STEM Education from Asia

Trends and Perspectives

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ISBN: 978-0-367-56915-0 (hbk)

ISBN: 978-0-367-56916-7 (pbk)

ISBN: 978-1-003-09988-8 (ebk)

First published 2022

Chapter 11

**STEM/STEAM education research
in South Korea**

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DOI: 10.4324/9781003099888-11

**The funder for this chapter is Korea
Foundation for the Advancement of Science
& Creativity (KOFAC)**

Routledge
Taylor & Francis Group
LONDON AND NEW YORK

**The
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Foundation**

11 STEM/STEAM education research in South Korea

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Introduction: Science, Mathematics, Informatics, and STEAM education in Korea

With the fourth industrial revolution bringing about fundamental changes in the industrial structure and reshaping the future of jobs, current education systems aim to cultivate future talent with complex problem solving, critical thinking, and creativity (World Economic Forum [WEF], 2016). In particular, Science, Technology, Engineering, and Mathematics (STEM) education has gained enormous global traction in recent years, with new jobs expected to be created in the STEM field due to the rapid development of science and technology such as artificial intelligence (AI), big data, and Internet of Things (IoT).

The Korean government enacted the Science, Mathematics, and Informatics Education Promotion Act (hereinafter the “Act”) in 2018 intending to establish a support system for the education of Science, Mathematics, and Informatics (SMI), which are core subjects associated with the Fourth Industrial Revolution (4IR). The Act aims at nurturing future talents with convergent skills to lead the era of 4IR by promoting activities such as research on the evaluation of the contents and methods of SMI education, development of textbooks and educational materials, and the operation of teacher professional development programs. In line with the Act, the Korean Ministry of Education (MOE) and the Korea Foundation for the Advancement of Science and Creativity (KOFAC) developed a “Master plan for Science, Mathematics, Informatics, and Convergence Education” to be applied for five years, which started in 2020. This plan, which pursues the vision of developing future global leaders with competencies and qualities required by the intelligent information society, contains mid-to-long-term policy directions and concrete tasks. Driven by this master plan, educational institutions will step up their efforts to promote Korean STEM education.

One of the most salient Korean STEM education features is its emphasis on Science, Technology, Engineering, Arts, and Mathematics (STEAM) education to highlight STEM’s integration-oriented approach. STEAM education aims to foster students’ ability to solve real-world problems. Most real-world problems cannot be solved with the knowledge of a single subject but can be solved by connecting and utilising knowledge gathered from various academic

fields. Thus, STEAM education aims at the natural integration needed in solving real-world problems and requires the integration of two or more subjects among S, T, E, A, and M (Korea Foundation for the Advancement of Science and Creativity [KOFAC], 2016). In this context, convergence is being used as a keyword to highlight the characteristics of Korean STEAM education with an integration-oriented approach. The Korean government has continually driven STEAM education since 2011; Korean STEAM education is positively evaluated because it has contributed to enhancing students' self-directed learning abilities, science preferences, interests in science and mathematics, and self-efficacy, naturally achieving a paradigm shift from traditional lecture-centred to student-centred classes (Ministry of Education [MOE], 2018).

Korea is now in the process of a national curriculum revision scheduled for 2022. At present, subjects are organised under the 2015 national curriculum, which was established to foster creative-integrated talents with humanistic imagination, scientific creativity, and upright characters who can create new knowledge and values by integrating various knowledge (Kim et al., 2015). Two main directions of change set by the 2022 revision of the national curriculum are (1) The implementation of the high school credit system aimed at allowing students more academic freedom and supporting aptitude-based personalised education, including the reorganisation of science, mathematics, and informatics curricula; and (2) Curriculum operation taking account of the spread of non-face-to-face education due to COVID-19. The demand for personalised, customised, problem-based, and collaborative forms of learning, which have been set as the direction of educational transformation for the future generations, has been accelerated by COVID-19, and there are heated discussions about the curricular contents and learning processes to realise this demand.

In the sections that follow, trends of the STEM/STEAM education in Korea will be examined, revolving around the policy and research promoted by the KOFAC as the government agency responsible for the STEM/STEAM education in Korea.

Research in science education

The 2015 national curriculum currently in place is a competency-based curriculum, in which overarching and subject-specific competencies are identified. The national science curriculum was developed to cultivate five competencies: Scientific thinking ability, scientific inquiry ability, scientific problem-solving ability, scientific communication ability, scientific participation, and lifelong learning ability (MOE, 2015; see Table 11.1 for the science subjects). The 2015 science curriculum differentiates itself from the previous ones in the following aspects: (1) Prioritization of affective domain as a learning objective; (2) Consideration of lifelong learning of science for competencies; and (3) Addition of the subject "Integrated Science" centring on core concepts of natural phenomena (Song, 2020).

Table 11.1 Subjects of the science curriculum of the 2015 national curriculum in Korea

School-level	Common curriculum	Elective-centred curriculum		
		Common courses	General electives course	Career-related electives course
Elementary School	Science			
Middle School	Science			
High School		<ul style="list-style-type: none"> • Integrated Science • Science Inquiry Lab 	<ul style="list-style-type: none"> • Physics I • Chemistry I • Life Science I • Earth Science I 	<ul style="list-style-type: none"> • Physics II • Chemistry II • Life Science II • Earth Science II • Science History • Life and Science • Convergence Science

With the aim of setting guidelines for future-oriented science education to develop creative-integrated talents, KOFAC released the Korean Science Education Standards for the Next Generation (KSES-NG) after five years of preparation (2014–2019) and developed the model Tree of Scientific Literacy (ToSL) (Song et al., 2019). The ToSL model has three roots representing scientific literacy: Competence, knowledge, and participation and action. Each dimension consists of domains and subdomains (Figure 11.1). The ToSL model defines scientific literacy, the goal of science education, as “the attitudes and abilities as democratic citizens to participate in and act for solving personal as well as social problems using science-related competencies and knowledge”.

Currently, MOE-led research for curriculum revision is underway under the heading of “research on future-oriented science curriculum organisation to cope with post-COVID challenges” to redesign science subjects taking into account the scientific competencies and deriving teaching and learning strategies and assessment methods tailored to the post-COVID world (Jeong et al., 2021). This research project kicks off of the full-fledged science curriculum development research towards the publication of the new national curriculum in 2022, to be applied from 2025 onwards.

In Korea, all science education policies are established based on the Five-Year Master Plan for Science Education. The current master plan (2020–2024) proposes six action plans and 16 priority tasks to attain the three objectives of science education compacting the foundation, enjoying the cutting edge, and leading the future (MOE, 2020). One of the core objectives of this master plan is expanding the “intelligent science lab” to all primary and secondary schools by 2024 as an online and offline space in which scientific inquiry can be made using cutting-edge scientific technologies, such as AI, Augmented Reality (AR)/Virtual Reality (VR), and IoT. Given that the abilities to predict the future based on data and solve problems in the real world are the core

Figure 11.1 ToSL model of “scientific literacy” in KSES-NG (Song et al., 2019).

competitiveness in the intelligent information society, the intelligent science lab supports scientific inquiry activities using real data through an online scientific inquiry platform named “Intelligent Science Lab-ON”. The online platform has the following features: (1) Scientific inquiry data platform; (2) IoT sensor and device information sharing system for data measurement and collection; (3) Data-based inquiry activity sharing network; (4) Teaching and learning platform and scientific inquiry software platform interface (Lim et al., 2020).

In order to empower science teachers in their research and practice, KOFAC has been supporting the project “IDEA (Interest, Development, Engagement, and Association) Science Teacher Research Groups” since 2016. The IDEA Science Teacher Research Groups contribute to science teachers’ competence self-empowerment through research-based development of teaching materials on various topics and using them in classrooms and the spread of exemplary classroom activities across the country by reinforcing teachers’ networks. In 2020, 46 IDEA Science Teacher Research Groups were supported, and a range of science class models have been developed, such as advanced technology utilisation (e.g., AI, big data, and IoT), empirical problem-solving, real-life problem-solving (e.g., SSI: Socio-Scientific Issue), and student-centred collaboration (KOFAC, 2021).

To further disseminate innovation models of science education, many projects were conducted at the school level. First, the “creative-integrated-science-lab

schools” operated in schools across the country to innovate school science labs to where students can conduct active and inquiry-based learning, encompassing not only scientific inquiry activities (e.g., experiments, investigations, and debates), but also project activities (e.g., problem-based learning and creative problem-solving). The creative-integrated science lab has sections of physical spaces for presentation, learning, experimentation, discussion, preparation, exhibition, and creation to reinforce students’ collaboration and scientific inquiry. From 2021 onwards, the creative-integrated science lab will be operated in tandem with the intelligent science lab. According to the survey results analysing 120 schools that operated as creative-integrated science lab schools from 2017 to 2019, the creative-integrated science labs had a positive effect in increasing interest in scientific inquiry and improving science inquiry ability, presentation ability, and collaboration skills (Son et al., 2020).

The “student-participatory-science-class leading school” is also being operated across the country to encourage active student participation in science classes. There are six class types proposed for this model: Discussion/debate, investigation/presentation, production/expression, project, experiment/observation, and problem-solving. The process of student-initiated learning is also included in performance assessment so that various facets of each student’s changes and growth are documented, and appropriate feedback is provided (Kim, Yong-jin et al., 2019). In 2020, the COVID-19 pandemic forced schools to switch to online classes for the student participation model. Science teachers, who participated in the “Forum on student participation online science classes in the post-COVID era” organised by KOFAC suggested that student-participatory science classes might as well be continued through the revitalisation of intramural and extramural learning communities, expansion of digital literacy education for teachers and students, sharing-centred teacher training, and proactive use of EdTech (KOFAC, 2020a).

The “science core schools” operating since 2009 are high schools specialising in science and mathematics. The curriculum operation of science core schools is characterised by the emphasis on curricula that form the basis for furthering creativity by strengthening students’ proficiency in mathematics, physics, chemistry, life science, and earth science. Currently, there are 124 science core schools across the country in 2021. According to the results of a survey conducted in 2020, students enrolled in science core school were satisfied with programs such as science and mathematics experiential activities, club activities, and research & education (R&E), and graduates acknowledged that the curricula and educational activities in science core schools helped them learn their majors at the post-secondary level (Choi et al., 2021).

For cutting-edge technologies to be reflected in primary and secondary science education, the space of science education needs to go beyond the school context to society. To this end, KOFAC-led “STAR (school teacher and research) Bridge Centre” model development research is underway intending to transform science education by connecting schools to universities, businesses, and local communities and establishing a collaboration network between teachers and

science and technology professionals. Specifically, STAR Bridge Centres aim to develop future-oriented teaching materials, run teacher training programs, and develop an AI-based learning content management system, under joint collaborative research with the institute of science and technology, science museums and centres, and EdTech companies (Im et al., 2020).

As examined above, a variety of national-level research and practice activities are being carried out in science education, and the Korean Science Education Index (KSEI) has recently been developed to comprehensively examine and assess the quality of science education (Hong et al., 2021c). Based on a Delphi survey conducted with 25 experts in science education, science education policy, and science and technology, the categories of the KSEI were grouped into input, process, and outcome. The “input” category consists of the factors “student characteristics”, “teacher characteristics”, and “education infrastructure”; the “process” category comprises “science curriculum operation”, “science contents development and program operation”, and “teacher professional development program operation”; and the “outcomes” category includes “cognitive achievements”, “affective achievements”, “scientific competencies”, and “participation and action.” The KSEI will be used for the annual collection of data for a comprehensive assessment of the current state of science education, and the results of data analysis will be used for setting up a national science education policy.

Research in Mathematics education

The 2015 Korean Mathematics National Curriculum was developed to help students understand and acquire knowledge and skills of mathematics, as well as cultivate six mathematical competencies: Problem-solving, reasoning, creativity and integration, communication, information processing, and attitude and practice (MOE, 2015). The revised curriculum differentiates itself from the previous ones in the following aspects: (1) Conceptualization of mathematical competencies, (2) Reduction of students’ learning burden, (3) Emphasis on the affective aspects, (4) Utilisation of technology, and (5) Reorganisation of real-life-centred statistics (Lee, 2020).

Among the mathematics curriculum subjects presented in Table 11.2, Basic Mathematics and Mathematics in Artificial Intelligence (AI) for high school were added in 2020 as newly developed subjects. First, Basic Mathematics contains basic-level content for students who have difficulty learning high school mathematics (Kwon et al., 2020). It was designed to substitute high school mathematics subjects in consideration of the school type and the student’s level of achievement and can be understood as an implementation of a curriculum tailored to students. Mathematics in Artificial Intelligence is a future-oriented new subject in which students can learn and experience how mathematical concepts are applied to AI. This subject consists of four domains: AI and mathematics, data presentation, classification and prediction, and optimisation (Lee et al., 2020).

Table 11.2 Subjects of the mathematics curriculum of the 2015 national curriculum in Korea

<i>School-level</i>	<i>Common curriculum</i>	<i>Elective-centred curriculum</i>		
		<i>Common courses</i>	<i>General electives course</i>	<i>Career-related electives course</i>
Elementary School	Mathematics			
Middle School	Mathematics			
High School		<ul style="list-style-type: none"> • Mathematics 	<ul style="list-style-type: none"> • Mathematics I • Mathematics II • Calculus • Probability and Statistics 	<ul style="list-style-type: none"> • Geometry • Practical Mathematics • Mathematics for Economics • Mathematics Project • Basic Mathematics • Mathematics in Artificial Intelligence (AI)

Currently, MOE-led research for curriculum revision is underway under the heading of “Research on future-oriented mathematics curriculum organisation to cope with post-COVID challenges” to derive the vision and content of mathematics education in consideration of the changes in society such as changes in the demographic structure, the development of science and technology, and the advent of a hyper-connected society (Lee et al., 2021). This research will serve as the basis for the national mathematics curriculum to be released in 2022.

In Korea, all mathematics education policies are established based on the Five-Year Master Plan for Mathematics Education. The current master plan (2020–2024) proposes five action plans and 14 priority tasks to attain the three objectives of “mathematics classroom without students giving up on math”, “fostering real-life problem-solving skills”, and “developing core math talents” (MOE, 2020). This plan includes strategies for the “AI Mathematics Learning System” capable of AI-based diagnosis of individual achievement levels and learning deficiency elements and providing learning content to make up for the deficiencies. It aims to contribute to the realisation of education for all students’ mathematical literacy and the improvement of equity in education by providing the necessary AI system free of charge to all schools. To this end, a KOFAC-led research project is underway to develop a model that supports customised education tailored to each student’s achievement level by collecting and analysing big data reflecting each student’s cognitive and affective characteristics (Park et al., 2021).

MOE and KOFAC have been supporting primary and secondary mathematics education using technology. First, AlgeoMath (www.algeomath.kr) as –

the name suggests – covering all mathematics from algebra to geometry, is a software program that allows the user to draw graphs and charts according to the input equations. Features such as geometric, algebraic, block coding, data utilisation, and 3D functions are available on the user interface of the online platform, and teaching and learning materials and teacher training programs are continuously being developed (Hong et al., 2021a). The Toctoc Math Expedition (www.toctocmath.kr) [“toctoc” is a homonym meaning smart or knock-knock], an AI-based elementary mathematics class support system using a gamification approach, was developed to minimise math learning deficiencies in lower graders. The baseline number sense test and basic arithmetic test are used for diagnosing students’ level of mathematics learning, and customised learning contents recommended by AI based on the scores are provided to students. It has been used nationwide since 2020 and has been particularly efficient in improving students’ learning in the underachiever group, as per the developments’ intentions (Hong et al., 2021b).

To support engagement in math for all, out-of-school facilities are necessary. In Korea, base-type math cultural centres (differently named in each city, e.g., Math Park in Busan and Math Is Our Mate in Daejeon), are being operated in Seoul and Gyeongnam. In the basic research for the establishment of math cultural centres, the following roles they need to play were proposed: (1) Inform the essence of mathematics; (2) Show cutting-edge mathematics; (3) Exhibit and experience mathematics; (4) Communicate mathematics; (5) Motivate students to learn mathematics; (6) Recognise the importance and necessity of mathematics; (7) Experience the joy of mathematics; and (8) Provide information about mathematics (Do et al., 2015). Currently, math cultural centres are increasingly playing an important role in math communication and education.

Research in Informatics education

One of the most salient features of the 2015 national curriculum is the emphasis on software education, which reflects the need to foster computational thinking: A core competence indispensable to future generations. This demand was reflected in the 2015 national curriculum by making informatics a compulsory subject at the secondary level (see Table 11.3 for main changes in the 2015 informatics curriculum). Computational thinking refers to mental skills for understanding and solving problems in everyday life and various academic fields based on computer science’s basic concepts and principles (MOE, 2015). Although researchers and educators have agreed on the significance of computational thinking, many teachers faced the challenge of the lack of assessment standards and tasks. KOFAC developed an assessment model of computational thinking using the evidence-centred design (ECD) approach and derived four key assessment areas (i.e., decomposition, abstraction, algorithm, and automation) and three supporting assessment areas (i.e., analysis, communication, and collaboration) (Park et al., 2017).

Table 11.3 Changes in the 2015 informatics curriculum

School-level (Application year)	Main changes		Contents
	Before	After	
Elementary school (2019–Present)	ICT unit in practical arts (12 hours)	Software education in practical arts (over 17 hours)	<ul style="list-style-type: none"> • Problem-solving process, algorithm, programming concepts
Middle school (2018–Present)	Informatics * elective subject	Informatics (over 34 hours) * compulsory subject	<ul style="list-style-type: none"> • Information ethics • Problem-solving based on CT • Developing algorithms and programming (Intermediate level focusing on the block-based coding)
High school (2018–Present)	Informatics * advanced elective subject	Informatics * general elective subject	<ul style="list-style-type: none"> • Designing algorithms and programs with various fields (Advanced level focusing on the text-based coding)

KOFAC and the Korea Information Science Education Foundation (KiSEF) jointly developed a next-generation software education standard model by itemising the contents at the elementary, middle school, and high school levels considering the sequential flow, continuity, and connectivity (Kim, KapSu et al., 2019). As shown in Figure 11.2, information and computer literacy were

Figure 11.2 Framework of the next generation informatics education standard model (Kim, KapSu et al., 2019).

presented as big ideas, and computational thinking, information culture literacy, digital collaborative ability, and convergent problem-solving ability were proposed as core competencies. The knowledge dimension was classified into five domains of information culture, data and information, algorithms and programming, a computing system, and AI and convergence, whereby “AI and convergence” were newly added to the 2015 national curriculum.

With AI gaining traction as a new core issue, KOFAC conducted a basic study on primary and secondary level AI education. In the study, it defined AI literacy, AI-driven problem-solving ability, and AI-driven ethical thinking as core competencies that students should be equipped with, and proposed “Understanding of AI”, “AI and data”, “AI algorithms”, “Application of AI”, and “AI and social impact” as five learning areas (Yoo et al., 2020). An extension of these core competencies and learning areas, Artificial Intelligence (AI) Basics was added in 2020 as a newly developed subject for a national curriculum for high school education (Kim, Jaehyun et al., 2020; see Table 11.4 for the details).

In 2020, the MOE set up the First Master Plan for Informatics Education and proposed three objectives (i.e., systemisation of curriculum, the establishment of future-oriented educational infrastructure, and development of AI talents), seven action plans and 17 priority tasks (MOE, 2020). This plan includes an AI education platform development project for all applicable to pre-collegiate students, university students, and the general public who want to learn the principles of AI, machine learning, and data science. The AI education platform will gradually enter the full-fledged implementation stage starting from 2021, beginning with 2,000 AI/Software leading schools across the country.

With increasing emphasis on informatics education at primary and secondary education levels, there has been a growing interest in improving teachers’ competencies. KOFAC developed a teacher training curriculum optimised for the school levels (elementary, middle, and high schools) and achievement levels (basic, general, and advanced) and is operating training sessions in both offline and online settings (KOFAC, 2020b). Furthermore, KOFAC is currently proceeding with the SWEET (SW Education for all Elementary Teachers) project to bring elementary teacher education colleges into offering software-related compulsory courses to provide pre-service teachers with adequate professional competencies. A significant positive correlation was observed in the questionnaire survey between the respondents’ self-efficacy level and the number of software-related courses they completed (Kim Ja Mee et al., 2020).

Research in STEAM education

STEAM education in Korea aims to enhance student’s interest and understanding in science and technology (S&T) and foster integrative thinking and problem-solving. It pursues three core competencies: (1) “Knowledge and information processing”: The ability to process and utilise knowledge and information in various areas to reasonably resolve problems; (2) “Creative thinking”: The ability to create new things by using the knowledge, skills, and experience

Table 11.4 Contents of artificial intelligence basics for high school (Kim, Jaehyun et al., 2020)

<i>Subject area</i>	<i>Concept</i>	<i>Generalized knowledge</i>	<i>Content elements</i>
Understanding AI	AI and society	AI is a core technology that constitutes the Fourth Industrial Revolution and is leading social and occupational changes.	<ul style="list-style-type: none"> • Concept and characteristics of AI • The evolution of AI technology and social changes
	AI and agents	AI solves problems by perceiving, learning, reasoning about, and acting on its environment in the form of an intelligent agent.	<ul style="list-style-type: none"> • The concept and role of intelligent agents
Principles and applications of AI	Perception	Intelligent agents interact with the world through visual, auditory, and other means of perception.	<ul style="list-style-type: none"> • Sensors and perception • Computer vision • Voice recognition and language comprehension
	Search and reasoning	Search explores diverse paths to problem-solving knowledge of the world is represented in a structured way and used to find solutions by reasoning.	<ul style="list-style-type: none"> • Problem-solving and search • Knowledge representation and reasoning
Data and machine learning	Learning	Learning in AI is the automatic creation of a model from data, which handles classification, clustering, prediction, and other tasks.	<ul style="list-style-type: none"> • Machine learning concepts and applications • Deep learning concepts and applications
	Data	Data is used to implement a machine learning model. It can be classified into structured and unstructured data.	<ul style="list-style-type: none"> • Data attributes • Structured vs. unstructured data
	Machine learning model	A machine learning model is implemented by defining intelligent problems, preparing data necessary for problem-solving, training the model, and testing.	<ul style="list-style-type: none"> • Classification model • Machine learning model implementation
Social impact of AI	The impact of AI	AI can have positive and negative impacts on individual lives and society at large.	<ul style="list-style-type: none"> • Solving social problems • Data bias
	AI ethics	AI ethics is a set of values and a mode of behaviour required of society members to ensure proper utilisation of AI.	<ul style="list-style-type: none"> • Ethical dilemmas • Social responsibility and fairness

in various areas of expertise in an integrated manner based on basic knowledge; and (3) “Communication”: The ability to effectively express one’s thoughts and feelings in various situations and attentively listen to others’ opinions and respect them (MOE, 2018). STEAM education has been implemented since 2011 as part of government-led policy projects to develop S&T talents. MOE has supported primary and secondary schools by implementing the following four action plans to promote STEAM education: (1) Integration of STEAM education into educational settings by specifying the STEAM-related contents in the objectives of the curriculum; (2) Promotion of STEAM education by supporting the STEAM leading schools and teacher research groups; (3) Development of STEAM programs by supporting collaborative work among universities, enterprises, research institutions, and other professionals and wide distribution of the programs to schools; and (4) Exploration of improvement and expansion strategies for STEAM education by supporting policy research on STEAM education.

In the meantime, MOE released the Master Plan for Science, Mathematics, and Informatics Education along with the Five-Year Convergence Master Plan (2020–2024). The Convergence Master Plan reflects the intention to strengthen interdisciplinary convergence education, centring on science, mathematics, and informatics, to develop creative-integrated talents with core competencies required for coping with the future society based on the achievements and efforts of STEAM education thus far. In setting up this master plan, a KOFAC-led study was conducted, and the direction and core competencies of convergence education derived in the study are presented in Figure 11.3 (Park et al., 2019).

The 2015 national curriculum emphasised fostering creative-integrated talents equipped with core competencies, such as the 4C (i.e., Critical thinking,

Figure 11.3 Direction and core competencies of convergence education 2030 (Park et al., 2019).

Communication, Collaboration, and Creativity), cultivated through STEAM education that pursues interdisciplinary convergence and connection between academia and everyday life. STEAM education was reflected in the national science curriculum, and STEAM-type activities were included in the science textbooks (MOE, 2015). For STEAM education to be effectively implemented in school, adequate assessment of learning outcomes is indispensable. In this respect, the “STEAM Learning Assessment Model” was proposed considering the objectives of STEAM education, which the authors defined as enhancing students’ interest and understanding in the S&T fields, fostering S&T-based convergence thinking, and real-world problem-solving ability (Ryu et al., 2019). The proposed model designed as a competence-centred modular assessment model links STEAM classroom learning and assessment and is capable of both process-centred and product-centred assessments (Figure 11.4).

For the direction of the convergence education 2030 (Figure 11.3) to be put in place, a spatial model is necessary. Thus, a study on future-oriented space for convergence education was conducted, which proposed four modular spaces: (1) Personalisation space for information processing; (2) Understanding space for self-directed activities and presentation; (3) Collaboration space for group activities and project implementation; and (4) Sharing space for sharing experiences and connecting to the other spaces (Hong et al., 2019). This study emphasised the design of convergence education space tailored to participants – specifically, play-driven convergence education for elementary school students, process-oriented convergence education for middle school students, convergence

Figure 11.4 STEAM learning assessment model (Ryu et al., 2019).

education based on the basic knowledge of various fields for high school students, convergence education leading to the creation of new values based on the majors and area expertise for university students and postgraduate/doctoral students, and convergence education based on social issues and personal interests for the general citizens.

Given that a variety of STEAM education materials have been developed under the initiatives of MOE and KOFAC, a study performed a comprehensive analysis of these materials in conjunction with the subject areas of the 2015 national curriculum and compiled a content map (Kim et al., 2017). According to the study findings, the main focus of STEAM education materials in Korea is on extracurricular activities such as creative experience for elementary school students, free semester system for middle school students, and after-school activities for high school students. In particular, students' satisfaction with the topic-dependent convergence, high-tech product application, science-art convergence, and future job-linked programs developed by experts in various fields was high. In recent years, to actively introduce STEAM education in regular classes, programs linked to national curriculum are also being developed. All the materials developed to date are posted on the STEAM education website (<https://steam.kofac.re.kr/>).

Conclusions: Future directions for STEM/STEAM education

In the preceding sections, the research trends of STEM/STEAM education in Korea have been examined, focusing on the results of related policy projects and studies carried out by KOFAC. The STEM/STEAM education in Korea can be characterised as follows: (1) Systematisation of core competencies, objectives, content arrangement, and teaching methods for each subject of SMI as specified in the national curriculum; (2) Establishment of mid-to-long-term vision and future-oriented priority tasks according to national-level master plans; and the (3) Enhancement of the quality of education by improving teacher empowerment and developing high-quality contents. This section gives a brief overview of the future directions of STEM/STEAM education in Korea based on the research results yielded so far. The directions proposed here are mainly based on the vision of convergence education described in the master plan for convergence education (2020–2024) (MOE, 2020), and the objectives pursued by the SMI education in the AI age proposed by Hong (2020).

Firstly, it is necessary to strengthen basic education in science, mathematics, and informatics and restore student interest and confidence. “Convergence” is the most important keyword in our times caught in tremendous civilisational changes across the industrial fields and social (living) domains due to the rapid development of AI technology. However, “domain knowledge” is essential in bringing about convergence-based AI-driven transformative changes in society's various domains. Such domain knowledge stems from a solid basic education in science, mathematics, and informatics at the primary and secondary levels.

Furthermore, despite Korean students' high scientific and mathematical literacy achievements, they tend to show low interest and confidence (KICE, 2020). According to the results of a survey on teachers' perceptions, "science-related activities out of school", "student-centred research projects", "ICT-related materials", and "performance assessment" were found to have positive effects on students' positive experiences. Therefore, these approaches should be actively brought to bear in all school classes.

Secondly, it is necessary to establish a more flexible educational environment with an integrated approach in dealing with offline school environments and online platform environments. As explored above, in Korea, a range of studies are being conducted on the intelligent science lab, AI-driven math learning support systems, AI education platforms, and future-oriented convergence education spaces and they are sequentially applied to the educational settings. To implement future-oriented education, learning environments must be redesigned, and cutting-edge technologies and tools must be employed to transform education. Changes in the educational environment will be accelerated to meet the growing demand for EdTech-driven personalised, problem-based, and collaborative learning due to the ongoing non-face-to-face education situation caused by COVID-19. In line with this trend, it is necessary to establish a flexible on/offline learning environment that enables students and teachers to undertake various educational activities, coupled with the upgrading of teaching materials and enhancement of teacher empowerment to keep abreast with the changing environments.

Thirdly, an ecosystem needs to be established for science, mathematics, and informatics education through the concerted efforts of individuals, schools, and society. Korea's school-centred, well-organised education system has been considered desirable for Korean primary and secondary education. However, considering the rapid changes in science, technology, and society, a more flexible curriculum operation is required, and a sustainable education ecosystem needs to be established to ensure efficient and organic utilisation of various educational resources through cooperation with universities, companies, public institutions, science museums, math cultural centres, and other related facilities. In light of this movement, it is under review to recognise the credit hours gained in informal settings in the high school credit system, which will be progressively applied from 2022 onwards. Like the aforementioned STAR (School Teacher and Research) Bridge Centre, various extramural institutions can develop forward-looking educational materials, operate teacher training programs, and improve primary and secondary education quality.

When future generations have jobs that do not currently exist, talented leaders who are to implement innovative transformations in many fields of society through the convergence across fields will be needed. Currently, not a convergence occurring in an individual's brain, but a convergence occurring in close collaboration with experts from various disciplines is changing the world by creating new values and cultures. This chapter looks forward to the Korean STEM/STEAM education contributing to the training of talents who will contribute to people and society's well-being.

References

- Choi, Jae-Hyeok et al., *A report on consulting and research on 2020 science core schools* (Seoul: KOFAC, 2021).
- Do, Young Hae et al., *Basic research of establishing the center for Mathematical culture* (Seoul: KOFAC, 2015).
- Hong, Jun Euy et al., *A study on the plan to create future convergence education space* (Seoul: KOFAC, 2019).
- Hong, Oksu, "The latest trends and orientations in science, mathematics, and informatics education in the AI era." *The Science & Technology* 609 (2020): 25–29.
- Hong, Oksu et al., *AlgeoMath 4th year development research report* (Seoul: KOFAC, 2021a).
- Hong, Oksu et al., *A study on the development and operation of AI-based elementary mathematics class support system* (Sejong: Ministry of Education, 2021b).
- Hong, Oksu et al., *Development of a comprehensive index for Korean science education* (Seoul: KOFAC, 2021c).
- Im, Sung Min et al., *Research on the establishment of the center for supporting science education* (Seoul: KOFAC, 2020).
- Jeong, Dae Hong et al., *Research on future-oriented science curriculum organization to cope with post-COVID challenges* (Sejong: Ministry of Education, 2021).
- Korea Foundation for the Advancement of Science and Creativity (KOFAC). *Online forum on student participation online science classes in the post-COVID era* (Seoul: KOFAC, 2020a).
- Korea Foundation for the Advancement of Science and Creativity (KOFAC). *2020 KOFAC science education data book* (Seoul: KOFAC, 2021).
- Korea Foundation for the Advancement of Science and Creativity (KOFAC). *2020 software education annual report* (Seoul: KOFAC, 2020b).
- Korea Foundation for the Advancement of Science and Creativity (KOFAC). *Introduction to STEAM education* (Seoul: KOFAC, 2016).
- Korea Institute for Curriculum and Evaluation (KICE). *The Trends in International Mathematics and Science Study (TIMSS): finding from TIMSS 2019 for Korea* (Jincheon: KICE, 2020).
- Kim, Jaehyun et al., *A study on the development of <Artificial Intelligence Basics> subject according to the 2015 national curriculum* (Sejong: Ministry of Education, 2020).
- Kim, KapSu et al., *A study on the development of the standard of software education for the next generation* (Seoul: KOFAC, 2019).
- Kim, Kyung Ja et al., *2015 revised national curriculum general outline development* (Ministry of Education, 2015).
- Kim, Ja Mee et al., *A study on effectiveness of support program for strengthening software education in teacher training college* (Seoul: KOFAC, 2020).
- Kim, Yong-jin et al., *Development of STEAM contents map and analyses of STEAM programs in 2017* (Seoul: KOFAC, 2017).
- Kim, Yong-jin et al., *Guidelines for student-participatory-science-class leading school* (Seoul: KOFAC, 2019).
- Kwon, Oh Nam et al., *A study on the development of <Basic Mathematics> subject according to the 2015 national curriculum* (Sejong: Ministry of Education, 2020).
- Lee, Kyeong Hwa et al., *Research on future-oriented mathematics curriculum organization to cope with post-COVID challenges* (Sejong: Ministry of Education, 2021).

- Lee, Sang-gu et al., *A study on the development of <mathematics in artificial intelligence (AI)> subject according to the 2015 national curriculum* (Sejong: Ministry of Education, 2020).
- Lee, YoungJun, "Tasks and orientation of national science curriculum," in *The reflections on the Korean national curriculum reform*, ed. Young Dal, Cho (Gyeonggi: Kyoyook Book, 2020), 5–27.
- Lim, Wan Chul et al., *A study on the development of software for scientific inquiry* (Seoul: KOFAC, 2020).
- Ministry of Education (MOE). *2015 revised national curriculum* (Sejong: Ministry of Education, 2015). <http://ncic.re.kr/mobile.dwn.ogf.inventoryList.do#>.
- Ministry of Education (MOE). *The master plan for STEAM education (2018–2022)* (Sejong: Ministry of Education, 2018).
- Ministry of Education (MOE). *The master plan for science, mathematics, informatics, and convergence education (2020–2024)* (Sejong: Ministry of Education, 2020).
- Park, Hyunju et al., *A study for establishing the master plan of convergence education* (Seoul: KOFAC, 2019).
- Park, Man Goo et al., *Planning and research on the AI mathematics learning system to support math learning* (Seoul: KOFAC, 2021).
- Park, Seman et al., *Designing an evidence-centered assessment model of computational thinking in elementary and secondary education* (Seoul: KOFAC, 2017).
- Ryu, Suna et al., *A study on the assessment method for STEAM education* (Seoul: KOFAC, 2019).
- Son, Jeongwoo et al., *A study on the development of creative-integrated-science-lab schools through analysis of satisfaction* (Seoul: KOFAC, 2020).
- Song, Jinwoong et al., *Scientific literacy for all Koreans: Korean science education standards for the next generation* (Seoul: KOFAC, 2019).
- Song, Jinwoong, "Tasks and orientation of national science curriculum," in *The reflections on the Korean national curriculum reform*, ed. Young Dal, Cho (Gyeonggi: Kyoyook Book, 2020), 157–180.
- World Economic Forum (WEF). *The future of jobs: Employment, skills and workforce strategy for the fourth industrial revolution* (Geneva: World Economic Forum, 2016), http://www3.weforum.org/docs/WEF_Future_of_Jobs.pdf.
- Yoo, JeongSu et al., *An exploratory study on the content system of artificial intelligence education in elementary and secondary schools* (Seoul: KOFAC, 2020).