Chapter 12
Arts-Integrated STEM in Korean Schools

Hye-Eun Chu, Sonya Martin, Ei Seul Kim, and Hyeong Moon Lee

Abstract This chapter addresses the theme of innovative teaching approaches, reporting on three funded studies investigating the effects of a STEAM teaching approach where the arts are integrated into STEM teaching/learning activities. 'Arts' is defined as any event or product that reflects a community's sociocultural practices and values, for example, paintings, architecture, literature, leisure activities, and festivals. The STEAM approach has been adopted into Korea's national science curriculum. The chapter describes the STEAM teaching/learning process, including classroom activities: encouraging students to ask inquiry questions and hypothesize answers; engaging students in activities aimed at verifying their hypotheses; and inviting peer collaboration in testing, applying, and evaluating their hypotheses. Throughout the teaching/learning process, arts-related sociocultural events (e.g. a light festival) and/or products (e.g. 3D quasi holograms) are used to demonstrate to students how science concepts (e.g. light propagation) create or explain a sociocultural experience. Samples of students' work provide evidence of their developing understanding of science concepts. The chapter also reports on the effect of the STEAM approach on students' perceptions of and attitudes towards science and studying science, and presents some evidence of scientific creativity in STEAM lessons. The chapter concludes with a discussion of the potential benefits and challenges of the STEAM approach.

Keywords STEAM · STEM · Perceptions to science learning · Perceptions of science

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Introduction

This chapter reports on the STEAM approach implemented in Korea that incorporates the arts into teaching/learning activities. The STEAM approach has been defined in the literature (Paik et al., 2012; Park et al., 2012; Yakman & Lee, 2012), with the letter ‘A’ standing for the integration of the arts into STEM lessons. The STEAM approach presented in this chapter integrated science, technology, engineering, and mathematics (STEM) with the arts or culture to afford students the experience of seeing science concepts operating in real-world contexts. In the sections that follow, we provide examples from three STEAM projects implemented in Korea to provide some evidence of the potential of STEAM education to develop students’ understanding of science concepts in the context of sociocultural environments familiar to the students. We also present evidence that these STEAM learning experiences can support positive attitudes towards and perceptions of science and science learning, besides promoting scientific creativity in the science classroom. The Korean evidence was collected in an Australia-Korea Foundation funded project involving intercultural interactions between students in STEAM classes in Korean and Australian schools. A total of eight schools in Korea and Australia participated in this project from 2016 to 2020. In this chapter, however, only data from the Korean classrooms will be reported.

What is STEAM?

What distinguishes STEAM from STEM is the intentional use of the arts in the teaching/learning process. The term ‘arts’ refers to non-STEM school subjects such as art, history, and literature (Yakman & Lee, 2012), as well as sociocultural products and events familiar to students (e.g. photography, traditional foods, and musical instruments). In STEAM lessons, the arts activity or product is integral to the process of guiding students’ understanding of STEM.

The theoretical framework underlying many STEAM initiatives is that of social constructivist theory (Chu et al., 2019; Chu et al., 2019; Holbrook et al., 2020). The social constructivist model of learning holds that learners construct knowledge and concepts through interaction with others and with their environment (Duit & Treagust, 1998; Ernest, 1998). Applied to the STEAM classroom, this means that science concepts and scientific ways of thinking, speaking, and reasoning about the world are learned through interacting with teachers and peers, and interacting with the environment, such as objects, sociocultural events, natural phenomena, and experimental results.

Through these interactions, learners verbalize their questions and nascent understanding and, in the process, form mental approximations of the science concept, and finally arrive at a scientifically acceptable concept. In the context of STEAM lessons, interaction with the environment includes asking questions and talking about the arts or any other sociocultural activity that occurs in the student's community. Integrating sociocultural elements with the teaching and learning of science allows students to see the role of science concepts in a sociocultural activity or product, for example, Korean science students investigating the working of the Korean flute (daegeum). Observing how science concepts help to explain phenomena in their sociocultural life can create in students' minds the perception that science is relevant to real life (Chu et al., 2019; Chu et al., 2019).

STEAM in Korean Schools

The initial inclusion of STEAM in Korean schools was in response to PISA and TIMSS reports about students' negative attitudes towards learning science. Although Korean students consistently ranked in the top achievement category (with an average science score of 561 in the 1999 TIMSS assessment), since 1999 few Korean students have displayed positive attitudes towards science (below 20%) (Mullis et al., 2020), and this has not changed substantially as of 2019. In these assessments, many Korean students disagree with statements such as, 'I enjoy learning science' and 'I learn many interesting things in science'.

In response to the substantial difference between students' high achievement in science and the lack of positive attitudes towards science, the Korean Foundation for the Advancement of Science and Creativity (KOFAC) and the Ministry of Education, Science, and Technology (MOEST) proposed modifications to the way science was being taught. Their proposals included the integration of non-science subjects into the teaching of science and mathematics, an approach known as 'STEAM' in the United States (MOEST, 2010; MOEST & KOFAC, 2012). Through STEAM lessons, KOFAC aimed to encourage students' curiosity about phenomena, engagement in inquiry, and participation in creative experiences to build an awareness of the connection between science and the students' real-world sociocultural lives (KOFAC, n.d.).

The STEAM approach is currently practised in many schools in Korea. A survey in 2015 revealed that of about 6,551 schools which responded to the survey, 54% of elementary schools, 47% of middle schools, and 32% of high schools offered STEAM lessons (Park et al., 2016). The STEAM programs generally take the form of integrating science lessons with students' out-of-school experiences, discussing socioscientific issues, and student-initiated projects in which students pose questions or define problems, and seek solutions. It is likely that more schools will adopt a STEAM approach to science teaching as the Korean Ministry of Education (MOE, 2020) has announced that from 2024 schools can choose to replace some parts of the national curriculum with school-designed integrated lessons, including STEAM lessons.

Three STEAM Research Projects

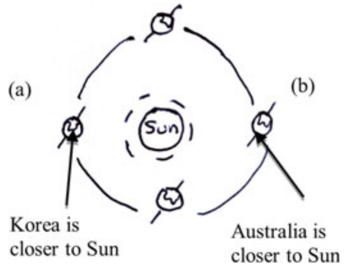
This section reports on the trial implementation of three STEAM programs in Korean schools with about 100 students in grades 5, 8, and 10 between 2016 and 2020. Project 1, which was related to the teaching of seasonal change to Year 5 students, illustrates the four-phase design based on a social constructivist view, and offers examples of teaching materials and activities. Project 2, which was implemented with the topic of light reflection for Year 8 students, shows how STEAM lessons differ from regular science classes and highlights the impact on student learning. Both projects describe STEAM lesson design and impact on students' concept development and attitudes towards and perceptions of science learning. Project 3, which focused on Year 10 lessons on the topic of thermal energy and energy efficiency, describes the impact on students' scientific creativity and critical thinking.

Project 1: A Four-Phased Design Adopting the STEAM Approach

Project 1 relates to the teaching of seasonal change with Year 5 (9–10 year-olds) and took place in 2016–2017. There were 23–25 students in each class from two schools. Arts-related elements were specifically incorporated throughout the STEAM lessons using a four-phased design: engagement, collaborative exploration, elaboration, and communication, and peer evaluation of revised explanations. Students paid attention to the design (colour, choice of symbols, visual representations, and organization of information) of their explanatory models about what causes seasonal change. Creating visual depictions of explanatory models has been recognized as not simply a passive communication tool, but also a generative reasoning process that helps students actively shape their knowledge (Tytler et al., 2020).

Engagement: Students are presented with a situation or phenomenon that invites them to be curious and to pose questions (why?/how?/what consequences?). Korean Year 5 students discovered through Skype conversations with Australian students that Christmas celebrations occur in winter in Korea but in summer in Australia. The different seasons occurring at the same time of the year triggered questions such as, 'Why is it winter in Seoul but summer in Sydney?' The teacher steered students to questions likely to lead to scientific inquiry, explaining that scientists observe the world around them, get curious about phenomena, and ask questions to start a process of investigation and discovery (Driver et al., 1996; Windschitl et al., 2008). The use of a sociocultural event (in this case, Christmas in summer/winter) was intended to show students that science can explain phenomena observed in our daily life.

Collaborative exploration: Group activities enhance construction of knowledge through social interaction. Students were asked to produce an explanatory model in the form of a drawing to explain why it was winter in one country but summer in the other at the same time of year (see Fig. 12.1). By getting the students to verbally



Written explanation:

The Earth's rotation axis is tilted, and this causes the different seasons in Korea and Australia at the same time of the year. In the diagram, the Earth revolves around the sun. When Korea is closer to the sun [see (a)], it is summer in Korea. When Australia is closer to the sun, it is summer in Australia [see (b)].

Fig. 12.1 An example of a group's initial model explaining seasonal differences in two countries at the same time of the year

present their hypothesized group answers or submit their written answers, the teacher can identify gaps in students' knowledge and/or alternative conceptions. This enables the teacher to prepare a learning activity to guide students towards building more accurate understandings of the targeted science concept.

Figure 12.1 shows that some students initially thought the main reason for seasonal change was the differential distance between different places of the Earth and the sun, caused by the tilt of the Earth's axis. To invite students to question this view, the teacher provided students with an experiment using two heat lamps, each directed at a tray of soil. One lamp was angled at 75 degrees and the other at 40 degrees, with both lamps positioned at the same distance from the soil. Using a thermometer, students measured the temperature of the soil in each tray, leading them to observe that the soil in the tray with the lamp positioned at 75 degrees above it was hotter than the soil in the other tray. This learning activity engaged students in the scientific practice of experimenting, together with observing, and collecting data. The aim was to help them to understand the importance of the angle of the sun on the temperature of the Earth.

Next, the teacher helped students interpret the data with reference to their previous models to help students develop a more complete scientific explanation. To do this, the teacher reminded students of a concept they learnt in Year 4 by measuring the shadow of a stick: that the angle at which the sun's rays strikes the earth changes from sunrise to sunset, and with the change the intensity of the sun's light (heat energy) will become stronger or weaker. Through guided discussion, the teacher showed students that when the heat lamp, representing the sun, is at a 75-degree angle to the tray of soil, the soil is hotter due to the higher intensity of heat reaching it. The teacher related this observation to the difference in the sun's altitude (the solar elevation angle relative to the horizon, for example, the elevation is 0 degrees at sunrise and sunset) in summer and winter, higher in summer and lower in winter. Students reviewed their hypothesized answers to the initial Engagement phase question and were able to revise their explanations (Chu et al., 2019; Chu et al., 2019).

Elaboration: From the students' revised answers, the teacher noted the shortcomings in the students' construction of the target science concept. The teacher planned another learning experience (e.g. a demonstration, an additional experiment, or a video clip) aimed at enabling students to make observations that could lead to their construction of a more scientifically accurate science concept. Students reviewed their revised answer, further refining it with the new understanding gained from the Elaboration activity. The teacher noted that the students seemed to have difficulty integrating the two phenomena that cause the seasons: the Earth's tilted axis, which affects the altitude of the sun, and the Earth's revolution around the sun.

The teacher demonstrated the effect of the Earth's tilted axis on the intensity of heat at two different locations (Korea and the south-eastern part of Australia) on a globe, using a lamp to represent the sun as the Earth moved around it (see ② in Fig. 12.2). Affixed to each of the two locations was a disc with a scale for measuring the length of the shadow of a pin one centimetre high planted in the middle of the disc (see ① in Fig. 12.2). The length of the shadow enabled students to observe the sun's altitude changing as the earth moved around the sun.

The teacher instructed the students to observe the sun's altitude at the two locations and drew their attention to the effect of the Earth's tilted axis on the angle at which the sun's rays reach the earth which determines the intensity of light received at each location. Next, to demonstrate the effect of the Earth's revolution around the sun, the teacher positioned the globe in two opposing locations with respect to the lamp (sun). Through questioning and guided discussion, students were led to see that the Earth's revolution and its tilted axis affect the number of hours of daylight and the altitude of the sun relative to the earth in each country, resulting in summer when there are more daylight hours and a greater intensity of light.

After the demonstration, students reviewed their group answer to the inquiry question a second time, integrating into their explanatory model the effect of the Earth's tilted axis and revolution on the sun's distance and altitude. They then checked whether their model was correct by performing tests using equipment similar to that

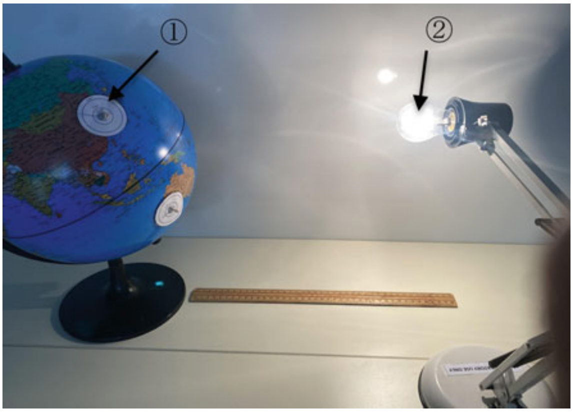


Fig. 12.2 Demonstrating the effect of the Earth's tilted axis on the sun's altitude and therefore the intensity of the heat from the sunlight

which the teacher had used. In doing so, the students moved gradually towards a closer approximation to the scientific concepts that account for seasonal change.

Communication and peer evaluation of revised explanations: Student groups next presented to each other and the teacher their final responses to the inquiry question. Students and the teacher asked questions to clarify their understanding. The teacher also pointed out limitations or alternative conceptions and corrected them. Students then selected the best presentation after appraising each presentation using rubrics provided by the teacher.

The rubrics related to the accuracy of the science concepts (e.g. Does the model include the role of the Earth's tilted axis?). Peer evaluation offered an additional opportunity to reflect on the students' current understanding of the science concepts (e.g. factors causing seasonal change) and to revise understandings with the aim of developing more accurate construction of those concepts.

The arts and culture element in the Project 1 STEAM lessons lies in the social interaction the students experienced in three video conferences over Skype with Australian students studying the same topic in Sydney. Despite some language difficulty, meeting with and talking to fellow students of a different culture heightened and sustained the Korean students' motivation in the science learning activities. They were thrilled to see the Australians dressed in summer clothes in December and to hear them speak about school and out-of-school activities. Excited to be engaging in the same science learning activities, they were driven to work enthusiastically so as to have learning artefacts (drawings, models) to show the Australian students via the project's online platform. At the conclusion of the project the Korean students described the intercultural sessions as "great" (Student, p. 201) and "helpful" (Student, p. 202).

Project 2: Promoting Students' Conceptual Understandings of Science, and Attitudes Towards and Perceptions of Learning Science through STEAM

The context for project 2 is a Year 8 class (12–13 year-olds) doing a unit on light in the 2016–2017 academic year. There were 30 students in the class. Here, we focus on the design of a quasi-3D hologram, with students using their mobile phones/iPads and a pyramid made of four trapezoid-shaped pieces of clear plastic placed over the phone (see Fig. 12.3).

The goal was to create an image (e.g. a butterfly or a cultural symbol) appearing to float above the phone or iPad screen in the middle of the pyramid. To achieve this effect, students needed to synthesize two concepts: light from the mobile phone travels through the pyramid and reflects into the eye, and the brain's interpretation of the pattern of reflected light as an image hovering above the phone. Whereas a traditional science lesson introducing these concepts is likely to deliver a teacher's explanation of the link between light reflection and seeing, the STEAM lesson engages

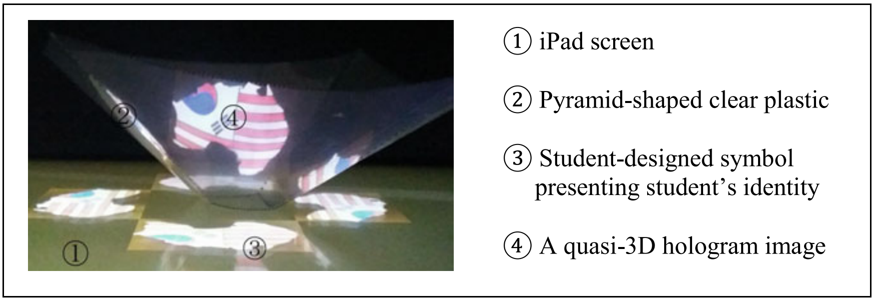


Fig. 12.3 Quasi-3D hologram using iPad and pyramid-shaped clear plastic

students in the experience of positioning the eye so that the created image can be clearly observed. The hologram creating activity took place in art classes with the science teacher present to provide guidance on the scientific aspects of how to make the image visible to the observer.

In this project, we collected students' learning artefacts, conducted a survey of 30 students, and interviewed four groups of three to four students before and after the project. The findings suggest that the STEAM approach appeared to facilitate students' movement from basic, and sometimes incorrect, understanding of science concepts, to more scientifically acceptable understanding. Interview responses revealed the development of students' favourable attitudes towards studying science and positive perceptions of science.

Songer and Linn (1991) posited that the development of scientific understanding is evidenced when science concepts are used to explain what might be viewed as unrelated events. In this case, the two seemingly unrelated events of seeing things, and light bouncing off the surface of objects was difficult to understand as over 70% of students failed to recognize that we see objects due to light being reflected off the objects with some of the light entering our eyes. After the STEAM lessons, students understood the concept.

The transcripts of the post-project interviews showed that students were appreciative of the teaching/learning methods of STEAM, such as arts integration, and the small-group collaboration that they reported helped them to 'think better'. Indicative comments, translated from Korean and made in the post-project interviews, included:

> 'It is amazing to learn science in this way, with knowledge from non-science subjects included.' (Student, p. 201)
> 'These science lessons taught me to think, to see other things besides science.' (Student, p. 205)
> 'We were not interested in the topic of light before but now I am, after observing its connection to light festivals.' (Student, p. 206)

Negative statements were markedly reduced in the post-project interviews, from five comments made pre-project to just one comment made post-project, with one student reporting that some members in her group had not participated fully.

The transcripts of the post-project interviews showed students' positive perceptions that when science is differently presented, it can be better understood:

> 'This program is very different from usual science programs. These subjects seem new to me. We realized that science is involved in many different aspects in our life and culture.' (Student, p. 201)
>
> 'We apply the same science concepts and theories to explain .... We could easily communicate our science explanations even though our languages are different.' (Student, p. 202)
>
> 'Science could be fun and not so difficult if we learn science related to cultural events or everyday life phenomena, like in this program.' (Student, p. 206)

The arts and cultural dimension integrated in the Project 2 lessons lay in the students' efforts to design the image for their hologram. For instance, the image in Fig. 12.3, consisting of an outline of the Australian continent holding elements of the Korean and United States flags, was created by Student p211 to express the multiple facets of her identity. She was Korean by birth but had lived in the US before her family moved to Australia. Expression of personal identity through art is one aspect of creativity in art recognized by art authorities such as the Museum of Modern Art in New York (https://www.moma.org/learn/moma_learning/themes/investigating-identity/). Other students in Project 3 designed or chose images expressing their thoughts and feelings about their world (e.g. traditional Korean costumes). It must be reiterated that the students' artistic expression of themselves in the making of the hologram involved them in learning the science concept of light and how we see.

Project 3: STEAM Learning and Creativity

Project 3 took place in 2020 in a Year 10 class in Korea, with 27 students aged 14–15 years. It focused on whether STEAM learning had any effect on scientific creativity. Scientific creativity is defined as a combination of divergent thinking, which is the ability to explore multiple possible solutions to generate creative ideas from an initial problem or reference point (de Vries & Lubart, 2017). Convergent thinking is the application of logical reasoning to deduce a solution from known information (de Vries & Lubart, 2017). In convergent thinking, the solution to problems must be preceded by the process of defining the problem space (de Vries & Lubart, 2017; Kocabas, 1993), which is a practice integral to the culture of science. To be creative in science, students must experience viewing things from different perspectives and then be able to generate new possibilities or alternatives (Franken, 1994).

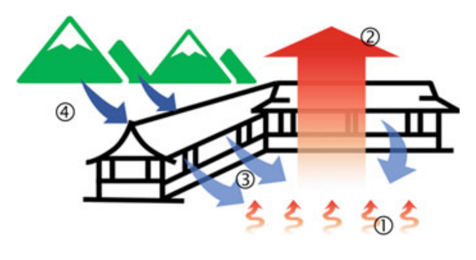
In Project 3, scientific creativity was encouraged by engaging students in solving a problem that required them to apply their knowledge of science in the context of exploring the traditional architecture of houses in the two cultures of Korea and Australia. The Korean students' problem was to design a zero-energy school building for students in Sydney. The Korean students met a class of Australian students over Skype to exchange knowledge about the design of buildings in their respective countries. The conversation was directed at discovering what architectural features in each community's house were designed to accommodate the climate of the region. The Korean students learnt that many traditional Australian houses have high ceilings so that hot air will rise and rooms will be cooler in contexts where air conditioning is not available. In designing a zero-energy school, the science that the students had to consider was related to conduction of building materials and insulation/heat transfer via convection, radiation, and conduction.

The learning activities gave students scope to practise divergent and convergent thinking. One activity requiring divergent thinking had students examining how the structure of a traditional Korean house (*hanok*) allowed for energy efficiency. Using knowledge from the teacher's explanation of energy efficiency in house design, the students explored different characteristics of hanoks to work out how each feature facilitated heat conservation in winter and/or free flow of cooler air into the house in summer. Students discovered that heat channelling tunnels (*gorae*) were constructed so that smoke was prevented from escaping rapidly through the chimney, keeping the house warm long after the fire had died out.

Students were engaged in deductive logical reasoning (convergent thinking) by investigating the effect of roof overhangs on the amount of sunlight entering a house. Students cut windows in a box representing a house. The teacher gave the students the sun's altitude at noon in winter (39.5 degrees) and in summer (76.5 degrees). The students used a lamp, representing the sun, to simulate these altitudes and used a light meter app on a mobile phone to measure the amount of light entering the house through the windows. Then the students attached a cardboard overhang to the roof of the house and measured the amount of light entering the house again. Studying the data they collected, and using logical reasoning and deductive thinking, the students learnt that overhangs block some sunlight from streaming into a house in summer while still allowing low -angle winter sun to enter.

Students deployed divergent thinking when they explored strategies for reducing energy transfer between the interior of the building and its exterior, and maximizing the use of natural methods for cooling and heating. The different strategies students discussed included the use of double-glazed glass for windows, the choice of insulating material with reference to heat transfer, the direction of the windows with reference to whether the building is in the northern or southern hemisphere, and whether window location would maximize the entry of sunlight in winter and maximize airflow in summer. They also considered the L-shaped layout of the *hanok*. Students' discussion of these strategies was targeted to find the best solution: the design of an energy-efficient school building for students in a country situated in a different hemisphere from their own. Their discussion exemplified divergent thinking leading to creativity (Harvey, 2014).

The students' school building designs also showed thinking processes characteristic of scientific creativity. One group of students reasoned that an L-shaped building would allow windows to be placed on opposite walls, thereby maximizing air circulation in summer, reducing reliance on non-renewable energy for air conditioning (see



① The temperature of the soil in the yard rises due to solar heat.
② The air in the yard is heated and forms an upward airflow.
③ Cool wind flows from the backyard of the *hanok* due to differences in air pressure.
④ The backyard of the *hanok* is set facing a mountain or covered with trees and plants to provide cool air.

Fig. 12.4 L-shaped *hanok* and air movement in/out

Fig. 12.4). Thus, through evaluations and logical reasoning in convergent thinking (Brophy, 2001), the students were able to synthesize knowledge and ideas from different sources to generate a creative solution to an architectural problem.

Scientific creativity includes the ability to recognize the existence of a problem (Sternberg et al., 2020). In the case of the L-shaped design, the students realized that windows in summer would let sunlight in. The solar heat-reduction solution they arrived at was to plant trees near the west-facing windows, which, they reasoned would provide shade and reduce solar radiation onto the windows.

The thinking processes used in these STEAM lessons have the potential to promote students' scientific creativity. Three features of the STEAM method appear to play a role in encouraging scientific creativity. The first is presenting students with a situation and problem that interests them and which they perceive to be relevant to their lives. The second feature is the integration of arts- and culture-related elements in science teaching/learning activities. By bringing these areas together in the school curriculum, the STEAM approach opens students' minds to the generation of new possibilities (Franken, 1994). The third feature is group collaboration when discussing problems and working out solutions. Collaboration involves conversations in which students must articulate ideas to contribute to the group's endeavours. Communication and cooperation-oriented climates are significant factors in scientific inquiry leading to creativity (Hong & Song, 2020).

Discussion

Impacts of STEAM Approaches on Student Learning

STEAM teaching/learning has the potential to enhance students' attitudes towards science learning by helping them to experience the application of science in real-life contexts. Millar (1991) suggested that the abstract nature of science was a reason for students' perceptions of science as being difficult. STEAM learning activities engage students in constructing and applying their understanding of abstract concepts in real-life situations. For example, Project 3 challenged students to learn how to keep the interior of a building warm during winter and cool during summer by using natural systems rather than fossil fuel. When students focus on concrete issues (e.g. would eaves keep the inside of the building cooler in summer? How?), the science concepts involved do not seem as difficult as memorizing the definition of heat transfer and listening to a lecture on the different types of heat transfer. Having students consider the arts dimension of Korean traditional house design added to their appreciation of how an ancient method of achieving energy efficiency can be explained with modern-day science concepts. By demonstrating science concepts in real-life contexts and incorporating the arts into science learning, STEAM makes science interesting and relevant, countering the view that science is difficult.

In the 'learn to think' study (Hu et al., 2013), learning activities also incorporate daily life experiences. Hu et al. believe that requiring students to apply their learning to daily life accelerates the development of scientific creativity. In the STEAM approach, events or products from the students' sociocultural life provide not only the context for the application of science concepts but also form the context for identifying problems, hypothesizing initial explanations, and synthesizing disparate pieces of science knowledge in problem solving. As Project 3 demonstrates, the incorporation of a sociocultural product (e.g. a traditional Korean house) can have the effect of developing scientific creativity.

Another factor that appears to play a role in promoting scientific creativity is the classroom environment. Hu and colleagues (2013) argue that "a free, open, democratic…environment is a key factor for the development of students' scientific creativity" (p. 7). A collaborative, high-trust learning environment was created in their study by allowing students to make mistakes and take risks without fear of censure and by encouraging them to explore learning strategies by themselves. Similarly, STEAM approaches generally provide students with the space to verbalize their thoughts, prior knowledge, and hypothesized explanations or solutions without fear of correction from a teacher. The STEAM method also allows students the freedom to choose the form their explanation or solution will take (e.g. the colours, image, and symbols in a quasi-hologram).

Challenges of STEAM Implementation in Korean Schools

As with all innovations in pedagogy, there are challenges to address in the implementation of STEAM. The first is the gulf between the objectives and methods of STEAM and the traditional forms of assessing science learning in schools. Traditional pen-and-paper tests assess students' recall of facts, theories, or problem-solving solutions, and there is generally only one correct answer. Because the STEAM approach engages students in learning science in the context of real-life problems, assessment must evaluate students' application of science to sociocultural issues. There may not be a single correct answer. Rather, students are required to demonstrate understanding of the target science concepts with reference to the context in which those concepts are applied. In Project 3, a good answer would demonstrate students' understanding of the concepts of heat transfer and solar altitude, with reference to aspects of the design of a zero-energy school building. Until science examinations, especially national examinations, are aligned with the philosophy of the STEAM approach, teachers may hesitate to implement STEAM for fear of disadvantaging their students in classes preparing for a public examination.

Secondly, arts-science integration is challenging, as it requires science and non-science subject teachers to collaborate to plan what and how arts/culture-related content will be employed in science lessons, or vice versa. For example, in Project 2, the hologram creation activity occurred in art classes but required the science teacher to also be present to engage students in applying the principles of the science of light and vision when problems arose (e.g. the hologram image was not visible). The solution may be co-teaching, with science and non-science teachers planning and delivering integrated lessons in the same classroom. However, most Korean schools do not have a culture of team teaching, and the traditional structure of school timetables is an obstacle.

A third challenge for teachers is managing classroom discourse to provide as many opportunities as possible for students to think for themselves and to have some freedom in exploring alternative solutions for problems. The familiar traditional scenario of teacher-centred classrooms with teachers seeking correct answers must be replaced with teacher-student and student-to-student dialogue that encourages students to explore and question ideas, and to express their thoughts, however nascent. To maintain an encouraging learning environment in STEAM lessons, teachers' responses to students' contributions need to be affirming rather than deficit-focused. Teachers who are used to the teacher-centred classroom models may need professional development and support to shift away from prescriptive talk to a more affirming tone that opens up further dialogue and thinking.

In summary, teachers need help to guide classroom talk towards dialogic discourse between students and between students and the teacher, instead of the conventional IRE (initiate, respond, and evaluate) model typical of the traditional science classroom. It should also be noted that, in the quasi-3D hologram creation activity, there were times when students were so absorbed in making their hologram image visible to their classmates that there was no discussion of the science involved. The image was supposed to appear to be floating over the surface of their phone inside a transparent plastic pyramid with its sides at a 45-degree angle to the phone. The teacher had to constantly direct the discussion to the science concept of the angle of light reflection in relation to the eyes of the viewer. Dialogic discourse creates an environment in which teachers can exploit opportunities for students to probe each other's ideas, evaluate arguments relating to their ideas and evidence (Duschl & Osborne, 2002), and articulate dissenting views (Kelly et al., 2001). The importance of dialogic discourse in advancing knowledge construction in science has also been acknowledged by Ritchie (2001). Developing the skill of engendering dialogic discourse with and among students is a challenge STEAM teachers must address. Not surprisingly, there are ongoing challenges for Korean teachers and students to successfully bridge the gap between traditional science examinations that value the single correct answer and the focus in STEAM on demonstrating understanding of science concepts through their application in real-life sociocultural contexts. In response to this challenge, initiatives have begun in Korea to allow schools to opt for project-based assessment more aligned with the goals and methods of STEAM.

Conclusions

This chapter has reported the experiences of an arts-integrated approach (STEAM) in Korean schools. The trial implementation of three STEAM programs revealed positive impacts on students' conceptual understanding of the science concepts taught, attitudes towards and perceptions of science and the study of science, and indications of improved scientific creativity. The projects reported in this chapter showcase the potential advantages of moving away from the traditional teacher-fronted science classroom towards a collaborative student-centred teaching/learning approach. STEAM offers a path to promoting STEM learning in Asian science classrooms, which may translate to creative innovations in Asian industry and technology.

In 2022, the Korean education system began moving towards a theme-centred convergence model (MOE, 2021) so that school subjects like science and home economics can be thematically integrated so that students can learn about a topic like the science of cooking. The aim of the integration of STEM and non-STEM subjects in the Korean convergence model is to develop school graduates who are creative and able to respond flexibly to rapid social changes (MOE, 2021; Song et al., 2019) and to environmental and other problems of the twenty-first century. The outcomes of the STEAM projects presented here provide reason to believe that the convergence model may support positive attitudes towards learning, including science learning, and would encourage creativity in the next generation of citizens.

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