Will to solve problems, Use of tools, and Ability to cooperate.* Students learning through STEAM classes also showed a higher level of creative and integrative thinking ability.

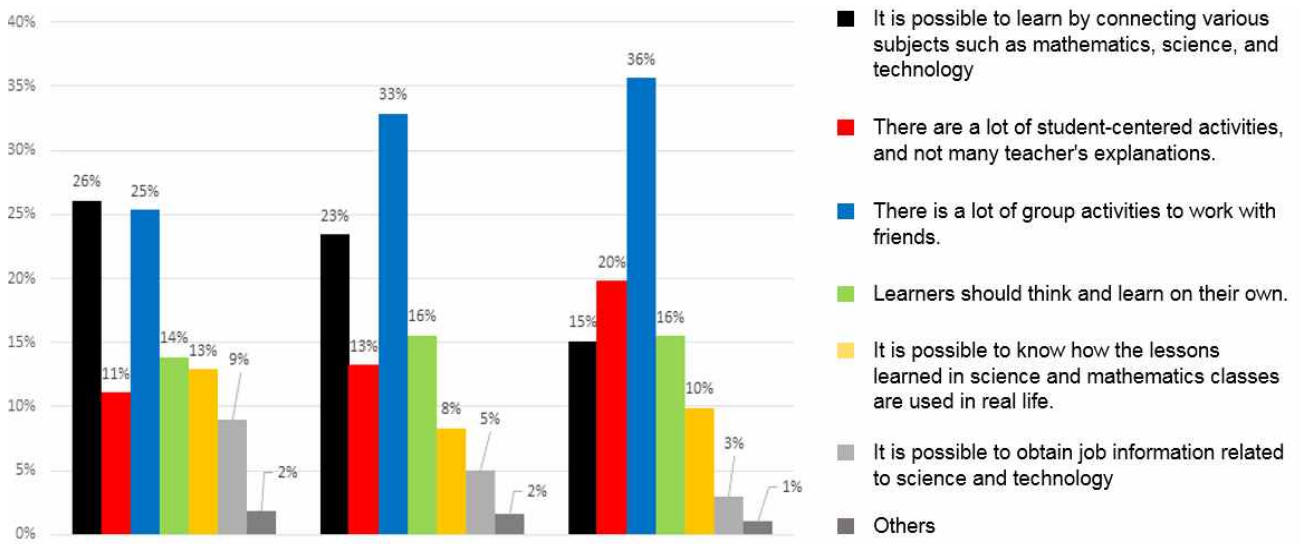
What are the characteristics of STEAM education that have brought about positive changes for students? According to the results of a survey of 19,147 elementary, middle, and high school students participating in STEAM education, the most crucial characteristic of a STEAM class that differentiates it from existing classes was "a lot of group activities to work with friends" (Kang *et al.*, 2016). Many students also identified "to learn by connecting various subjects, such as mathematics, science, and technology" as another important feature of STEAM education. In addition, there were opinions presented on STEAM education's features that encourage students to think and learn on their own, lead learners' active learning through student-centered activities, and link learning content with real life.

Figure 4. Effects of STEAM classes



Source: KOFAC, 2014

Figure 5. Students' thoughts on the characteristics of STEAM education



Source: Kang *et al*., 2016

In order to continue these positive changes for learners through STEAM education, policies to promote interactive and exploratory activities for students are being implemented, such as STEAM Research and Education (R&E) and STEAM outreach programs.

STEAM R&E aims to enhance students' research capabilities and encourage an atmosphere of autonomous inquiry by supporting student-led research activities on integration-based themes. Students who organize a team to participate in STEAM R&E come up with their own problems in daily life, define research problems, design research methods, and then submit their research proposals. Research projects are selected for funding through expert reviews, and the results are published at R&E festivals. According to research exploring the effects of STEAM R&E, conducted by Mun *et al*. (2017), students' creative leader competencies, consisting of cognitive, affective, and societal domains, improved after participating in STEAM R&E. In addition, R&E has a positive impact on students' creative thinking by providing students with experiences related to research field careers and collaborative research activities carried out with friends (Choi & Park, 2015).

STEAM outreach programs aim to help students plan science-related careers by giving opportunities to experience the latest in science and technology available at actual industrial and research sites. Since 2013, about ten universities, government-funded research institutes, and companies have been selected as STEAM outreach operating organizations on an annual basis. They have developed and implemented STEAM education programs that meet the characteristics of the organization by utilizing their infrastructures for students across the country. Overall, STEAM outreach programs have shown a high level of student interest and satisfaction, and they have also displayed a positive impact on students' desires to pursue careers related to science (Kang *et al*., 2016).

4. STEAM Education Content that Brings Positive Change

According to the analysis of 821 STEM/STEAM related research papers published in Korea over the last ten years (Kim & Kim, 2017), the most frequently researched topic was 'program/instructional materials,' which accounted for 72% of the total. Furthermore, 'program' and 'development' were the keywords that emerged most often. This shows that studies in the field of STEAM education have been focused on the development of diverse educational materials and programs that promote the practice of STEAM education.

The Korean Ministry of Education and KOFAC are continuing to develop four types of STEAM programs to be used in schools: Integration-based programs for each theme of STEAM (e.g., biotechnology, global environment, and appropriate technology), Programs to utilize up-to-date products (e.g., up-to-date ICT, up-to-date medical appliances, and up-to-date vehicles), Integration-based programs in science and art (e.g., topographical maps in science and art, creative activities in manufacturing, and world-changing designs), and Design-based programs connected to promising future jobs (e.g., cognitive engineers, robot engineers, and information systems professionals). In addition, STEAM research groups of teachers, in which teachers and experts work together, have continuously developed a variety of high-quality teaching materials. STEAM educational materials and programs developed through these processes are uploaded to the STEAM homepage (http://steam.kofac.re.kr) and can be freely accessed by anyone.

Table 2 shows a checklist that can be used in designing a STEAM class. It consists of the following four categories: Purpose of STEAM education, Concept of STEAM education, Learning standards framework for STEAM classes (i.e., Context presentation, Creative design, and Emotional touch), and Evaluation of STEAM education. In order to apply STEAM classes that satisfy the checklist, despite the already organized schedules based on each subject, three types of curriculum activity can be applied: Subject curriculum activity connecting the factors of S, T, E, A, and M with a main subject; Creative curriculum activity connecting multiple subjects for a main theme; and Extra-curriculum activity reconstructing the curriculum or developing a separate program for a main theme. Among these, an example of 'Subject curriculum activity' can be found in Table 3.

Some studies analyzing STEAM programs and educational materials have pointed out that the degree of integration was limited. According to the results of analyzing STEAM educational materials developed by STEAM leading groups, such as leader schools and research groups of teachers, based on the linking frequency of each of S, T, E, A, and M in elementary educational materials, linkages between science (S) and arts (A) have been frequent, while technology (T) and engineering (E) are not frequently connected with other fields (Ahn & Kwon, 2013). For secondary educational materials, the frequency of linkages between technology and engineering was higher than for elementary materials.

According to the research analyzing 821 theses and articles on STEAM education published in Korea, research on science (S) accounted for the highest percentage (27%) when the core subject covered by the research included a single subject, and research dealing with science (S) and arts (A) together accounted for the highest percentage (2.6%) when the core subject covered by the research was an integrative type. Although STEAM education emphasizes Creative Design as an element of the learning standards framework for STEAM classes, technology (T) and engineering (E) were not emphasized in both academic research and educational program development.

Table 2. STEAM class checklist

Category		Element	Details
Purpose of STEAM Education		Nurturing Talents for Integration	Is the class appropriate for the purpose of nurturing talents for integration?
Concept of STEAM Education		Increasing Students' Interest	Is the class designed to increase the students' interest in scientific technology?
		Connection to the Real World	In the theme related to scientific technology in the real world?
		Cultivation of Integrated Thinking Abilities	Is the program designed to cultivate the integrated thinking abilities of students?
Learning Standards Framework of STEAM Classes	Context Presentation	Connections to the Real World	Does the class present problematic situations for student to solve in the real world?
		Interest and Immersion	Is it a specific situation that can arouse the interest of students and appropriate for their level?
	Creative Design	Creativity	Is the process of creative design clearly revealed for the students to think about how they will solve the problem?
		Focusing on Students	Is the class made up of activities focusing on play and experiences, and is there a process for the students to personally devise and think about the issues at hand?
		Results (Ideas)	Is the class designed for various results (or ideas) to be presented by each students (or group) as a result of creative design?
		Use of Tools	Is the class designed for students to solve problems using devices from the real world?
	Emotional Touch	Solving Problems	Are the contents presented in the context presentation step for students to feel the joys of success in solving a problem?
		Learning through Cooperation	Is the class designed for students to solve problems through cooperation in coming up with their results?
		Sprit of Challenge	Is the class guided for students to challenge new tasks through the process of solving problems?
Evaluation of STEAM Education		Detailed Perspective	Is it made to evaluate the experience of success for students having solved the problem?
			Are various results (ideas) analyzed in the evaluation of students?
			Is the aim to conduct not a results-focused evaluation but rather an evaluation focusing on the process and its steps?

Source: Korea Foundation for the Advancement of Science and Creativity, 2016 (pp.33-34)

Table 3. Example of Subject Curriculum Activity of STEAM Education from Teacher's Guide

Target	Science ① Grades 3 and 4	Unit	3. Life Cycles of Animals/ Lessons 2-5	Theme	Observing the life cycle of a cabbage butterfly
Content	• Students can make a plan to obeserve the life cycle of a cabbage butterfly, and build a cage for the plan. • Students can understand the changes of the cabbage butterfly as it goes around the life cycle through the activities of growing and observing a cabbage butterfly.				
Elements of Integrated Talents Education	• **Context Presentation:** Motivate students to take an interest in observing the life cycle of a cabbage butterfly and learning about how they look. You may ask questions like, "Have you ever wondered why the animals around us, like butterflies, look the way they do?" or "Were they butterflies from birth, or can they have looked different?" • **Creative Design:** Let each group of students make a plan for their observation of the life cycle and start the observation in accordance with the plans. You may consider asking questions like "What plans do we need to observe a cabbage butterfly?", "Which part do we need to observe to locate the eggs?" or "What plans do we need to make to observe the incubation of the eggs?" Let students think about how they can share the results of their observation with others: e.g., pictures, text, etc. • **Emotional Touch:** Let each group of students compare their results of observation with those of other groups, consider the differences, and talk about what they have learned.				
Extension	• In connection to Art, Lesson 5, "Expressions of Observation," have students express how insects look like. • In connection to Korean, Lesson 4, "Collect Information," have students think of the best ways to share with friends what they have observed.				

Source: Ministry of Education (2014), Korea Foundation for the Advancement of Science and Creativity, 2016 (pp.33-34)

5. Suggestions for Future Directions of STEAM Education

In the previous chapters, I presented the current policy of STEAM education in Korea based on the three elements of education: the teacher, the student, and the educational content. Based on this, I would like to briefly suggest potential future directions for STEAM education.

Firstly, for teachers, systematic educational opportunities should be provided so that teachers can bridge the gap between education and our changing world. For this, it is suggested to develop a model for (and implement) a 'STEAM bridge center' (Cho *et al*., 2017) in which academic and industry experts and experienced teachers can work together to develop educational materials, teach students, and collect and analyze data on students. The National Science Foundation (NSF) supported 'Research + Practice Collaboratory' programs that develop curriculum, technology, and after-school programs through the cooperation of researchers and teachers, from the point of view that STEM education research should be promoted through the active participation of teachers (http://collaboratory.mspnet.org). In order to strengthen the capabilities of STEAM teachers, it is necessary to construct research and learning communities beyond individual-level training programs (Jho, Hong, & Song, 2016). The 'STEAM bridge center' model for collaborative research between researchers and teachers will contribute to the improvement of teacher capabilities and can also be used as an effective method for the development of qualified STEAM educational content.

Secondly, for students, more experience in participating in social problem-solving projects should be provided so that they can highlight social problems and solve them through STEAM education. These experiences help students to grow as democratic citizens who participate and practice, and to grow as leaders who solve diverse problems caused by rapid changes in industry. Furthermore, until now, STEAM education has been mainly implemented in primary and secondary education, but it should be extended to university education. Recently, the Japanese government announced the 'Articulation Reforms of High Schools and Universities (ARHSUS)' in order to transform high school and university education into something more adequate for future inhabitants of our society (Anzai, 2017). Since 2011, STEAM education aiming to transform the curriculum to prepare students for the future society has brought positive changes to primary and secondary school classes. If STEAM education is implemented in universities, realistic projects dealing with problems in real industries and communities will be pursued based on the ideas of university students, and student-led Research and Solution Development (R & SD) for solving social problems will be realized. Furthermore, STEAM education in universities will help students develop the problem-solving, collaborative, and creative talents required for future jobs and careers.

Thirdly, for educational content, the degree of integration should be expanded so that STEAM classes can reveal students' creativity by naturally linking various subjects or disciplines − as was the original purpose. More attention should be given to technology (T) and engineering (E), which have not been emphasized in current STEAM educational materials, despite their importance in the Creative Design process. Furthermore, it is necessary to place additional emphasis on computational thinking, an approach to solve problems efficiently by integrating human ability and computing power, in STEAM education, as many problems emerging with our future society will be difficult to solve without the help of computing devices. The NSF has supported 'STEM+Computing Partnerships (STEM+C)' programs that integrate computing with one or more STEM disciplines, or integrate STEM into computing education (NSF, 2017). In 2017, in a similar vein, KOFAC published a series of educational books titled 'Problem-Solving Activities for Computational Thinkers' to provide various STEAM activities based on computational thinking with topics related to cutting-edge technologies (e.g., Artificial Intelligence, Autonomous Cars, Virtual Reality, Space Launch Vehicles, Natural Disasters, and Sports Statistics). It is believed that computational thinking is a very important keyword in presenting the future directions of STEAM education.

Finally, teachers, students, and educational content are all important elements in understanding STEAM education, but an integrated approach − rather than an individual approach − must be taken in order to understand and properly analyze STEAM classes. According to Kim & Kim (2017), 'creativity' was the most frequently presented keyword as a dependent variable in the study of the effectiveness of STEAM education. Creativity is highlighted time and again as a key skill required for future generations. Recently, in Korea, there has been much discussion regarding collective creativity at the group level, along with an attempt to conceptualize and analyze 'classroom creativity' that integrally considers students, teachers, environment, engagement, and creative behavior (Hong, 2016). As a representative future education policy in Korea, STEAM education make students actively participate and communicate with others in order for creativity to be naturally revealed in the process. Therefore, in order to design the next step of STEAM education policy, it is necessary to holistically understand and analyze STEAM classes that enhance the active interaction between teachers, students, and educational content.

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