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Teachers' Perceptions and Practices of STEAM Education in South Korea

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This study examined teachers' perceptions and practices of science, technology, engineering, arts, and mathematics (STEAM) education in South Korea, drawing on a survey of teachers in STEAM model schools. Results showed that the majority of Korean teachers, especially experienced teachers and male teachers, had a positive view on the role of STEAM education. At the same time, Korean teachers highlighted various challenges in implementing STEAM education, such as finding time to carry out STEAM lessons, increased workloads, and lack of administrative and financial support. Our findings suggest that sufficient support from the government, the reconstruction of national curriculum, and significant changes in the national assessment system are needed to better promote STEAM education.

Keywords: STEAM education, Korean education, challenges, policy implications, K-12

INTRODUCTION

Students in South Korea (hereafter Korea) are well-known for extraordinary success in international student assessments, such as the Programme for International Student Assessment (PISA) and the Trends in International Mathematics and Science Study (TIMSS). For instance, in the most recent PISA (i.e., 2012), Korea reached the fifth highest mean score in mathematics among the 64

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PISA participating countries yet the highest among the Organisation for Economic Co-operation and Development (OECD) countries (OECD, 2014). At the same time, however, Korean students are notorious for their low levels of interest in and enjoyment of learning science and mathematics. For example, among the 57 PISA 2006 participating countries, Korean students had the second lowest level of interest in learning science (OECD, 2010). These contradictory results led Korean educators to make an effort to increase the interest of students in learning science and mathematics (Lee, Kim, & Byun, 2012).

It is in this context that, in 2011, the Korean Ministry of Education (MOE) proposed a policy on the reconstruction of Science, Technology, Engineering, and Math (STEM) education via enhancing interdisciplinary learning and adding "Arts" to STEM, which led to what is known as Science, Technology, Engineering, Arts, and Math (STEAM) (MOE, 2011). Since then, MOE has made concentrated efforts to foster successful implementation of STEAM education in elementary and secondary schools. For example, the ministry has clearly articulated the necessity and importance of STEAM education in the National Curriculum to ensure a direct connection to the planning of classroom lessons. In addition, not only have the so-called STEAM model schools and STEAM groups of teachers expanded during this period[1] but also it became mandatory for these schools to include 20% of STEAM related contents in syllabi for science, mathematics, technology & home economics, and music & art classes. Furthermore, a wide range of STEAM teaching/learning models and programs have been developed at the national level and distributed to local schools across the country (MOE, 2011).

State of the literature

- STEAM education emphasizes the convergence and integration across science, technology, engineering, mathematics (STEM) disciplines. Yet, it may increase workloads among teachers and weaken the curriculum coherence.
- Although numerous studies have examined STEAM education, most research has focused on students' attitudes towards their STEM career choices, neglecting the "arts" component.
- Little research has investigated variations in teachers' perceptions and practices of STEAM education by their background characteristics.

Contribution of this paper to the literature

- This study examines teachers' perceptions and practices of STEAM education in South Korea, drawing on a recent survey of teachers in STEAM model schools.
- The study identifies challenges that Korean teachers face when executing STEAM lessons.
- The study has important policy implications for successful implementation of STEAM education in South Korea and elsewhere.

Despite such efforts, little is known about how STEAM education is actually implemented in school. In particular, we know little about how teachers, as a key agent of policy implementation, value and practice STEAM education. In fact, most prior research on STEAM education in Korea (e.g., Kwon, Nam, & Lee, 2012; Lee & Park, 2010; Son, Jung, Kwon, Kim, & Kim, 2012; Yoon, Park, & Myeong, 2006) and elsewhere (Owen, 2000; Raines, 2012; Sahin, 2013; Silvera & Rushtonb, 2008) has focused on how STEAM education promotes students' interest in STEM majors and careers. In short, despite the high interest in STEAM education by the government and within the scientific community, scholarship on roles of teachers in STEAM education has not yet been well established (Scott, 2012; Shin & Han, 2011).

In this study, we address these issues by studying STEAM education in Korea. In particular, we are interested in investigating how Korean teachers actually practice STEAM education in the classroom. We also examine the extent to which Korean teachers value STEAM education and what challenges they face while introducing STEAM education. As such, our study aims to offer important insights into the status of STEAM education in Korea. We begin with a brief description of the Korean

[1] Starting from 16 in 2011, STEAM model schools have increased to 80 in 2012, 88 in 2013 and 252 in 2014; a concurrent increase in teachers' STEAM groups has been observed.

education system, and discuss math and science education in Korea followed by the introduction of a Korean STEAM education policy. Next, we describe the methodologies of this study and examine how Korean teachers practice and value STEAM education. Finally, the paper concludes with a discussion of the results and policy implications.

BACKGROUND

The educational system in Korea

The Korean K-12 education system represents a 6-3-3 pattern: primary (Grade 1-6), middle (Grade 7-9), and high (Grade 10-12) schools. Primary and middle school is compulsory education with no between-school tracking; almost all primary school graduates enter middle schools and receive uniform education. High school is not compulsory education and a relatively small amount of tuition is charged. When students graduate from middle schools, they are selected into academic and vocational high schools based largely on their middle school performance (Byun, Kim, & Park, 2012; Byun & Park, 2014). Academic high schools are college preparatory schools in which the majority of Korean students enroll (about 72% of all high school students in 2010). Beginning in 11th grade, academic high school students are required to choose one of the two curriculum tracks: liberal arts (humanities and social sciences) and natural sciences, where the latter track emphasizes math and science more than the former (Byun et al., 2012a; Byun & Park, 2014). Vocational high schools are schools for students who want to develop vocational skills. Traditionally, within-school curriculum tracking such as ability grouping was not widely practiced within the high school system in Korea. In recent years, however, an increasing number of secondary schools adopted within-school tracking practices (Byun & Kim, 2010).

It is important to note that in Korea, high-stakes tests play a key role in college entrance. As a result, most Korean secondary schools, especially academic high schools, heavily focus on test preparation (Byun, Schofer, & Kim, 2012). In addition, many Korean students participate in various forms of private supplementary tutoring, collectively known as shadow education (Byun, 2014; Byun et al., 2012b; Park, Byun, & Kim, 2011), to better prepare for high-stakes exams. In 2010, seven out of ten students used at least one or more forms of shadow education, and their families spent a total of approximately 19 billion US dollars on shadow education in 2010 (Korea National Statistical Office, 2011, cited in Byun, 2014). Regardless of its type, shadow education institutions focus on helping students to memorize large amounts of material for particular tests in a very short period of time, rather than fostering critical thinking (Byun, 2014; Byun et al., 2012b).

Science and mathematics education in Korea

Although Korean students show, on average, high performance on international science and mathematics assessments, their motivation for learning science and mathematics is quite low (Lee et al., 2010). Furthermore, research suggests that many Korean students do not value science and mathematics and instead have negative attitudes towards learning science and mathematics (Kim et. al., 2012; Park, 2007). Among others, the educational system's focus on test preparation has been cited as the main source of this issue (Lee et al., 2010). Indeed, much of Korea's science and mathematics education used to focus on the memorization of knowledge and the repetition of problem solving exercises, rather than on developing students' higher order thinking and creativity. The assessment of science and mathematics was also tied to testing memorization. In addition, there was a lack of diversity in instructional methods for mathematics education. In other words, various approaches such as hands-on activity, inquiry, and connection to real life situations were not widely used.

To address these issues, there have been increasing efforts to reform science and mathematics education in Korea. For example, MOE announced the first National Mathematics Education Advanced Plan in 2012 and the second Mathematics Education Comprehensive Plan in 2015. One of the common directions of the Mathematics Education Plans in both years was to implement integrated education such as STEM/STEAM. In the field of science education, STEAM education is considered an effective educational strategy to resolve problems faced by Korea's science education. The following section further describes STEAM education in Korea.

STEAM education in Korea

STEAM education in Korea aims at seeking the convergence of educational foundation and motivation by encouraging self-directed learning and inspiring the enjoyment of learning, as well as connecting contents to the learning experiences of individuals (Baek et al., 2011; Park et al., 2012). Korean STEAM education highlights three components: (a) creative design, (b) emotional touch, and (c) convergence and integration of contents (Baek et al., 2011; KOFAC, 2014). Here, creative design refers to the comprehensive process by which the learner demonstrates creativity, efficiency, and an economic and aesthetic sense to find the optimal solution to a problem. It includes the concept of engineering, which refers to a technological design and a creative problem-solving skill for the shared values of humanity (Jarratt et al., 2011; Kelley, Brenner, & Pieper, 2010).

Open-endedness and collaboration are the nature of creative design (Apedoe et al., 2008; Householder & Hailey, 2012; Hynes et al., 2011). Open-endedness encourages creative approaches by students, and includes the process of reflection. The collaborative nature of this process allows for enhanced communication and consideration among students through hands-on and hands-in collaborative activities. The creative design also includes a provision of educational opportunities for students to experience the entire self-directed process until the final product of learning is applied in practice.

Emotional touch, on the other hand, refers to experiences that enable a positive cycle of self-directed learning where students feel interest, confidence, intellectual satisfaction and a sense of achievement, as they find motivation, passion, flow and personal meaning in learning. Emotional touch also includes the formation of a clear and actual relationship between the learner and the subject, where the learner perceives the subject as a personal objective. This emotional touch addresses elements that are often neglected in education.

Affective factors that influence learning are more cultivated compared to intellectual characteristics and are susceptible to change through learning. This means that the causal factors behind academic performance lie more in affective characteristics than in intellectual capabilities. An increasing number of studies indicates that affective characteristics of learners should be taken into account as an important determinant of learning. Creativity and values are demonstrated through the process of collaboration and competitiveness in groups based on a positive self-image (Fang, 2013). Thus, cognitive and affective development should be organically connected in the process of learning based on emotional touch and the experience of positive cycles. Finally, integration and convergence of content aims at connecting the contents of study to real life in a holistic perspective.

The creative design is the process by which students (as an individual or a group) have the experience of solving problematic situations in a self-directed and creative manner. Students feel a sense of accomplishment through the experience of the self-directed problem solving, while having an emotional experience that inspires courage and confidence in solving future challenges. The core of STEAM education in Korea lies in designing one's own thoughts and attempting to understand the tendencies of others through various learning situations. STEAM education goes beyond the concept of convergence as it has been detailed so far in subject content. The planning of lessons to provide innate rewards to students through creative design, emotional touch, and content convergence and integration is an important factor in STEAM education. Yet, little is known about how Korean teachers actually practice STEAM education in a classroom setting.

Prior literature and its limitations

With an increasing interest in STEAM education, a number of studies have examined teachers' perceptions and their practices of STEAM education (e.g., Han & Lee, 2012; Lee, Park, & Kim, 2013; Lim & Oh, 2015; Lim, Kim, & Lee, 2014; Noh & Paik, 2014; Shin, 2013; Shin & Han, 2011). These prior studies suggest that the majority of teachers think that STEAM education is needed (Han & Lee, 2012; Lim & Oh, 2015; Shin & Han, 2011), and that STEAM education would have a positive impact on students' motivation and learning (Lee, Park, & Kim, 2013; Lim & Oh, 2015; Shin & Han, 2011). However, some research found a significant gap between teachers' perceptions and actual practices of STEAM education. For example, using survey data for 987 elementary and secondary school teachers in a metropolitan region, Shin (2013) found that although the majority of Korean teachers (about 65%) agreed on the necessity of STEAM education, only about 18% actually implemented STEAM lessons in their class.

Other studies investigated challenges and difficulties teachers face to implement STEAM education. Research identified difficulties in finding time for preparing STEAM lessons, insufficient instructional materials, and a lack of teachers' expertise on STEAM education as major problems in implementing STEAM lessons (Han & Lee, 2012; Lee, Park, & Kim, 2013; Lim & Oh, 2015; Shin, 2013). A lack of understanding of the relation among STEAM content areas for content convergence and difficulty in cooperating with other teachers were also cited as challenges in implementing STEAM lessons (Lee, Park, & Kim, 2013; Noh & Paik, 2014).

Although prior literature offers important information with respect to teachers' perceptions and their practices of STEAM education, much remains to be unknown. For example, we know little about how and when teachers actually introduce STEAM lessons, and how teachers' practices of STEAM education differ, if any, by their background characteristics. Likewise, little is known about the association between perceived challenges and teachers' background characteristics.

The current study

In this study, we address this gap in the existing literature by examining teachers' perceptions and practices of STEAM education in Korea. The current study was guided by four research questions:

1. How and when do teachers introduce STEAM lessons in their class?
2. How do teachers perceive STEAM education and its potential impact on the student learning?
3. What challenges do teachers face when implementing STEAM education?
4. How do teacher's background characteristics (i.e., school level, gender, teaching experiences) relate to their perception of STEAM education?

DATA AND METHODS

Data and sample

To address these research questions, we used data collected as part of the Korea STEAM Education Project, which aimed at understanding the current status of STEAM education. This project surveyed 729 teachers who practiced STEAM education in 252 STEAM model schools across the country during the fall of 2014. Each participating teacher spent about 30 minutes completing the on-line survey (developed by our research team) which consists of 38 items asking about the frequencies of the use of STEAM, attitudes towards STEAM education, challenges and difficulties that teachers faced when implementing STEAM, and teachers' expectations for and satisfactions with STEAM education. Participating teachers were also asked about their demographic characteristics (e.g., gender, years of teaching experiences). Item formats were either selected multiple-choice response (presenting several statements from which teachers were required to choose one) or open-ended questions. For the current investigation, we excluded 24 cases whose demographic information was missing. This resulted in the analytic sample of N = 705.

Measures

Demographics

We were interested in whether and how teachers' practice and perception of STEAM education differed in terms of (a) the school level, (b) gender of the teacher, and (c) years of teaching experience. The school level was based on teachers' self-report of whether they taught in (a) elementary school, (b) middle school, and (c) high school. Gender was based on teachers' self-report of their sex. Years of teaching experience was based on teacher's self-report (1 = 1-5 years, 2 = 6-10 years, 3 = 11-15 years, 4 = 15 years and more).

Teachers' practice of STEAM lessons

Measures of teachers' practice of STEAM lessons included (a) the frequency of the use of STEAM lessons, (b) the type of curriculum, and (c) the subject in which teachers taught STEAM lessons. The frequency of the use of STEAM lessons was measured by teachers' self-report on how many times they taught STEAM lessons per month (1 = 1-2 lessons, 2 = 3-4 lessons, 3 = 5-6 lessons, 4 = every lesson, and 5 = others). The type of curriculum was measured by teachers' report of the curriculum in which they taught STEAM lessons (1 = extracurricular activity, 2 = afterschool program, 3 = regular curricular, 4 = special activity, and 5 = others). Finally, the subject in which teachers taught STEAM lessons was based on teachers' report as well (e.g., science, math, Korean language, and etc.).

Teachers' perception of STEAM education

We were interested in how teachers perceived (a) STEAM education, (b) its potential impact, and (c) challenges they faced. Teachers' overall perception of STEAM education was based on their response on the following three items: (a) "I think that STEAM education is needed," (b) "I recommend STEAM education to my peer teachers," and (c) "I am willing to continue to use STEAM education." Teachers were required to respond on a five-point scale of disagreement-agreement, and the average score of the three items was used to represent teachers' perception of STEAM. Item factor loadings ranged from .77 to .94. Reliability statistics (i.e., Cronbach's alpha) were .92. Teachers' perception of the potential impact of STEAM education was measured by averaging the responses of the following three items: (a)

Table 1. The distribution of teachers by school level, gender, and years of teaching experiences

		School Level			
		Elementary school	**Middle school**	**High school**	**Total (% of row)**
Gender					
Male	N	122	69	75	266
	% (column)	34.5	33.3	52.1	37.7
Female	N	232	138	69	439
	% (column)	65.5	66.7	47.9	62.3
Total	N	354	207	144	705
	% (column)	50.2	29.4	20.4	100.0
Years of teaching experiences					
1-5 years	N	73	45	27	145
	% (column)	20.6	21.7	18.8	20.6
6-10 years	N	85	38	22	145
	% (column)	24.0	18.4	15.3	20.6
11-15 years	N	87	37	31	155
	% (column)	24.6	17.9	21.5	22.0
15 years or more	N	109	87	64	260
	% (column)	30.8	42.0	44.4	36.9
Total	N	354	207	144	705
	% (cloumn)	50.2	29.4	20.4	100.0

"STEAM education has a positive impact on convergent thinking," (b) "STEAM education has a positive impact on creativity," and (c) "STEAM education has a positive impact on character building." Likewise, participants were asked to choose a response from a five-point scale of disagreement-agreement. Item factor loadings ranged from .74 to .91, and the reliability statistics were .89. Finally, teachers' perception of challenges in implementing STEAM education were based on their responses on a five-point scale of disagreement-agreement in the following aspects: (a) lack of administrative and financial support, (b) difficulties in finding time for preparing STEAM lessons, (c) increased workloads, and (d) difficulties in using new media and experimental equipment. Note that unlike the items used to measure teachers' perception of STEAM education and its potential impact, we examined each aspect separately to better understand the challenges that teachers face when implementing STEAM education.

Analytic strategy

We first conducted cross-tabulate and chi-square analyses to examine differences in teachers' practice and perception of STEAM education by school level. Next, given the continuous measure of the dependent variables, we additionally conducted ordinary least squares (OLS) regression analysis of teachers' perception of STEAM education. The aim was to see whether the school level was associated with teachers' perception of STEAM education, after controlling for gender and years of teaching experience. Results from this OLS regression were also expected to inform whether and how teachers' gender and years of teaching experience were related to their perception of STEAM.

RESULTS

Characteristics of the teacher sample

Table 1 presents the proportion of teachers by school level, gender, and years of teaching experience. To briefly summarize, out of 705 teachers, approximately 50% were elementary teachers, and 29% and 20% were middle and high school teachers, respectively. Approximately 62% were female. The proportion of male teachers was relatively higher among high school teachers (52%) than elementary (35%) and middle (33%) school teachers. In terms of years of teaching experience, approximately 37% taught for 15 years or more, while 21% did so for 1-5 years. The proportion of teachers who taught for 15 years or more was relatively higher among middle (42%) and high (44%) school teachers, compared to elementary school teachers (31%).

Teachers' practice of STEAM lessons

Table 2 presents the distributions of the frequency of the use of STEAM lessons, the type of curriculum, and the school subject across different levels of the school system. Overall, approximately half of the surveyed teachers indicated that they carried out one or two STEAM lessons per month. In addition, approximately 21% indicated carrying out three to four lessons per month and approximately 11% indicated carrying out five to six lessons per month. Furthermore, approximately 7% reported that they implemented STEAM education in every lesson. However, there were some differences in the frequencies of the use of STEAM lessons by school level, χ^2 (8, N = 705) = 96.34, p = .000. For example, approximately 19% of elementary school teachers stated that they carried out five or six STEAM lessons per month and this percentage was more than five times higher than the corresponding percentage for middle (3%) and high (3%) school teachers.

In terms of the type of curriculum where teachers implemented STEAM education, about seven out of ten teachers reported that they used the regular curricular time for STEAM lessons. Yet there were some variations in the type of curriculum used for STEAM education across school levels, χ^2 (8, N = 705) = 137.65, p = .000. For example, approximately 66% and 74% of elementary and middle school teachers, respectively, indicated that they taught STEAM lessons during regular sessions, whereas only about 50% of high school teachers did so. In addition, only about 3% of elementary school teachers used the extracurricular activity time for STEAM education, while approximately 12% and 23% of middle and high school teachers, respectively, did so. In addition, the percentage of teachers using after-school hours for STEAM lessons was approximately 14% among high school teachers, whereas the corresponding proportions were approximately 2% and 4% among elementary and middle school teachers, respectively.

Finally, in terms of the distribution of the school subject in which teachers taught STEAM lessons, about six out of ten teachers implemented STEAM education in science classes. However, there were pronounced differences by the level of school system, χ^2 (10, N = 705) = 142.13, p = .000. Specifically, 75% of elementary school teachers chose science as the core subjects in which they taught STEAM lessons, whereas only 25% and 49% of middle and high school teachers, respectively, did so. It is interesting to note that among middle school teachers, the most popular choices following science were technology and home economics (14%) and mathematics (11%). Among high school teachers, mathematics (10%) was the second most popular choice following science.

Teachers' perception of STEAM education

Now we turn to how Korean teachers perceived STEAM education and its potential impact on the student learning as well as challenges in implementing STEAM lessons.

Table 3 presents descriptive statistics for teachers' perception of STEAM education by school level. Overall, most teachers agreed that STEAM education is needed (M = 4.28, SD = .70). In addition, the majority of teachers agreed that STEAM education would potentially have a positive impact on the student learning, such as convergent thinking, creativity, and character building (M = 4.33, SD = .65). However, at the same time, many teachers reported that they had difficulties in finding time for preparing STEAM lessons (M = 3.79, SD = 1.08) and that STEAM education tended to increase their workloads (M = 3.77, SD = 1.03).

Table 2. Teachers' practice of steam lessons by school level

		School Level			Total (% of row)	χ^2
		Elementary school	Middle school	High school		
Frequency						96.34***
Every lesson per month	N	29	11	12	52	
	% (column)	8.2	5.3	8.3	7.4	
1-2 lessons per month	N	153	120	81	354	
	% (column)	43.2	58.0	56.3	50.2	
3-4 lessons per month	N	96	34	19	149	
	% (column)	27.1	16.4	13.2	21.1	
5-6 lessons per month	N	66	7	5	78	
	% (column)	18.6	3.4	3.5	11.1	
Other	N	10	35	27	72	
	% (column)	2.8	16.9	18.8	10.2	
Total	N	354	207	144	705	
	% (column)	50.2	29.4	20.4	100.0	
Type of curriculum						137.65***
Extracurricular Activity	N	11	24	33	68	
	% (column)	3.1	11.6	22.9	9.7	
After Schools Program	N	6	8	20	34	
	% (column)	1.7	3.9	13.9	4.8	
Regular Curricular	N	233	153	72	458	
	% (column)	65.8	73.9	50.0	65.0	
Special Activities	N	98	10	12	120	
	% (column)	27.7	4.8	8.3	17.0	
Other	N	6	12	7	25	
	% (column)	1.7	5.8	4.9	3.6	
Total	N	354	207	144	705	
	% (column)	50.2	29.4	20.4	100.0	
Subject						142.13***
Science	N	264	52	71	387	
	% (column)	74.6	25.1	49.3	54.9	
Math	N	8	23	14	45	
	% (column)	2.3	11.1	9.7	6.4	
Korean	N	9	18	8	35	
	% (column)	2.5	8.7	5.6	5.0	
Social Studies	N	7	18	7	32	
	% (column)	2.0	8.7	4.9	4.5	
Technology and Home Economics	N	12	29	7	48	
	% (column)	3.4	14.0	4.9	6.8	
Other	N	54	67	37	158	
	% (column)	15.3	32.4	25.7	22.4	
Total	N	354	207	144	705	
	% (column)	50.2	29.4	20.4	100.0	

Next we examine whether teachers' perception of STEAM education differed by school level, gender, and years of teaching experiences. Table 4 presents the results from the OLS regression. Results showed that there were significant differences in teachers' perception of STEAM education by school level, gender, and years of teaching experiences. Specifically, middle and high school teachers tended to have a more negative view of STEAM education, compared to elementary school teachers. In other words, elementary school had the most positive view of STEAM education. In addition, female teachers had a more negative view of STEAM education, compared to male teachers. Finally, teachers who taught for 15 years or more had a more positive view, compared to teachers who taught for one to five years.

There were also significant differences in teachers' perception of the potential impact of STEAM education by school level and years of teaching experiences. For example, middle and high school teachers had a more negative view of the potential impact of STEAM education on student learning, compared to elementary school teachers. In addition, teachers who taught for 15 years or more had a more positive view of the potential impact of STEAM education, compared to teachers who taught for one to five years.

Table 3. Teachers' perception of STEAM education by school level

	School Level						Total	
	Elementary school		Middle school		High school			
	M	SD	M	SD	M	SD	M	SD
STEAM education	4.28	0.70	3.78	0.80	3.83	0.91	4.04	0.81
Potential impact of STEAM education	4.33	0.65	3.88	0.74	3.96	0.83	4.12	0.75
Challenge								
A lack of administrative and financial support	3.45	1.09	3.34	0.96	3.49	0.97	3.43	1.03
Difficulties in finding time for preparing STEAM lessons	3.79	1.08	3.86	0.92	3.84	0.95	3.82	1.01
Increased workloads	3.77	1.03	3.83	0.92	3.90	0.94	3.81	0.98
Difficulties in using new media and experimental equipment	3.45	1.11	3.44	0.96	3.49	0.95	3.46	1.03
	354		207		144		705	

Table 4. Regression analysis of teachers' perception of STEAM education

	STEAM Education		A potential impact of STEAM education		Challenge							
					(a) A lack of administrative and financial support		(b) Difficulties in finding time for preparing STEAM lessons		(c) Increased workloads		(d) Difficulties in using new media and experimental equipment	
Variable	**B**	**SE**	**B**	**SE**	**B**	**SE**	**B**	**SE**	**B**	**SE**	**B**	**SE**
School level												
Elementary (ref.)												
Middle	-0.51***	0.07	-0.46***	0.06	-0.08	0.09	0.09	0.09	0.08	0.09	0.00	0.09
High	-0.49***	0.08	-0.41***	0.07	0.05	0.10	0.10	0.10	0.19*	0.10	0.09	0.10
Female	-0.17**	0.06	-0.07	0.06	-0.07	0.08	0.09	0.08	0.20*	0.08	0.21*	0.08
Years of teaching												
1-5 years (ref.)												
6-10 years	0.01	0.09	0.01	0.08	0.20	0.12	0.18	0.12	-0.05	0.11	0.18	0.12
11-15 years	0.06	0.09	0.09	0.08	0.09	0.12	-0.06	0.12	-0.03	0.11	0.13	0.12
15 years or more	0.16*	0.08	0.18*	0.07	-0.05	0.11	-0.13	0.11	-0.19	0.10	0.09	0.11
Constant	4.32***	0.08	4.30***	0.08	3.44***	0.11	3.74***	0.11	3.72***	0.11	3.21***	0.11
R-squared	0.105		0.093		0.013		0.015		0.020		0.012	
N	705											

In terms of challenges perceived by teachers, there were some significant differences by school level and gender. For example, high school teachers had more concerns about increased workloads than did elementary school teachers. In addition, female teachers also had more concerns about increased workloads than did male teachers. Female teachers were also more likely than male teachers to report difficulties in using new media and experimental equipment.

DISCUSSION AND CONCLUSION

Using data from 705 STEAM model school teachers in Korea, we examined how Korean teachers actually taught STEAM lessons and how they perceived STEAM education and its potential impact on the student learning. We also investigated challenges that Korean teachers faced when introducing STEAM education. Given the lack of scholarly attention to the roles of teachers as a key agent of policy implementation, the current study generates new information that can extend our knowledge about STEAM education in Korea, even though our results may not be generalizable to all Korean school teachers.

Key findings

To highlight several key findings, first, we found that elementary school teachers most frequently used STEAM education in their class, followed by middle and high school teachers. Furthermore, we found that a much higher proportion of elementary school teachers taught STEAM lessons during science class, compared to secondary school teachers.

Second, we found that the majority of Korean teachers had a positive view of STEAM education. Additionally, the majority of Korean teachers believed that STEAM education would help to promote the student learning in terms of convergent thinking, creativity, and character building. Specifically, elementary school teachers had the strongest belief in the potential positive role of STEAM education in promoting student learning. These findings support prior findings of the positive views of Korean teachers towards STEAM education (Han & Lee, 2012; Lee, Park, & Kim, 2013; Lim & Oh, 2015; Shin & Han, 2011).

Third, we found that finding time and added workload were the most serious challenges for Korean teachers to implement STEAM education. In particular, high school teachers showed more concerns about increased workloads, compared to elementary school teachers. In addition, we found that a substantial proportion of teachers highlighted lack of administrative and financial support for implementing STEAM lessons. Finally, we found that beginning teachers and female teachers tended to have a more negative view of STEAM education, compared to their experienced and male counterparts.

Policy implications for Korea and other countries

Our result showed that elementary school teachers had a more positive view of STEAM education and more frequently practiced STEAM lessons during regular classes compared to secondary school teachers. This finding suggests that STEAM lessons could be more easily implemented within the elementary curriculum. On the one hand, this finding may be explained by the fact that there is much less pressure on test preparation in elementary schools compared to secondary schools. In other words, because secondary school lessons should be more directly related to test preparation for college entrance exams, it would be a burden for secondary school teachers to conduct STEAM lessons as frequently as elementary teachers during regular class sessions.

On the other hand, the finding could be explained by the nature of curriculum in teacher education programs in Korea. In Korea, pre-service elementary school teachers are trained to cover all school subjects, whereas most of the secondary school teachers are trained to teach one specialized school subject. Given this nature of training in teacher education programs as well as the feature of STEAM lessons, elementary school teachers may feel more confident in implementing STEAM lessons than do secondary school teachers. If the latter were the case, one policy implication for STEAM education would be to revise the curriculum in secondary teacher education programs and to enhance collaborations among secondary teachers across school subjects.

Korea's national curriculum framework in K-12 should also be restructured to incorporate more STEAM education. This is because Korean teachers may not perceive STEAM education as extra work if the national curriculum reflects major components of STEAM education. In fact, the Next Generation Science Standards (NGSS) in the United States suggests a similar idea by claiming that the science education curriculum should be reflective of STEM education and integrate engineering into the K-12 science curriculum (NGSS, 2013). Specifically, NGSS (2013) suggests that the major concepts of engineering should be introduced as an important part of scientific exploration in the K-12 science class, rather than as a separate entity. NGSS (2013) also suggests that students' performance on engineering should not be assessed separately from science.

Our result also showed that many Korean teachers had a positive view of STEAM education, believing that it would have a positive impact on students' learning outcomes. This finding is quite promising, given that teachers play a key role in policy implementation. Yet, a question that remains to be answered is how STEAM education can be effectively implemented within the existing school system that highly focuses on test preparation. Together, our findings indicate that Korean teachers may perceive teaching STEAM lessons as extra work load unless there are additional administrative and financial support, reconstruction of national curriculum, and significant changes in the national assessment system.

In sum, even though there were some differences across different levels of the school system, most of Korean teachers agreed on the importance of STEAM education. They acknowledged that STEAM education would help to foster students' interest in science and mathematics, to enhance students' convergent thinking and creativity, and to improve students' understanding of core subject contents. At the same time, however, teachers highlighted difficulties and constraints of implementing STEAM education in the Korean context. Therefore, in order for STEAM education to succeed in Korea, additional governmental and institutional support should be provided with the revision of national curriculum and assessment.

Although we focused on Korea, our study also has broader implications for STEAM education beyond this country. Our results suggest that Korean teachers may regard STEAM education as extra work and be less willing to implement STEAM education unless STEAM education is a part of regular teaching loads. This is likely true for teachers in other countries. In other words, teachers elsewhere may not have a legitimate reason to implement STEAM lessons unless STEAM education is integrated into the school curriculum. In this regard, STEAM education would be more successful and sustainable when STEAM education is part of the regular curriculum.

Limitations of the study and directions for future research

The present study points to several fruitful directions for future research. The focus here was teachers' perspectives, but a full analysis of all different stakeholders, including principals, parents, and students, is a topic ripe for future research. In addition, we provided only descriptive results based on non-representative data for Korean teachers. In other words, our data were drawn from STEAM model teachers and schools selected by MOE, and their responses might be biased upward. A more sophisticated analysis with representative data for teachers will allow us to more fully understand conditions under which teachers most effectively implement STEAM education. Most importantly, future research should examine how STEAM education achieves its proposed goals by examining its effect on students' interest in learning science and mathematics.

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