Chapter 14
Overview of Science Education Research and Practice in Korea

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Abstract The aim of this chapter was to examine science education research trends that have been constructed in Korea. We were then interested in examining what impact these works have had on K-12 science teaching and learning. We conducted a content analysis of articles published in the *Journal of Korea Association for Science Education* with respect to research topics and contents. We also discussed the impacts of these research studies on science curriculum, science instruction, and science teacher education in Korea. Importantly, all of these particular foci provide an insight to the various applications of research and to ways how current research informs teaching practice, and thus raise questions of what needs to be done next.

14.1 Introduction

It has been 120 years since the modern science education in Korea has begun. The modern public school education started by laws in 1895 and since then the science subject has been taught at schools in Korea (Kim 1976). The importance of school science education has been recognized by the government since 1962. The government of the Republic of Korea released the national economic development plan and recognized the importance of science and technology development for the economic improvement. The government of the Republic of Korea emphasized the importance of science education with the slogan of 'Science Education for National Prosperity.'

School science education should be supported by research studies in science education. In other words, research in science education and school science education support each other. The master program in science education was begun at

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the graduate school of education at a few universities in Korea in 1964. And the science education curriculum projects developed in the United States were introduced to and conducted in Korea in the 1960s. These two historical events that occurred at the same time period were the foundation of science education research in Korea. In this chapter, we overviewed the trends of science education research in Korea for the past 40 years and examined what impacts these works have had on K-12 school science education.

14.2 Review of Science Education Research in Korea

Research on science education in Korea has begun since 1964 when master programs were available at a small number of graduate schools of education including the Seoul National University (Park 1984). The science education improvement project supported by the UNESCO/UNICEF in 1968 activated the research in science education at the 20 science education research centers at the college of education of the national university and teachers college (Jeong 1984). The strands of research studies were extended with the doctoral program available at the Seoul National University in 1984. The doctoral programs in science education are available at 20 institutions now.

Research studies in science education were published at journals issued by science education research centers at institutions and the "*Journal of Korean Chemical Education*" issued by the Korean Chemical Society, "*Biology Education*" issued by the Korean Society for Biotechnology and Bioengineering, and "*Physics Education*" issued by the Korean Physical Society. The science education community and the numbers of articles were small. The Korea Association for Science Education founded in 1976 has been a center of science education research in Korea. The first issue of the *Journal of Korea Association for Science Education* was published in 1978. The journal published an issue every two years at the beginning but now eight volumes a year.

This chapter was intended as an overview of research trends of science education in Korea since the 1960s. We also examined influences of science education research on teaching and learning in Korea school science classrooms. We classified the time from the 1960s to current into the four periods: Embryo, Infancy, Growth, and Maturity. The Embryo period was from the mid-1960s to 1977. The initiatives in Korea science education began in the mid-1960s by presentations of scholarly work in science education research. Since then, the development in science education research has been driven by the first issue of *Journal of the Korean Association for Science Education* in 1978. The Infancy period was from 1978 to 1991 wherein a few science educators published research studies in a small number of research areas. The Growth period from 1992 to 2003 was led by a number of science educators studied in both Korea and international institutions with increasing numbers of publications in the extended scope. The Maturity period from 2004 to 2013 meant a significant development both in the research fields and the numbers of publications. The international exchanges among science educators were active in the Maturity period. For research studies after the Infancy period, our examination have limited ones published at the *Journal of Korea Association for Science Education*.

14.2.1 Embryo Period (1965–1977)

According to the National Assembly Library of Korea, the first published science education research article in Korea was in 1965 (Kim et al. 1987). During the Embryo period in the history of Korea Science Education Research (1965–1977), research studies focused mostly on science education curriculum and science teaching. With support from the UNESCO/UNICEF (1968–1977), the science education curriculum projects such as ESS, IPS, PSSC, and CHEM Study were introduced to and conducted as pilot sessions in Korea. The related in-service teacher professional development programs were implemented at the college of education and teachers college (Kwon et al. 2003a, b). The researchers in science education were interested in the new curriculum movement by the United States and discussed about its influences and implications on Korea science education curriculum. Most graduate students in the master program of science education were in-service teachers. And the science educators at the college of education had doctoral degrees in natural science not in science education. As a consequence, the scope and fields in science education research in this period were limited. The scholarly works of science education were published at the academic journals issued by the science education research centers at institutions, *Biology Education* issued by the Korean Society for Biotechnology and Bioengineering, and the *Journal of Korean Chemical Education* issued by the Korean Chemical Society.

1. **Research on science curriculum**

Before the introduction of the post-Sputnik reform programs developed by the United States, Korea science education curriculum focused on science-in-everyday-life. The emphasis of the new science curriculum aiming both the science principles and scientific inquiry grasped attention of Korea science researchers and educators. The first implementation of the new science curriculum was in the PSSC physics laboratory class for Kyungbuk medical school students in 1961. A few science teachers in the Kyungbuk Province had research meeting and made experiment kits for the new science curriculum and they conducted a science teacher workshop on the PSSC physics in 1963 (Kwon et al. 2003b). Building upon the researchers' attention to the new science curriculum around the college of education at both primary and secondary levels, 10 year support from the UNESCO/UNICEF (1968–1977) disseminated the programs across the country. The institutions of training elementary teachers and secondary science teaches opened pilot courses and the professional development programs on new programs such as ESS, SAPA, SCIS, IPS, PSSC, CHEM Study, BSCS, and ESCP. Researches related to their applications into Korea science classrooms were also conducted (Kang 1968; Kim 1967; Kwon 1968; Han 1969; Park 1967) such as comparing the new science curriculum with Korea science curriculum (Joung et al. 1969) and suggesting implications of the new science curriculum on Korea science education curriculum reform (Chung and Row 1977; Lee 1974). Further, a framework of the new Korea science curriculum was suggested (Woo 1976).

2. **Research on science teaching**

There were marked changes in orientation between the new science curriculum and the science curriculum focused on the science-in-everyday-life. With comparisons between the new science curriculum and the previous science curriculum, research on goals, contents, instructional strategies, assessments, and teacher roles were conducted (Kim 1976; Han 1971; Oh et al. 1976; Park et al. 1974). As the new science curriculum emphasized scientific inquiry, the effective ways of guiding student engagement in science experiments, the requirements of laboratory classrooms, and the extent to which each school had experimental supplies and materials were investigated (Lim 1973; Moon et al. 1975).

14.2.2 Infancy Period (1978–1991)

There has been a significant development in science education researches in Korea since researchers with a doctoral degree from institutions in the United States joined Korea science education research community in the 1970s. Since then into the 1980s, researchers in science education from institutions in the United States or the Unites Kingdom have been teaching students in the undergraduate and graduate programs of science education and conducting researches in science education. Research studies conducted by those prominent science researchers were the foundations of the Korea science education research and published at the *Journal of the Korean Association for Science Education*. The main research agenda during the Infancy period (1978–1991) were as follows: teacher education, science education research based on Piaget cognitive theory, students' preconceptions/misconceptions, and school science teaching and learning. There were also a few research studies regarding integrated science curriculum, scientific inquiry and problem solving, and low achieving students.

1. **Foundation study on science teacher education**

While general education courses and science content courses were available in science teacher education programs, science education courses that were critical to educate professional science teachers were rarely open in the 1970s. As science educators recognized the problem, they developed science teacher education curriculum (Park 1978) and the running model for the curriculum (Cho et al. 1985).

Also, researches constructing instructional models and developing teaching materials were conducted to create courses such as 'Theoretical Foundations of Science Education' (Park 1984) and 'Research in Science Education (Park 1982).'

2. **Research on science instruction based on Piaget's theory**

Piaget's theory of cognitive development has provided important implications on school science education and research studies in science education. Kim (1978) examined the elementary students' concepts of 'movement and speed' and analyzed the science contents presented in the grade 4–6 science textbooks with respect to the stages of Piaget' cognitive development (Kim et al. 1986). Choi et al. (1985) examined cognitive levels of grade 7–12 students and Han (1986) analyzed cognitive levels of grade 7–12 students with respect to districts, grade levels, ages, sex, and social economic levels. Choi and Hur (1987) analyzed the relationships between students' cognitive levels and science contents presented in the science textbooks. They claimed that the cognitive levels required for science contents presented in textbooks were higher than student cognitive levels.

3. **Research on preconceptions in science instruction**

Researches on students' understanding of science concepts were led by Kim et al. (1978, 1980). They examined students' conceptions of 'movement and speed' with respect to sex and districts. Researches on students' preconceptions on various topics were activated since Cho (1984) presented the article of 'Relationships among philosophical foundations of students' preconceptions, misconceptions, and science learning.' During the Infancy period, research on students' preconceptions focused on physics and biology such as genetics, reproduction, fertilization, cell division, photosynthesis, force, and movement, Newton's third law, dynamics, temperature, electronic current, and changing states of water. There was little research on chemistry as chemistry deals with micro-level phenomenon.

4. **Research on school science education**

Identifying problems or difficulties in school science education needs to be done in order to improve school science education. Science educators examined how the science curriculum was conducted in schools (Kwon et al. 1987) and provided suggestions on the ways how to improve school science education (Cho et al. 1989; Park and Lee 1987; Park et al. 1988).

The college entrance examination has great influences on school education in Korea. With respect to this, in 1986 a special volume 6(1) of the *Journal of Korea Association for Science Education* was issued for the topics of the relationship between the college entrance examination and secondary school science education; relationships between college entrance examinations and school science education in the United States, England, German, China, and Japan; the new plan for the college entrance examination and assessment systems aiming for the proper school science education.

14.2.3 Growth Period (1992–2003)

14.2.3.1 Research in Science Education

Since 1979, the Korea government supported for the graduate student study abroad program contributed to bring up researchers and experts in science education. Since 1983, they come back from the United States and the United Kingdom and worked as professors at the college of education and then researches in science education were activated. Researchers with a doctoral degree from the Korea institutions also worked at the college of education and the universities of education, and also played a central role in Korea science education. There was significant progress in the researches of science education compared to the Infancy period. The research agenda were various and the numbers of research papers have increased. The *Journal of Korea Association for Science Education* was issued three times a year in the Growth period and six times a year in 2003. Table 14.1 indicates trends in the numbers of articles published in the *Journal of Korea Association for Science Education* during the Growth period.

14.2.3.2 Research in Each of the Main Research Agenda

Research topics such as preconceptions and conceptual change, scientific inquiry, teaching strategies, curriculum, problem solving, verbal interaction, teacher education and professional development, and educational technology were focused in the Growth period.

1. **Preconceptions and conceptual change**

Research on student preconceptions was conducted since the Infancy period. Results provided science teachers with information of what preconceptions students held on certain scientific concepts and helped them lead effective class discussions. Also, information on student misconceptions provided teachers with cues on how to generate conceptual conflicts in science instruction. Researches of student misconceptions on several topics such as light, gravity, free-fall, acid and base,

Table 14.1 Trends in the numbers of articles published in the *Journal of Korea Association for Science Education* during the Growth period

	Early-term				Medium-term				Late-term			
Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Number of articles	28	34	36	49	46	48	55	61	58	75	88	57
Mean number of articles	36.8				52.5				69.5			

evaporation and condensation, acid rain, heredity and evolution, life, homeostasis, tide, and astronomy were conducted and used for developing textbooks.

Then, why do students hold their own preconceptions on scientific concepts? Research during the Growth period focused on what preconceptions or misconceptions students hold. However, there were few research studies looking for causes why students hold those misconceptions. It may be because the approach should be long-term and based on epistemology. There were a few studies investigating factors that influence the formation of student misconceptions. Kim and Chung (1997a) indicated that high school students held more misconceptions on 'diffusion and osmosis' and claimed that the science textbooks included unclear and brief descriptions on the scientific concept. Kim and Chung (1997b) also suggested that 38.3 % of teachers did not clearly understand 'homeostasis,' 'classification of animals and plants,' and 'formation of food in plants.' They indicated that teachers would play a role on the formation of student misconceptions. These findings provided important implications that school science classes would be a critical factor for the formation of student misconceptions.

Researchers recognized that it is hard to change student misconceptions into scientific concepts. With respect to this, Lee and Kwon (1993) identified factors impacting on the robustness of student misconceptions and developed a formula to generate index numbers indicating the robustness of student misconceptions. They expected that the formula would help design an instruction model to change student misconceptions into scientific concepts as they considered all factors impacting on the robustness of student misconceptions.

School science instruction tried to find ways how to change student misconceptions into scientific concepts and researchers suggested various instructional strategies and teaching methods for student conceptual change. Kwon and his fellows identified three factors impacting on cognitive conflicts such as factors of students, tasks, and instruction and investigated influences of the factors (Kim et al. 2001). The patterns of cognitive conflict and the characteristics of student responses with respect to the complexity of science contents were examined (Lee and Kwon 1999; Kim and Kwon 1995). They presented a model explaining the process of cognitive conflict and developed an assessment tool to evaluate the levels of cognitive conflict (Lee et al. 2003). Also, the effects of the teaching strategy using cognitive conflict on conceptual change were investigated (Kim and Kwon 1995; Kwon et al. 2003a, b).

While cognitive conflict was identified as an effective strategy for student conceptual change, other strategies such as evidence-based critique, deductive logic, history of science, interaction reinforcement, and multiple comparisons were used for student conceptual change.

2. **Scientific inquiry and inquiry ability**

Since scientific inquiry was identified as a major goal for science education in the third Korea national science curriculum in 1974 (Ministry of Education 2000), inquiry-based science teaching has been emphasized in school science instruction.

Hur's (1984) article on scientific inquiry model and assessment framework of scientific inquiry initiated researches on scientific inquiry in Korea. Cho (1992) identified the definitions of scientific inquiry, scientific research, scientific methods, scientific process skills and suggested science teaching methods for improving students' scientific process skills.

The college admission examination since 1994 (Korea Institution for Curriculum and Evaluation 2005) activated researches on scientific inquiry and scientific inquiry ability. The Ministry of Education in Korea implemented the college admission examination to evaluate the extent to which students are able to study in college. The parts of social studies and science focused on student inquiry ability. This approach reinforced inquiry-based science teaching in science classes and led a number of research studies on development of teaching materials and methods to improve student inquiry ability, multiple choice assessment method to evaluate student inquiry-based thinking, and assessment tools to evaluate scientific process skills. There have been also several research studies such as analyzing thinking process for each of the inquiry levels, identifying factors impacting on inquiry-based thinking, and developing the national level assessment of inquiry ability.

Choi and his fellows (Choi et al. 2002; Nam et al. 2002) recognized student scientific inquiry as a major goal of science education and investigated the effects of Thinking Science program on students' inquiry ability. They pointed out that cognitive conflict strategy using the Thinking Science program, verbal interactions during the process of resolving conflicts, and metacognition influenced the student inquiry ability such as compensation logic and variable control and resulted in student cognitive development (Lee et al. 2002).

3. **Teaching strategies**

In order to implement an effective science instruction, it is important to consider science contents, student understanding, learning goals, and proper teaching strategies. With respect to this, there have been several research studies investigating the relationships between instructional strategies and science contents. For instances, Kim et al. (1995) studied the use of metaphors for learning 'electricity.' Lee and Kim (1995) used the history of science to change student misconceptions on the concept of 'heat.' Noh and Jeon (1997) explored the effects of visual representations of molecules. And Jung et al. (1996) used a small group role-play for student understanding of astronomy.

A number of researches on the effects of cooperative learning were also conducted. The use of STAD or Jigsaw, relationship between cooperative learning and student characteristics, and grouping for effective cooperative learning were investigated. The use of concept map or Vee diagram, stimulation of student motivation, and questioning strategies were also explored.

4. **Curriculum**

Research on science curriculum centered on the integrated science curriculum and Science Technology and Society (STS). The integrated approach of science for grade 3–10 students had been accepted by the majority of the science researchers (Kwon and Park 1978). Then, there were needs to change the combined science curriculum into the integrated science curriculum. With respect to this, research studies such as theoretical reviews to develop the integrated science curriculum (Son and Lee 1999), development of the topics and contents for the integrated science curriculum (Choi and Choi 1999), and curriculum design for the integrated science education (Son et al. 2001) were conducted.

STS approach grasped researchers' attention since Kim (1988) reported the results of comparisons in elementary science contents between the United States and Korea. She indicated that the elementary school science emphasized student understanding of science concepts and scientific inquiry and insisted that the relationships among science, technology, and society should be included in elementary science curriculum to achieve goals of citizen education for students living in a society dependent on science, technology, and information. Kwon (1991) pointed out the problem of disciple-centered science education and claimed that there are needs to develop science textbooks including daily-life examples. Following his pioneer research, several research studies introducing STS programs (Cho 1991), investigating science teachers' perceptions on STS programs (Choi 1994), and identifying ways to apply STS approach (Chung et al. 1993) were presented. Researches of analyzing SATIS programs, exploring student attitudes to socio-scientific issues, examining the effects of STS programs on scientific attitudes and achievements, and professional development programs for STS approach were also conducted.

5. **Problem solving**

Since Kwon and Lee (1988) analyzed the process of students' problem solving, the majority of researches on problem solving focused on students' thinking processes for problem solving in physics (Bak and Kwon 1990; Bak and Lee 1993). Interactions between problem tasks and students are critical to problem solving. Then, researches centered on examining the relationship between problem solving and the characteristics of the problems such as problem context and the extent to which the problem requires students' attention (Ahn and Kwon 1995; Hong and Park 1995); the relationship between problem solving and the characteristics of students such as mental capacity, chunking level, recognition type, information process type, and visualization and organization ability.

6. **Verbal interaction**

While activity-centered scientific inquiry was emphasized, roles of verbal interactions in science classes did not attract researchers' attention much. Since 1980s, scientific literacy including communication skills and reasonable decision-making has been identified as an essential goal of science education.

A number of researches such as students' verbal interactions in cooperative learning, verbal interactions in group discussions, verbal communication-centered scientific inquiry, and learning environment for verbal communication were conducted. These research studies found that students' communications in science classes were inactive and superficial and there was little dialectic communication. They also implied that teachers should consider students' social and psychological aspects and utilize teaching strategies stimulating students' communications.

7. **Teacher education and professional development**

It would be in-service teachers that know what needs to be done for teacher education programs. With respect to this, Park's (1992) research grasped our attention. He examined 176 science teachers' perceptions on the teacher education programs and the requirements to be a good science teacher. Science teachers considered enthusiasm, science content knowledge, organization ability of teaching materials, instructional skills, and scientific philosophy. They also claimed that pre-service teachers should take more courses of 'science teaching methods.' This indicated that the portion of 'teaching methods' courses were relatively low compared to 'science content' courses in teacher education programs. Kwak and Kim (2003) observed and analyzed science classes by 10 science teachers who were recognized for the best science teaching in Korea. The good science teachers reorganized the science contents considering student level and learning context, used various teaching strategies, challenged students, stimulated students' cooperation, and used results of assessments of student learning for the next instruction. They were also joining the district science teacher association to become a better science teacher. They worked hard for good science teaching and loved to teach science and enjoyed to have 'highly engaged students.' These findings provided important implications on science teacher education and professional development programs.

8. **Educational technology**

While there were high expectations of using computers for science teaching with tremendous development of computers, the effects of the use of educational technology in science classes was not consistent. The early attempt of educational technology was simply using the functions of computers such as computer user interface or repetition learning. Research on educational technology extended to effectively connect the characteristics of science content with the strength of computers such as animations to show the movement of molecules and ions in dissolution, or simulation of chemical equilibrium and dynamics. Shim et al. (2003) investigated the effects of the '3D virtual reality technology' for the structure and function of eye.

14.2.4 *Maturity Period (2004–2013)*

14.2.4.1 Research in Science Education

In late 1990s, the Ministry of Education approved doctoral programs of science education at the major universities of education and the colleges of education. A number of science researchers from the institutions worked actively for research in science education across various research agenda. Table 14.2 indicates the trends in the number of articles published in the *Journal of Korea Association for Science Education* during the Maturity period.

There were significant increases in numbers of articles published in the *Journal of Korea Association for Science Education* during the Maturity period compared to the Growth period as shown in Tables 14.1 and 14.2. However, the increase of numbers of the articles during the Maturity period was not significant as the Growth period. It may be because of the high ratio of rejection for the manuscripts submitted to the *Journal of Korea Association for Science Education* during the Maturity period.

Research topics of the articles were more diverse compared to the Growth period. We analyzed articles published in the *Journal of Korea Association for Science Education* using the analysis framework by Tsai and Wen (2005). Table 14.3 shows frequencies and percentages of research topics of the articles published in the *Journal of Korea Association for Science Education* from 2004 to 2013 (Maturity period).

Table 14.3 indicates that researches on 'Teaching' and 'Learning-Context' have increased while ones on 'learning-conception' have decreased. Research on 'Teacher Education' and 'Gifted Education' increased over the years. There were a few researches on 'Culture, Social, and Gender' and 'Educational Technology.' Limitations of the results in Table 14.3 are that we analyzed only the articles published in the *Journal of Korea Association for Science Education*.

Lee et al. (2009) analyzed articles published in the *International Journal of Science Education* (IJSE), *Science Education* (SE), and the *Journal of Research in*

Table 14.2 Trends in the number of articles published in the *Journal of Korea Association for Science Education* during the Maturity period

	Early-term			Medium-term				Late-term		
Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Number of articles	109	90	81	84	82	76	79	78	110	94
Mean of the number of articles	93.3			80.3				94.0		

Table 14.3 Frequencies and percentages of research topics of the articles published in the *Journal of Korea Association for Science Education* from 2004 to 2013

Research topic	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	Total
Teacher education	8 (7.4)	8	5	3	12	10	16	13	16	19	110 (12.5)
Teaching	18 (16.5)	18	18	25	21	20	20	22	23	20	205 (23.2)
Learning -conception	11 (10.1)	6	13	8	4	2	2	3	6	4	59 (6.7)
Learning -context	30 (27.5)	19	17	12	13	18	16	10	26	18	179 (20.3)
Goals, policy and curriculum	18 (16.5)	11	9	16	9	10	11	13	14	12	123 (13.9)
Culture, social and gender	3 (2.8)	0	1	2	1	0	1	0	0	2	10 (1.1)
Philosophy, history and NOS	7 (6.4)	10	7	4	7	5	6	3	7	8	64 (7.3)
Educational technology	2 (1.8)	5	1	2	2	0	0	0	0	0	12 (1.4)
Informal learning	7 (6.4)	4	2	6	0	2	3	1	3	2	30 (3.4)
Gifted education	3 (2.8)	6	5	4	12	6	4	12	11	7	70 (7.9)
Others	2 (1.8)	3	3	2	1	3	0	1	4	2	21 (2.4)
	109 (100)	90 (100)	81 (100)	84 (100)	82 (100)	76 (100)	79 (100)	78 (100)	110 (100)	94 (100)	883 (100)

Science Teaching (JRST) from 2003 to 2007. We compared the frequencies and percentages of research topics published in the *Journal of Korea Association for Science Education* with the results of Lee et al.'s (2009) analyses as shown in Table 14.4.

Table 14.4 indicates that the top one topic was 'Learning-Contexts' in both the JKASE and the three international journals. The next top topics were in the order of 'teaching,' 'goals, policy, and curriculum,' and 'learning-conception' in the JKASE while 'learning-conception,' 'teaching,' 'goals, policy, and curriculum' in the three international journals. There were more studies on 'teaching' in the JKASE compared to ones in the three international journals, while less studies on 'culture, social, and gender' and 'educational technology' in the JKASE compared to ones in the three international journals.

Table 14.4 Comparison of frequencies and percentages of research topics between the three international journals (IJSE, SE, and JRST) and the *Journal of Korea Association for Science Education* (*JKASE*)

	IJSE, SE, and JRST (*n* = 869)	KJSE (*n* = 408[a])
Teacher education	78(9.0)	30(7.2)
Teaching	121(13.9)	96(22.9)
Learning-conception	133(15.3)	48(11.4)
Learning-contexts	204(23.5)	101(24.0)
Goals, policy and curriculum	110(12.7)	68(16.2)
Culture, social and gender	59(6.8)	9(2.1)
Philosophy, history and NOS	71(8.2)	32(7.7)
Educational technology	47(5.4)	12(2.8)
Informal learning	46(5.3)	24(5.7)

[a]Double-counting for research topics

14.2.4.2 Research in Each of the Main Research Agenda

There have been increase in research topics compared to the Growth period. The number of research studies on ‘preconceptions and conceptual change’ and ‘scientific inquiry and inquiry ability’ have significantly decreased compared to the Growth period. Instead, a number of studies on ‘science education for gifted students,’ ‘argumentation and writing in science,’ ‘pedagogical content knowledge,’ and ‘informal science education’ were presented. The top topics during the Maturity period were ‘teaching strategy,’ ‘curriculum,’ ‘teacher education and professional development,’ ‘PCK,’ ‘argumentation and writing in science,’ ‘verbal interaction,’ and ‘informal science education.’

1. **Teaching strategy**

Research studies on teaching strategy during the Maturity period were conducted as much as the Growth period. More diverse teaching strategies were explored during the Maturity period compared to the Growth period. For instances, the effects of using concept map, metaphor, cognitive conflict, role-play, history of science, STS approach, daily-life examples were explored. Also, the effects of using drawing, writing, multiple modes, and models were investigated. Researches exploring the effects of reciprocal peer tutoring/cooperative mentoring, investigating the effects of argumentation-focused/question-generated science instruction, developing programs to improve core capacities, and examining the effects of the programs stimulating students’ reflection were conducted.

There were also a few studies on student self-regulated learning that focused on learners. These researches are meaningful in that there are many students who are not engaged in science classes and have difficulties in learning science. Student-centered learning has been emphasized in science education so these researches would provide important implications on science teaching and learning.

2. **Curriculum**

The majority of the research studies on curriculum during the early Maturity period focused on examining the extent to which the emphases of the 7th Korea national science curriculum were applied in the science textbooks and science classes. According to Kwak's (2004) study investigating the elementary school science, the 7th Korea national science curriculum assigned more authority to schools or teachers. However, the majority of the elementary school teachers just followed the directions provided by the teacher-guidebooks for goals, contents, teaching methods, and assessments and did not reorganize the teaching materials for a creative science class.

Kim et al. (2006) analyzed middle school science textbooks to examine the extent to which middle school science textbook embed the contents to achieve the goal of science education, 'scientific literacy.' They found that the science textbooks included scientific knowledge and scientific inquiry process but there were not enough descriptions for science as thinking process or STS. Another study (Hong and Jeong 2004) critiqued that the science textbooks included simple reading materials for the STS approach and implied more diverse STS topics and approaches needed. Research studies examining the extent to which science textbooks included the science contents targeting for ICT literacy and the history of science that stimulates student motivations and helps understand the nature of science and scientific inquiry were also conducted.

The 2009 science curriculum centered on 'Integrated Science' that aimed student interest and integrated understanding of nature. Kim et al. (2013) examining student interest in science reported that students' interest in science topics was medium level while their motivation was higher level. Also, students who aimed to major in science/engineering had high motivation but students who aimed to major in liberal arts had interest in hands-on activities. Ahn et al. (2013) claimed that several aspects such as leadership, teacher colleague cooperation, year-long plan, flexible time management, and using community resources are critical to the integration-based science education. This approach would reform school science education and keep science teachers informed.

3. **Teacher education and professional development**

The science teacher professional development is critical to the school science education reform. With respect to this, researches on in-service teacher education and professional development programs are very important. The main themes of the science teacher professional development were constructivism, student misconceptions, conceptual change strategy, learning theory and epistemology, verbal communication based on Vygotsky's social constructivism. Then, researches on teacher education focused on investigating pre-service teacher understanding of learning theory and developing and implementing instructional strategies, examining the effects of the mentoring programs, exploring the effects of teacher colleague collaboration or cooperative mentoring on the professional development.

Early research on teacher profession focused on examining the PCK of novice teachers, investigating the PCK components identified by science teachers, analyzing the PCK by observing science teaching, exploring relationships between the content knowledge and the PCK, and defining the PCK. Understanding the PCK as a profession index, researchers in science education made efforts to find ways to improve teacher profession by examining PCK development through CoRe (Content Representation) and investigating pre-service teachers' PCK development through mentoring before and after student teaching.

4. **Argumentation and writing in science**

As student argumentation and writing have been emphasized as critical components to student science learning, there have been a number of studies on argumentation and writing since 2000. The 2007 Korea national science curriculum indicated the importance of writing and discussion as teaching strategy, the 2009 Korea national science curriculum emphasized writing as a way to understand science concepts and develop scientific literacy (Ministry of Education and Human Resources Development 2007; Ministry of Education, Science, and Technology 2009). For the past 10 years there have been increase in research studies on argumentation and writing in science and significantly since 2008. The majority of the researches were on the development of teaching strategies using argumentation and writing, analysis of argumentation and writing, and examination of the effects of the developed programs. For instances, examination of the effects of argumentation (Lee et al. 2005), analysis of argumentation components and process (Kang et al. 2004), identification of the roles of writing in science education (Jeong et al. 2004), examination of the function of written arguments (Lee et al. 2009), analysis of scientific writing (Park et al. 2007), examination of the effects of writing in science instruction (Nam et al. 2008).

5. **Verbal interaction**

Cognitive constructivism based on Piaget's development theory emphasized student cognition and led researches on interactions between science contents and learners. As researchers identified social context as an impacting factor of learning process and understood that science knowledge can be developed through negotiation according to Vygotsky's social constructivism, they become more interested in teacher–student as well as student–student verbal interactions in science classes. While there were a number of researches analyzing verbal communications in the late Growth period, researches on the analysis of impacting factors on verbal communications were added in the Maturity period. For instances, verbal interactions between teacher and students in middle school science classes, teacher facilitation in student group work, communication levels in each of the scientific inquiry investigations, verbal interactions by the leadership type in a group work, cooperative collaboration for better verbal communication, supporting verbal communications using questioning and feedback strategy, interaction types in a heterogeneous group, and roles of leader in science laboratory classes.

6. **Informal science education**

The informal science education has been emphasized as a way to help students understand science better and keep motivated using various community resources (Osborne and Dillon 2007; Rennie et al. 2003). The 7th Korea national science curriculum recommended diverse filed trips), the 2009 Korea national science curriculum introduced various types of experience-education and emphasized the importance of the informal science education (Ministry of Education, Science, and Technology 2009). With the emphasis, researches on informal education have been increased. For examples, functions of natural history museums, natural history museums in Korea, natural history museum management, education programs provided by the natural history museums in several countries (Lee et al. 2004), perceptions by students, teachers, and parents on the natural history museums (Choi et al. 2004), informal science education and programs in Korea (Song et al. 2004), argument structure of learning materials provided by informal science education (Lee et al. 2005), verbal communications between parents and children in museums (Kim et al. 2007), and teachers' perceptions on using resources from museums (Han et al. 2010).

We have organized our review in terms of four phases that we believe to capture broadly the progress that has been made in science education research in Korea. As we have discussed in the previous section, there have been remarkable progress in both quality and quantity of science education research in Korea last 50 years. It is surely related with social and contextual background in the early period of science education research in Korea. As a result of the ambitious financial and systemic supports, there have been numbers of research in various topics in science education. The increase of research studies on professional development for science teachers and informal science education suggests desirable implications on the development of science education in Korea. To make more advances in science education research in Korea, investigations must carefully take into account of lack of research on diversity and equity in science learning, i.e., culture, race, socioeconomic, and gender differences on student learning science. In line with the results of the TIMSS 2011, attempts should be made to reduce gaps between high academic achievement level and low scientific attitude and understanding of science levels. Also, linking science education research to school science education should be essential to improve the quality of classroom science teaching and learning. With the careful identification of the issues and problems in school science education, advances can be made in science education in Korea, and in turn problems can be solved for reducing gaps between research and practice.

14.3 School Science Education in Korea

The science textbooks that are developed based on the Korea national science curriculum are important resources for science instruction. The national science curriculum, therefore, plays a critical role in school science education and how the rationale of science curriculum is represented in the science textbooks would be dependent on the textbook authors. Considering student levels and learning environment, science teachers are encouraged to reorganize the content presented in the science textbooks instead of simply delivering information as the way how they are presented in the science textbooks. Science teachers consider the aims, lesson goals, student level and characteristics, and plan and implement science lessons so that goals, instruction, and assessment are aligned to each other. Science teacher expertise, the extent to which science teachers are well prepared for effective science teaching would be dependent to the quality of teacher education.

This chapter reviews the changes in school science education with respect to science curriculum, science instruction and assessment, and teacher education for the past 50 years. We will discuss how much researches in science education have influenced on science curriculum, science instruction, and assessment; and science teachers played their roles and had difficulties in working as a profession.

14.3.1 Science Curriculum

The Korea science curriculum has been revised nine times for the past 70 years and there were critical changes for the four revisions. The first change was the 3rd science curriculum in 1974 that was influenced by the science education reforms according to the structure focused approach from the late 1950s to the early 1960s. While previous science curriculum focused on student daily-life experiences and motivation based on the life-adjustment education, the 3rd Korea science curriculum emphasized inquiry-based science learning that adopted the rationale of the knowledge structure and the spiral curriculum. Table 14.5 indicates the changes in the science contents of the middle school science between the 2nd and the 3rd Korea science curriculum (Ministry of Education 2000). The Korea researchers' attention to the national science education reforms such as ESS, SAPA, IPS, PSSC, CHEM Study, and BSCS influenced the revision into the 3rd science curriculum.

Second, the 6th science curriculum in 1992 adopted the trends in science education of the international community as well as the needs for a change. This was different from the change in the 4th and 5th science curriculum as they kept the frame based on the knowledge structure approach. In the late 1980s, the importance of 'Science for All' was emphasized with the Project Synthesis and the Project 2061 in the United States (AAAS 1989). The science education standards in the United Kingdom also suggested 17 achieving goals for 5–16 years old students (DES 1989) and the SATIS (Science and Technology in Society) program was released to emphasize the relationship among science, technology, and society (ASE 1990). In Korea, there were needs for revising the science curriculum to achieve the goals for creative, ethical, and independent citizens in the twenty-first century. With respect to this, the 6th science curriculum in 1992 described the characteristics of the 'science' subject, that is, 'help students to understand scientific concepts, principles, and laws through scientific inquiry investigating natural world and discuss and

Table 14.5 Science contents of the 2nd and the 3rd Korea science curriculum

Grade	The 2nd science curriculum	The 3rd science curriculum
1	Water, air, fire, earth surface, plants, animals	Property of matter, separation of substance, elements and compounds, earth materials and earth surface, types of plants
2	Weather, magnet and electricity, acid, base, salt, food and nutrition, human body, force and movement	Atom and molecule, heat energy, electric energy, solar energy and weather change, living things and environment, nature and human life
3	Light, energy, transportation and communication network, chemical change, hygiene, development and management of resources, evolution of living things, solar system and universe	Chemical change, force and movement, energy conversion, solar system and universe, change of earth surface and earth's history, continuity of life, metabolism

recognize the relationship between science and daily-life.' This statement emphasized the importance of student understanding of the relationship among science, technology, and society as well as inquiry-based science learning. The research studies by Kim (1988), Kwon (1991), and Cho (1991), that indicated the importance of student understanding of the relationship among science, technology, and society in the late 1980s influenced on the attempt of the curriculum revision. Also, research on the integrated science since the 1970s resulted in the introduction of the 'Integrated Science' for grade 10 students to help them develop problem-solving ability through doing research on daily-life and technology-related problems.

Third, the 7th science curriculum in 1997 established the core curriculum for grade 1 to grade 10 students and the selective curriculum for grade 11 and 12 students. While the goal of the core curriculum for all students was scientific literacy, students could take their preferred science subjects selected according to their aptitude and prospective careers in the selective curriculum. Also, the advanced curriculum and the supplementary curriculum were the important feature of the core curriculum. The low achieving students on the core courses took courses from the supplementary curriculum and the high achieving students took courses from the advanced curriculum. The curriculum recommended implementing of the advanced and supplementary curriculum in a class but there were difficulties in implementing both the curriculums in real science classrooms.

Last, there were changes in the recent 2009 revised science curriculum that reestablished the core curriculum for the grade 1–9 compulsory education and the selective curriculum for the grade 10–12. The 2009 revised science curriculum suggested the science content standard according to grade clusters such as grade 3–4, 5–6, and 7–9 instead of each grade level. The significant change in the 2009 revised science curriculum was the integrated approach of the selective 'Science' course for high school students. This approach was based on the need for people capable of creative and integrative thinking in the future of science and technology. Table 14.6 suggests contents of the 'Science' as a selective course.

Table 14.6 Science contents of the 'Science' as a selective course

Universe and living thing	Origin and evolution of universe	Origin of universe, big bang and particles, atom formation, star and galaxy
	Solar system and earth	Formation of solar system, dynamics of solar system, atmosphere of planet, earth
	Evolution of living thing	Birth of living things, evolution of living things, continuity of living things
Science and civilization	Information communication and new materials	Information development, information storage and management, semiconductor and new materials, mineral resources
	Human health and technology	Food resources, scientific health care, advanced science and disease treatment
	energy and environment	Energy and civilization, carbon cycle and weather change, energy issue and future

In summary, there have been continuous attempts of improving science education by revising the science curriculum in Korea. The approach targeted for inquiry-based science education, integrated science, scientific literacy, and selective science courses.

14.3.2 Science Instruction

In which ways has science instruction changed in Korea K-12 science classrooms and how does it look like now? What were the impacts of the research in science education on school science education? Unfortunately it is very difficult to get answers to the questions because there was few long-term and continuous monitoring on school science education. Then, we introduce some aspects of school science education according to the findings of research in science education.

Students and teachers use a selected textbook among several published textbooks although teachers refer to other textbooks. So, science textbooks play a critical role in science instruction in Korea. The extent and scope of motivation, content, assessment, and applications of researches are different across textbooks. For examples, researches on constructivist learning theory, misconceptions/preconceptions, and conceptual change were applied in the science textbooks developed according to the 6th science curriculum. The science textbooks included a 'Think about' activity that stimulates uncovering student ideas, inducing cognitive conflicts, and identifying problems. However, there was only one textbook that suggested core concepts in each chapter, used an assessment requesting students to draw a concept map, and summarized each chapter using concept map. The science textbooks according to the 2009 revised science curriculum included activities of discussing on socio-scientific issues and arguing in verbal and written forms with claims and evidence. They were based on the researches of argumentation and writing in science. Taken as a whole, researches in science education have been applied in the majority of science textbooks although there were differences in the extent and scope. The description of goals, teaching and learning methods, and assessment in the Korea science curriculum required the authors of science textbooks for applying the results of recent research studies. In order to pass the textbook review, the authors of the science textbooks made efforts to apply the rationale and standards described in the science curriculum. It is promising that in-service science teachers join in writing science textbooks as they have years of teaching experiences and are qualified with master or doctoral degrees in science education.

Regardless of how much good science textbooks are, the quality of science instruction would be dependent to science teacher expertise due to the diversity of teacher background and characteristics. In this respect, it is important to observe and analyze science teaching. Park and Lee (1987) studied the characteristics of high school science instruction and indicated that 92 % of the science teachers used teacher-centered lecture and giving solutions to questions as their teaching methods while 76 % of the science teachers identified inquiry and scientific attitudes as the goals of science education. There was a conflict between teacher understanding of the goals for science education and their methods to achieve those goals. The majority (92 %) of the students wanted to do laboratory experiments in science classes but they (70 %) had opportunities of doing confirmation experiments only one or two times a semester. Cho et al. (1989) also pointed that it was problematic for secondary school students to do simply hands-on activities that led them to follow directions instead of designing experiments. This would be because the majority (70 %) of the science teachers believed that scientific experiments are not related to the college entrance examination. Recently, a study observing high school science classes reported that most class time were devoted for delivering scientific concepts and providing lecture and solutions to questions using summary sheets (KICE 2009). Also, the opportunities of experiments or discussions among students were provided with only one or two times a semester as a formative assessment. The development of assessment questions was for students to be prepared for the college entrance examination and focused on the understanding of advanced concepts as like the college entrance examination.

How do the science instructions in middle schools look like? According to the research comparing Korea middle school science instruction with ones in several other countries (Korea institute of curriculum and evaluation 2008), science teachers planned proper science instruction including diverse student-centered activities based on their understanding of student prior knowledge; and stimulated student interest and motivation to the lessons. Science teachers were provided diverse teaching materials by the local school districts or the science teacher associations and collaborated to reorganize them according to the lesson goal. Students perceived that they engaged in the activities in science classes, had a close relationship with their colleagues, and were treated fairly by their science teachers. According to the survey of class participation, however, only 20 % of the students answered that they participated in questioning, answering, proposing their ideas in science classes. Further, it seemed that there were a few teacher questionings that provoked student cognitive conflicts or high level thinking and the students rarely asked questions to the teachers or with curiosity. These findings were confirmed by a research observing science classes that rarely provided students with opportunities of brainstorming or problem solving. The science teachers were implementing teacher-centered and lecture-based science instruction instead of student-centered and inquiry-based one. According to the interview with the science teachers, they seemed to believe that school science practice should target for clear and accurate answers or conclusions although scientific inquiry is important. The science teachers understood that it is important to help and guide students to construct scientific knowledge through scientific inquiry. Due to the big class size, the amount of the tasks, teacher accountability, and the multiple choice college entrance examination, science teachers considered knowledge delivery important. Because of this complexity of reality in schools, Korea science teachers were not able to achieve good science teaching in a way how they believe for good science instruction.

Then, are these the only factors that lead science teachers to depend on lecture for knowledge delivery, use few provoking questions, and give few opportunities of constructing knowledge and solving problems? Korea science teachers who are well prepared for science instruction are not able to engage students in the lesson. What would be the reasons? Researches indicated that there was a difference in the PCK between what novice science teachers perceived and what they implemented in their science instruction (Ko et al. 2009; Min et al. 2009). The PCK of the science teachers, however, have improved through reflection writing, intensive professional development programs, and interviews to reflect their own experiences. Jang and Choi's (2010) research with experienced science teachers also reported similar findings. In summary, while the Korea science teachers learned knowledge for good science teaching in the teacher education programs, they were not good enough to implement in real science instruction.

The 'TIMSS 2011 report' also indicates the problem related to the science instruction (KICE, 2012). According to the TIMSS 2011, Korea grade 8 students achieved high levels in science. However, their interest to science, perception on science and science learning, and self-confidence were at a low level. This would be the problem that Korea science education needs to solve out. Recently, there was a movement to develop new school system, 'Innovation School' initiated by one school district. The innovation school practices the education of creativity and intelligence in a democratic and autonomous learning community. The innovation school pursues critical thinking instead of knowledge competition; essay writing or process assessment compared to fact memorization; and participation and collaboration with less than 25 students in a class; and democratic decision-making with teacher autonomy. With positive responses from teachers and students, we would expect solving our current problems regarding school science education by the alternative.

14.3.3 *Science Teacher Education and Professional Development*

Science teacher education includes both pre-service teacher education and in-service teacher professional development programs. The pre-service teacher education should be to guide pre-service teachers to establish the foundations to become good science teachers and the professional development programs for in-service teachers are to help them develop professionalism.

14.3.3.1 Pre-service Teacher Education

In Korea, elementary teachers are trained at university of education and secondary teachers at the college of education in a university. As the students graduate the college of education or university of education, they earn the teacher license and should pass the teacher appointment examination to work as a teacher at public schools. The programs of the pre-service science teacher education included courses of the liberal arts, general education, science education, science content, and student teaching.

The courses related to science education have been required for pre-service teachers since the Korea National University of Education reorganized the curriculum of pre-service teacher education into general education, subject education, subject content, and student teaching in 1985. In planning a new curriculum of pre-service teacher education, the courses of subject education that were not included in the previous one were added to train professional teachers. In this respect, researches developing the contents of science education courses were activated (Cho et al. 1985; Lee 1989; Ministry of Education 1996; Park 1984).

The courses related to science education in pre-service science education programs are comprehensive and diverse now. For instance, a chemistry education program in a university in Korea opens several courses such as theoretical foundations of science education, chemistry education curriculum and assessment, science teaching material development, chemistry teaching material development, student-centered chemistry teaching methods, and actual chemistry instruction, etc. The pre-service chemistry teachers experience a number of activities in each of the courses and are introduced to the recent research studies. Minimum requirements for the pre-service chemistry teachers are three science education courses. Researches on pre-service science teachers suggest several ways to develop pre-service teachers' professionalism (Jang and Choi 2014). However, the number of science education courses that pre-service teachers could take is limited due to time constraint. It would not be enough for pre-service science teachers to develop their professionalism during the pre-service teacher education. In this respect, the professional development programs for in-service science teachers would be essential for achieving excellence in science teaching.

14.3.3.2 Professional Development for in-Service Teachers

Taking a few courses of science education during the pre-service science education would not necessarily result in science teacher professionalism. Without teaching experiences, the pre-service teachers would not fully understand the rationale of the courses related to science education and the importance of science education compared to science content. Therefore, the professional development for in-service science teachers would be essential and effective. Especially the novice in-service teachers have strong desire to develop their professionalism as they recognize lack of pedagogical content knowledge through their teaching experiences.

The professional development programs for in-service science teachers included programs provided by local school districts, education of the master or doctoral programs, and teacher-organized seminars. Most programs by school districts are provided during summer or winter break and the online sessions during academic semesters. Some professional development programs such as science laboratory experiments are requirements for teachers to take as they are essential for teaching science. There are also a number of programs for developing teacher professionalism or teacher self-determined professional development. Teachers get financial support to take professional development programs and the course credit can be counted to get promoted or merits. In this respect, the majority of science teachers take courses as professional development programs for promotion, professionalism, and self-development

There are a number of in-service teachers who study in the graduate program. For instance, 40 % of secondary teachers have master or doctoral degree. In the master program in science education, science teachers study hard for better understanding of the alignment among goals, instruction, and assessment as well as science education curriculum. Further they aim for excellence in teaching practice. They conduct research on teaching and learning and earn master degree with confidence on theory and practice of science teaching and learning.

One of the critical characteristics related to teacher professionalism is enthusiasm. Science teachers who are enthusiastic for better science teaching join the local science teacher associations and have self-organized meetings or seminars. The science teacher associations collaborate to develop science teaching and experiment materials and share them with others through the website of the teacher association. Some science teacher associations open summer or winter sessions of science laboratory experiment for voluntary participant science teachers. According to the survey by the TIMSS 2011 (KICE 2012), Korea science teachers' participations in the professional development programs were relatively high compared to the international one. This indicates the Korea science teachers' active and passionate efforts for better science teaching.

14.4 Summary

Although the history of research in Korea science education was not long, there has been an expansion in the depth and width of research in science education. The field researches as well as the theoretical researches have been conducted for the last 20 years. Then, how much did the research in science education influence on school science education? We would argue that the impacts of research in science education on science curriculum and teacher education were immediate and significant. That was probably because researchers in science education participated in the curriculum development and teacher education. However, the research in science instruction would slowly influence on K-12 school science education then it would take quite a long time for significant differences. It is challenging for science teachers to make changes in school science education because of the complex social and cultural components such as accountability, parent perception, and social expectation.

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