

Consultant Report Securing Australia’s Future STEM: Country Comparisons

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STEM Report – Republic of Korea

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Introduction

Apparently Korean students have made outstanding achievements in math and science, according to international student assessment results, TIMSS (Trends in International Mathematics and Science Study) and PISA (Programme for International Student Assessment), as well as achievements from the International Science Olympiads (Korea Foundation for the Advancement of Science and Creativity (KOFAC), 2011). In the 2007 TIMSS, Korea ranked second in math and fourth in science, following other Asian countries such as Taiwan, Singapore, and Japan. In the 2009 PISA, Korea ranked fourth in math and sixth in science. These scores have also increased steadily, compared to previous assessment results. In addition, at the 2011 International Science Olympiads, Korea won first place in physics, astronomy, and earth science; second place in junior science; 6th place in informatics; and 13th and 17th place in math and biology, respectively.

However, Korean students' low level of interest, enjoyment, and confidence in science and math, as well as their motivation for and valuation of science and math were overall lower than the average, in both PISA and TIMSS (Cho et al., 2012).

Accomplishments made by Korea in science and technology are also considered to have played a key role in the rapid and marvelous economic development of Korea over the past 60 years. In fact, the Korean government concluded that the country's competitiveness in science and technology has contributed to Korea's achievement of a globally recognized higher status (Ministry of Education, Science, and Technology (MEST), 2012a).

Nevertheless, the recent perceptions regarding science and technology in Korean society have brought about concerns regarding a crisis in science and engineering. For example, the issue of avoiding the science and engineering fields in Korean society has received great attention from the government, media, and society.

Against this backdrop, the Korean government has initiated policies and strategies 1) to elevate students' interest in science and math so that they will choose to study and work in science and engineering; and 2) to educate talented human resources in science and technology so that national competitiveness and development can be advanced. Among the various policies and programs related to science and technology by the Korean government, STEAM education, which has added art to STEM, deserves attention here. STEAM education is particularly expected to address the issue of avoiding science and engineering in Korean society (Lee, H. et al., 2012). This topic will be further discussed later in this report.

1.1 Attitudes towards STEM, and the priority given to STEM, in: families, the community/media, government, educational institutions, employers and professional bodies.

1.1.1 Increased interest but avoiding science and engineering?

Over the past decade, Korean people have increased their interest in science and technology (KOFAC, 2011; Oh, 2012), as illustrated in Figure 1. Their interest in new scientific discoveries and the use of new inventions and technology has gradually grown. The reasons for their interest include the relevance of science and technology to their daily lives, the acquisition of new knowledge, and media influence. According to a comparative study among China, Japan, and Korea, Koreans consider science and technology as the most important job for the development of a society. The Japanese also show similar results, but the degree of importance is higher than that for Koreans (55.6% vs. 36.3%). The level of Koreans' interest in science and technology is higher than that of the Chinese, but still lower than those of Americans and the Japanese. More importantly related to the issue of avoiding science and engineering, Koreans prefer the careers of government officials, teachers, and doctors far more than those in science and technology (see Table 1). These results show that overall, Koreans have become more interested in STEM and consider it important for Korean society; however, they do not necessarily prefer to pursue STEM-related professions for themselves.

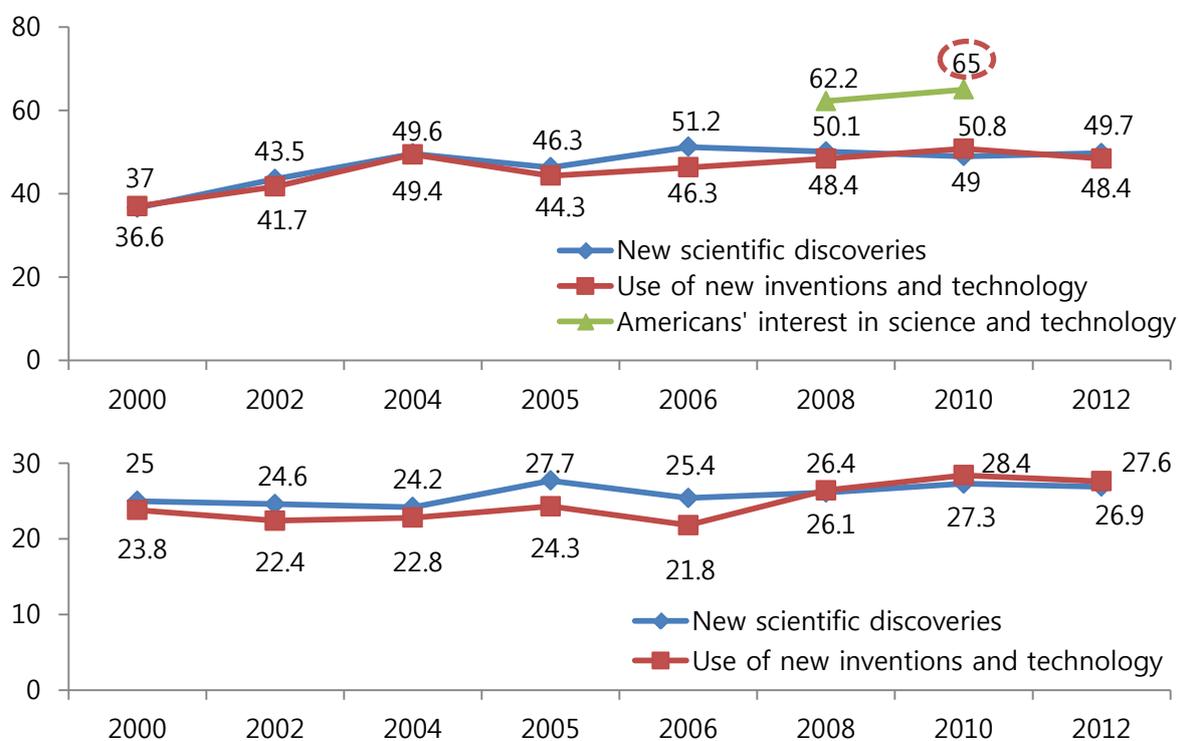


Figure 1. Level of interest and understanding in science and technology (Oh, 2012)

Table 1. Korean's job preferences

	Government officials	Teachers	Doctors	Science and technology	Business	Law	Journalism
Adults	25.6%	19.8%	17.4%	11.7%	9.6%	7.3%	4.2%
Adolescents	17%	16.4%	23.2%	11.8%	9.8%	7.4%	9.0%

Source: Oh (2012)

The kind of attitude that Koreans hold toward STEM can be seen again in one of the most significant issues related to STEM in Korean society: **Avoiding the STEM fields.**

The discourse of the crisis in science and engineering has been widespread since 2000, due to the phenomenon of avoiding science and engineering as fields of study and career paths (Song et al., 2008). The number of high school graduates choosing to study the natural sciences had decreased, and especially academically outstanding students tend to apply for programs in medicine more than before (Park et al., 2011). At the same time, the tendency for those who studied science and engineering as undergraduates to choose different fields for their future careers, such as medicine, has increased (Kim, 2010). In addition, more doctorates from overseas institutions, particularly from the U.S., prefer to stay abroad rather than return to Korea. In effect, the IMD Brain Drain Index has become worse over the last couple of decades (Kang, 2011).

While it is still debatable whether the field of science and engineering is truly in crisis, considering the matching rate between academic majors and jobs, the employment rate, and the level of wages (Park et al., 2011), even experts in science and engineering admit its seriousness. They also anticipate that this crisis will become worse in the future (Jin et al., 2012). Therefore, the following issues need attention with respect to this phenomenon for STEM in Korea.

First, it is widely perceived in Korean society that those working in science and engineering are not well respected any longer, nor are they financially well rewarded, especially considering the workload (Lee, W. et al., 2011; Oh, 2012; Jin et al., 2012). This perception was also discovered among students in science high schools and college students in science and engineering majors (Kang, 2011). In this case, people tend to compare jobs in science and engineering with those in medicine, law, and accounting.

Second, jobs in science and engineering are considered as unstable. One of the reasons for this perception can be attributed to the unstable status of government-affiliated research institutes upon the change of past regimes (Kim, 2010). In addition, the low satisfaction of those working in the science and technology industries has led them to move their jobs to higher education institutions (Park et al., 2010). Thus, they have very limited choices for career options. Moreover, the proportion of temporary jobs and those based on contracts has increased, especially those at the postdoctoral level of research positions in higher education institutions, which receive low levels of payment.

Third, as mentioned above, it is evident that high school students with excellent academic records tend to prefer studying medicine. Those already in science and engineering also plan to pursue careers outside of science and engineering (Park et al., 2010).

Lastly, traditional Korean culture, which respects scholars but disdains technicians and farmers, could be influential in shaping this phenomenon to some degree (Jin et al., 2012; Kim, 2010).

1.1.2 Families

Overall, families in Korea appear to have generally positive attitudes toward STEM, but this can differ by children’s gender and their choices for college entrance exams. According to a policy needs analysis, parents were very supportive of their children seeking to study or work in science and technology, as shown in Table 2 (Lee, H. et al., 2011). In another study, college students in the humanities and social sciences similarly answered that they would respect their children’s decision to study STEM. However, they added that they would rather encourage daughters to choose different fields (Lee, W. et al., 2011). Surprisingly, experts in the field of science and engineering did not want to recommend their field to their own families and friends (Jin et al., 2012).

Table 2. Encouraging children to seek future careers in science and technology

	By gender			By employment		
	Females	Males	Total	Parents	Teachers	Total
Yes, I will	126(88.7%)	35 (89.7%)	161 (89.0%)	67 (90.5%)	94 (87.9%)	161 (89%)
No, I won't	16(11.3%)	4(10.3%)	20(11%)	7(9.5%)	13(12.1%)	20(11%)
Total	142(100%)	39(100%)	181(100%)	74(100%)	107(100%)	181(100%)

Source: Lee, H. et al. (2011)

Interestingly in the context of Korean education, parents’ attitudes toward STEM education can also depend on changes in the system of the college entrance exam (Lee & Chun, 2012). Whether certain science subjects are elected as required for college entrance exams, nationwide or at certain top institutions, can predetermine the choice and investment by students, parents, and schools to learn certain STEM subjects.

1.1.3 Community/media

Media coverage on the excessive workloads of people working in IT was sensationalized in Korean society several years ago. Sarcasm was used to imply that IT employees work Monday, Tuesday, Wednesday, Thursday, Friday, Friday, and Friday, without weekends. Rocket launch trials, which failed in November 2012, were also an important topic in the media. It is difficult to determine the attitude of the media toward STEM, but it does not seem to be very positive.

1.1.4 Government

As will be discussed in Sections 1.2 and 1.7, the Korean government has shown tremendous interest in and emphasis on STEM for its economic development since the 1960s. Its recent projects for Korean higher education, such as BK21 and WCU, have also tended to concentrate more on science and engineering than on the humanities and social sciences.

Another example demonstrating governmental attitudes toward STEM is that of the past Lee, Myung-Bak administration (2008-2013), which established the Ministry of Education and Science Technology (MEST) by combining the Ministry of Education & Human Resources with the Ministry of Science & Technology in 2008. This sensational determination aimed to cultivate creative talents through connecting education with science and technology. This decision intended to generate synergy by merging primary, secondary, and higher education with R&D in science and technology.

In the beginning, the synergy effect among sectors in a new ministry did not meet expectations. In order to solve this problem, the Science & Technology Human Resources Office, a department dedicated to the development of talented individuals in science and technology, was set up in February 2011, and other organizational reforms were made across the board in MEST. As a result, policies aimed at merging the two sectors of education, as well as science and technology, were formulated for each sector. One of these policies was STEAM, the representative program created for the purpose of integration, as well as for the reform of the science and math curriculum (Lee, J. et al., 2011).

However, after much criticism, including the failure of the rocket launch in November 2012, the incoming Park, Geun-Hye administration (2013-2018) announced that it would divide MEST again into the Ministry of the Future, Creativity, and Science, and the Ministry of Education. The special taskforce for ICT will be created under the new ministry for science.

1.1.5 Educational institutions

What top universities require for their student recruitment can influence STEM education in high school, which eventually influences the level of math and science by incoming students.

Higher education institutions have also participated in STEM education prior to college. After MEST signed an MOU with five universities specialized in science and technology – KAIST, GIST (Gwangju Institute of Science and Technology), DGIST (Daegu Gyeongbuk Institute of Science and Technology), and UNIST (Ulsan National Institute of Science and Technology), these institutions made mutual exchanges in different fields, including joint operations of the Advanced Placement (AP) Program in affiliation with science high schools and schools for the gifted and talented (MEST & KOFAC, 2012). The government also plans to establish a support system for

expanding exchanges between elementary and middle schools and those outside of schools, e.g., companies, universities, and government-funded research institutes.

1.1.6 Students

Korean students' attitudes toward STEM are mixed. Students at all levels of education have generally considered STEM education to be difficult and in need of improvement. Students in science high schools or college students majoring in science and engineering have shown their satisfaction with STEM education and have planned their future careers in these fields. Nevertheless, they also agree with the perceptions of lower financial rewards and less social respect in science and technology jobs, compared to those in medicine. Factors affecting these kinds of students' attitudes toward STEM include the following: 1) STEM curriculum structure prior to college in terms of the level of difficulty, workload, and relationship with college entrance exams; 2) students' aptitude for STEM subjects; and 3) social perceptions of jobs, focusing on the level of income and job stability.

Students in primary and secondary education

In general education at the primary and secondary levels of education, students have been gradually losing their interest in science classes, but feel more pressure about them. In a national study conducted by the Korea Science Foundation in 2003, students in primary and secondary education showed low levels of interest and satisfaction in science classes (Korea Science Foundation, 2004). Their level of satisfaction continued to decrease by the level of education, from 56% in elementary school, 45% in middle school, and 32% in high school. Lee, H. et al.'s (2011) study also confirmed the same trend.

Seo (2007) attributed the reason for this trend to the reduced number of hours for science classes with the relatively extensive and unchanging amount of lessons to cover. This issue has been pointed out as problematic in causing students to experience difficulty in science classes, and eventually problematic in avoiding science and engineering majors in tertiary education. However, the number of hours for science classes has still continued to decrease in subsequent curriculum reforms (KOFAC, 2009). In addition, female students at the secondary level of education do not have enough information about pursuing future studies and careers in the fields of science and technology (Lee, H. et al., 2011).

Still, students in science high schools and high schools for the gifted and talented in science appear to have generally positive attitudes toward education for science (Jin et al., 2012; Lee et al., 2011). In both studies, they were overall satisfied with their education and schools, especially with their teachers. More than 80% of them also hoped to major in the natural sciences and engineering at colleges and universities. However, they also admitted that a medical career would be more financially rewarding than one in science or engineering.

Most importantly in the context of Korean society with a rigid hierarchy of higher

education institutions, high school students may avoid studying certain science subjects or may avoid studying them beyond a certain level, according to their strategies to excel on college entrance exam (Lee & Chun, 2012). For example, they may avoid choosing difficult subjects such as physics and chemistry for their elective subjects, or they may give up studying more than what is needed to take the exams. This fact has been often pointed out as a cause for the lower academic levels of college students in the natural sciences and engineering at college. In fact, they often experience difficulty taking basic courses in their academic majors so that universities must provide supplementary courses for them.

Students in tertiary education

College students in the natural sciences and engineering programs showed overall satisfaction with their academic majors, especially with their faculty (Jin et al., 2012; Lee, W. et al., 2011; Park et al., 2011). These students also tended to plan future careers related to their academic majors for intrinsically motivated reasons, such as interest in science, desire for self-realization and development, and autonomy. However, they emphasized the importance of income level as well, and they perceived the profession of medical doctor as being more socially respected, well paid, and stable. Graduate students in the natural sciences and engineering programs particularly took pride in their majors (Lee, W. et al., 2011). Their job preferences prioritized job stability and a good match with their majors; consequently, the majority of them wanted research positions, particularly at public research institutes.

On the other hand, college students in the humanities and social sciences generally thought that science education from primary to secondary education is not implemented well in Korean education, with their responses being at the average score of 2.48 on a scale of 5 (Lee, W. et al., 2011). They thought that science education needs to focus on classes for experimentation and observation. For the development of science education in Korea, they emphasized expanding facilities and supporting various activities in science.

1.1.7 Employers and professional bodies

Employers in Korean companies appear to understand the importance of science and technology. For example, a presentation by the Federation of Korean Industries showed concerns about the phenomenon of avoiding science and technology in Korean society and demanded an appropriate policy to educate and train qualified human resources in these fields (Lee, 2007). In Seo et al.'s (2012) study, companies, including those in IT, Biotechnology (BT), and Robot Technology (RT), responded that particularly CEOs need education to foresee the needs of the future society and technological change, compared to workers at other levels. They also emphasized the importance of technology management.

In addition, employers generally support on-site education for their workers in science and engineering through various programs (KISTEP, 2009). Such programs

include taking classes outside of work, providing short-term training, offering classes at work, and supporting attendance at conferences/seminars. However, the size of companies also matter in that big companies provide more opportunities from which employees can benefit.

On the other hand, in a survey on policy for human resources in science and technology, companies gave relatively lower priority to educating gifted children than other entities, such as policy experts, higher education institutions, and public research institutions (Lee et al., 2008). They also gave minimum priority to supporting women scientists and engineers. However, companies regarded it important to support current scientists and engineers for their research environment and competence, to support research in higher education institutions, and to assist college graduates' employment.

Nevertheless, it is noteworthy that companies have also initiated programs to support children's education in science and have advertised them through TV commercials. These kinds of Corporate Social Responsibility (CSR) activities are closely related to their own corporate interests and philanthropic activities. Not only do their philanthropic activities cultivate potential consumers, but they can also benefit children, youth, and future of the Korean society. Advertisements are also a very powerful strategy for creating a company's positive image.

Accordingly, many companies conduct and manage strategic support for various areas in a society, such as art and culture, education, and the environment. The rate of CSR for children and teenagers in Korea accounted for about 12.1% of total social contributions (Choi & Park, 2006). Most of them targeted gifted children in science and children's creative learning experiences. Examples include:

Example 1. The Hyundai Mobis' 'Nobel Project'

The 'Nobel Project' since 2005, representative social contribution activities of Hyundai Mobis, has run junior engineering classes for local elementary school students near the Hyundai Mobis workplace and has provided students with opportunities to visit the company. Its catch phrase is, 'The efforts to nurture scientific talent in Korea will continue in the future'. Its TV advertisement, which won the 2012 Korea Herald advertising award, is very impressive, which reflects the current trend of Korean society regarding science (see Figure 2). It says, 'We need idol stars, but we need more scientists'. This message reflects the reality that many children hope to become celebrities and think that becoming a scientist is not attractive. The advertisement emphasizes that 'science is the basis of a nation' and ends with 'Let's give back science to our children'.



Figure 2. Nobel project: ‘social contribution activities for fostering science-gifted students’ (Hyundai Mobis, 2012)

Example 2. Amway Korea’s ‘Thinking Green Frog Project’

A green frog represents disobedient children in Korean culture. This project began in 2012 to cultivate children’s creativity by supporting cultural, art, and science activities. In cooperation with the Sharing Community of Science and Technology (a nonprofit charity organization), Yonsei University, and Seoul City, this project supports events to experience educational programs for science and creativity, and provides scholarships to children from low-income families.

1.2 The perceived relevance of STEM to economic growth and well-being

1.2.1 Economic growth

Korea has achieved marvelous economic growth over the past 50 years. Its GDP per capita increased from 79 USD in 1960 to 17,175 USD in 2009 (Hong et al., 2010). Korea used to be an aid recipient country after the Korean War, but became an international aid donor, a member of the OECD-DAC as of 2009 (Organisation for Economic Co-operation and Development, Development Assistance Committee). As mentioned in the introduction, the Korean government has attributed the recent advancement of the Korean economy and its role in the global community to the development of science and technology. In a public message from the Lee government (2008-2013) on its accomplishments of science and technology policies, it acknowledged the enhanced competitiveness of science and technology over its regime (MEST, 2012a). For example, in this message, the Korean government emphasized that in the IMD Scientific Infrastructure Subindex, Korea moved up from 7th in 2007 to 5th in 2012, and Korean higher education institutions in the top 200 QS World University Rankings increased from two in 2007 to six in 2012. Similarly, the National Science & Technology Information Service (NTIS) listed the IMD world competitiveness results as evidence of science and technology achievements of Korea (see Table 3).

Table 3. IMD World Competitiveness Rankings of Korea

	2006	2007	2008	2009	2010	2011	2012
National competitiveness	32	29	31	27	23	22	22
Scientific infrastructure	10	7	5	3	4	5	5
-Total expenditure on R&D	7	7	7	7	7	7	7
-Total R&D personnel	6	7	7	8	8	9	7
Technological infrastructure	6	6	14	14	18	14	14
-Technological cooperation between companies	27	8	31	38	39	31	37
-Investment in telecommunications (% of GDP)	12	14	7	11	17	20	20

Source: National Science & Technology Information Service, Korea; IMD World Competitiveness Yearbook

In the same message from the government, it argued that these accomplishments in science and innovation contributed to the economic successes of Korea and its important role in the global community (MEST, 2012a). It also highlighted that Korea joined the exclusive 20-50 club in 2012, which represents countries with a per capita income exceeding 20,000 USD and a population of more than 50 million. It added that Korea hosted the G20 summit in 2010 for the first time in Asia, and it has three Korean corporations in the Best Global Brands, as reported by Interbrand (see Table 4).

Table 4. Best Global Brands in 2012 by Interbrand

2012		2011	2012		2011
1	Coca-Cola	1	5	Microsoft	3
2	Apple	8	9	Samsung	17
3	IBM	2	53	Hyundai	61
4	Google	4	87	KIA	-

Source: www.interbrand.com

A report from the Science and Technology Policy Institute (STEPI), 'Role of science and technology for Korean economic development and its implications for developing countries', confirms the aforementioned policy narrative by the government (Hong et al., 2010). The authors explained that Korea was successful in developing science and technology by stages, as needed. Technological innovation was a key factor over the course of Korean economic growth, which has been led by qualified people in science and technology. The stages are summarized below in Table 5.

Table 5. Stages of science and technology development

Development Stages	Industrialization by importing technology	Industrial development by internalizing imported technology	Industrial advancement by expanding independent technological competence
Period	Early 1960s ~ Late 1970s	Late 1970s ~ Early 1990s	Early 1990s ~ Mid 2000s
Main method of obtaining technology	Importing technology from overseas	Internalization of imported technology	Enhancement of advanced technology
Knowledge acquisition	Attention concentration	Acquisition of factorial knowledge	Acquisition of structural knowledge
Stages of national innovation system	Formation	Growth	Maturation
Main content	Formation of research entities (e.g., government research institutes)	Growth/Development of research entities (e.g., companies, universities) Aligning related systems and organizations	Cooperation between research entities Enhancing efficiency of related systems and organizations

Sources: Hong et al. (2010, p. 54)

1.2.2 Well-being

Koreans tend to consider science and technology as important for their well-being and quality of life. In a study on the quality of life based on technology, Korean people indicated the order of importance that determines the quality of life: 1) the economy, 2) culture, and 3) science and technology (Cho et al., 2007). Males put science and technology before culture. About 70% of Korean people also think that the government needs to make more investment in the development of science and technology in order to enhance their quality of life. In an international study by the European Commission in 2005, about 73% of Korean people expected that science and technology would enhance their quality of life. This figure was lower than those of the UK (82%), Germany (75%), and Sweden (74%), but higher than those of France (69%) and Switzerland (55%). Surprisingly, however, Korean people tend to perceive their overall quality of life based on technology to be low, despite Korea's competitiveness of science and technology (Cho et al., 2007; Kim et al., 2007; Yoo et al., 2011).

This finding contradicts what we can easily observe in Korean society these days: the convenience of daily life and the quality of life, both of which have apparently benefited from technological developments in Korea. Korea has top-running IT and communications companies, as well as car manufacturing firms. In addition, it lays claim to having the fastest high-speed Internet service in the world. Korea is also a global testing venue for various new information and IT products (Hong et al., 2010). A few more examples that show the fairly high level of life influenced by technological development are listed below, which have also received good international recognition.

For example, the public transportation system in the Seoul metropolitan area is highly regarded and received the Innovations in Policy award from the International Association of Public Transport (UITP) in 2005. Seoul has attracted international

groups of people who want to learn its public transportation system. For instance, this system uses IT technology to locate buses that people can check using smartphones, and bus information is displayed at bus stops. Bus fares are calculated considering other connecting buses and subways that people use by credit cards and transportation cards, such as T-money.

Another example is Korea’s e-government service. In 2012, Korea ranked first in the UN’s e-government index (United Nations, 2012). For instance, Korean people can issue public documents online for various purposes, and for tax returns, they can check and print their yearly expenditures using online service from the National Tax Service.

Online banking and smart banking is also very convenient and easy to use. Services that use smartphones like credit cards and bus cards are also available.

1.3 Current patterns of STEM provision in schooling, including STEM in primary education, and its influence on later participation in STEM; enrolments in STEM disciplines in secondary education; STEM provision, and participation, in tertiary (university and non university) education; and trends since 2005 in those secondary and tertiary enrolments.

1.3.1 Current patterns/ statistics of STEM provisions in schooling

It has been pointed out that the number of hours for science and math has decreased, while the amount of lessons to cover has remained the same in primary and secondary education, and changes to the college entrance exams have limited high school students’ motivation to learn diverse subjects in-depth within science and math (Lee & Chun, 2012; Seo, 2007). On the other hand, the teacher-student ratio in science has improved over the past decade from 6.2 in 2000 to 4.9 in 2012. The teacher-student ratio for foreign language subjects has also improved from 21.9 to 12.9, but it is still larger than that for science. Table 6 shows the number of teachers relative to science education students in secondary education.

Table 6. Number of teachers relative to education students in science and technology (2011)

	General curriculum		Specialized curriculum
	Math	Science	Science
Middle school	12,126	11,641	
High school	15,663	11,925	396
General high school	12,121	9,652	69
Specialized high school	565	375	233
(Science high school)	(118)	(267)	-

Source: KOFAC (2012)

Note. Specialized high schools include those in foreign languages, science, art, and physical education.

Interestingly, concerns in the previous section that outstanding students in high school tend to prefer medicine over the natural sciences and engineering prove to be true, as illustrated in Table 7.

Table 7. Comparison of high school grades between college students in the natural sciences/engineering and medical school

	Natural sciences (476)	Engineering (477)	Medicine (216)	Total (1,225)
Class 1	45.0	48.2	68.5	49.1
Class 2	30.7	26.2	18.5	25.9
Class 3	12.8	13.8	6.0	12.5
Class 4	5.7	4.8	3.7	6.0
Class 5 or below	3.6	3.8	2.8	4.2
Don't know/No response	2.3	3.1	0.5	2.4
Total	100.0	100.0	100.0	100.0

Note: Class 1 is the highest level of school grade that high school students use for their college entrance exam.

Source: Jin et al. (2012)

In Korea, the study of mathematics or other subjects is not compulsory throughout high school. In addition, it is customary in Korean schools for teachers to teach their subjects every semester (Han et al., 2012). Moreover, an intensive course completion system was introduced in 2009 which enabled schools to teach courses in block times by their own schedules. Accordingly, certain schools taught subjects that were unimportant to college entrance exams all at once such as art and sports, or they taught mathematics courses every other semester. However, this policy was practically abandoned in 2012. Even when this policy has been in effect, mathematics is one of the most important subjects for the college entrance exam; thus, it is always taught throughout the school year.

1.3.2 STEM in primary education and its influence on later participation in STEM

Most literature on STEM education in primary education and its influence has concentrated on its immediate impact on students. However, little research has been done using longitudinal data. Alternatively, data on when students and experts in science and engineering decide on their academic and career paths contribute to understanding the influence of prior education on their decisions to participate in STEM. As described in Table 8, most scientists and engineers, as well as female college and graduate students, decide to participate in STEM when they are in high school. Science high school graduates also indicate that their decision to continue STEM occurs in high school. In addition, teachers are influential in students' decision to study science and engineering. Comparatively, therefore, STEM in primary education does not appear to have much influence on Korean students' later participation in STEM.

Table 8. When scientists/engineers and female college/graduate students decide to work or study in the natural sciences and engineering fields and why

		Scientists /engineers	Female college/graduate students	Total
When I decided to major in the natural sciences and engineering	Before elementary school	5(1.6%)	4(1.2%)	9(1.4%)
	Elementary school	34(10.7%)	45(13.9%)	79(12.3%)
	Middle school	78(24.5%)	100(30.9%)	178(27.7%)
	High school	184(57.9%)	153(47.2%)	337(52.5%)
	After college	17(5.3%)	22(6.8%)	39(6.1%)
	Total	318(100%)	324(100%)	642(100%)
Why I chose the field of the natural sciences and engineering	Personal interest	105(33.1%)	167(52.2%)	272(42.7%)
	Good grades at math and science	71(22.4%)	72(22.5%)	143(22.4%)
	To become a scientist	69(21.8%)	25(8.1%)	95(14.9%)
	Good for future employment	41(12.9%)	20(6.3%)	61(9.6%)
	Recommended by people around me	22(6.9%)	24(7.5%)	46(7.2%)
	Other	9(2.8%)	11(3.4%)	20(3.1%)
	Total	317(100%)	320(100%)	637(100%)

Source: Lee, H. et al. (2011, p.198)

In addition, Jang and Kim (2002) pointed out that the science curriculum and teaching methods in primary and secondary education do not motivate students to have interest in science subjects.

1.3.3 Enrolments in STEM disciplines in secondary education

In Korean education, students need to choose their educational path, the humanities/social sciences or the natural sciences/engineering in high school, unless they go to high schools with a specific focus on science, foreign languages, art, or vocational training. As shown in Table 9, students in the natural sciences and engineering in general high schools tended to decrease from the 1990s, but started to increase again from 2007. However, it is difficult to explain the reasons for this change (Jin et al., 2012).

Table 9. Number of high school students in general education (2nd, 3rd grades) and their ratio by fields of study

	Total	Humanities/ Social sciences		Natural sciences/ engineering		Vocational training		Arts & Sports		Other	
		Number	%	Number	%	Number	%	Number	%	Number	%
2005	802,906	465,946	58.0	309,326	38.5	4,488	0.5	15,861	1.9	7,285	0.9
2006	810,688	481,444	59.3	311,158	38.3	4,172	0.5	7,496	0.9	6,418	0.7
2007	814,602	487,682	59.8	310,160	38.0	3,923	0.4	7,188	0.8	5,649	0.6
2008	866,863	521,239	60.1	330,426	38.1	4,111	0.4	6,055	0.6	5,032	0.5
20	939,	565,	60.1	360,	38.3	4,25	0.4	5,26	0.5	4,00	0.4

09	091	368	0. 2	197	8. 3	4	. 4	4	. 5	8	. 4
20 10	947, 899	558, 068	5 8. 8	374, 882	3 9. 5	4,60 0	0 .4	5,69 6	0 .6	4,65 3	0 .4
20 11	979, 437	553, 666	5 6. 5	390, 549	3 9. 8	3,72 8	0 .3	15,8 11	1 .6	15,6 83	1 .6

Source: Jin et al. (2012, p.39)

The number of high schools specialized in science and the number of students in these schools have also steadily increased since 2005 (see Tables 10 and 11).

Table 10. Number of high schools by type

	2005	2006	2007	2008	2009	2010	2011	2012
Total	82	89	93	96	97	99	120	128
Science	18	19	20	21	21	21	23	24
Foreign language	25	29	29	30	30	33	31	31
International	-	1	2	4	4	4	6	6
Art	25	26	27	26	27	26	25	26
Physical education	14	14	15	15	15	15	14	14
Meister	-	-	-	-	-	-	21	27

Source: Center for Education Statistics/Korean Education Development Institute (CES/KEDI) website

Table 11. Number of students by high school type

	2005	2006	2007	2008	2009	2010	2011	2012
Total	42,544	45,419	48,652	51,050	51,996	52,847	63,727	64,468
Science	3,340	3,585	3,708	3,898	4,003	4,097	4,494	4,918
Foreign language	19,164	21,687	23,819	25,580	25,778	26,258	23,870	23,376
International	-	100	644	1,044	1,359	1,607	2,041	2,458
Art	16,448	16,514	16,873	17,009	17,308	17,278	16,873	16,952
Physical education	3,592	3,533	3,608	3,519	3,548	3,607	3,563	3,574
Meister	-	-	-	-	-	-	12,886	13,190

Source: Center for Education Statistics/Korean Education Development Institute (CES/KEDI) website

Regarding female students, only about 30% of female high school students choose science and engineering across all fields of study, as shown in Table 12. The proportion of female students in the natural sciences and engineering in general high schools consist of 35% among the total high school student population in the natural sciences and engineering. This has increased from 126,277 in 2009, but the proportion has remained almost the same (35.1% in 2009) (MEST & WISET, 2012).

Table 12. Female students at general high schools by field of study (2010)

	Natural sciences/ Engineering	Humanities/Social science	Art & sports, others	Total
Female	131,383 (29.6%)	305,406 (68.8%)	7,400 (1.7%)	444,189 (100%)
Male	243,499 (48.3%)	252,662 (50.2%)	7,549 (1.5%)	503,710 (100%)
Total	374,882	558,068	14,949	947,899

Source: WISET (2012, p.27)

1.3.4 STEM provision, and participation, in tertiary (university and non university) education

Undergraduate education

The number of students enrolled in the natural sciences and engineering started to increase after the mid-2000s, but its increase rate was far below that of medicine and pharmacy or the social sciences (Jin et al., 2012). The enrolment rates of students in the natural sciences and engineering are also much lower than that in medicine/pharmacy, while the latter has continued to increase (see Table 13).

Table 13. Number of applicants, admitted students, and enrolment rates by field of study at four-year institutions

Year	Engineering			Natural sciences		
	A	B	C	A	B	C
2005	428,823	78,468	5.46	253,159	44,681	5.73
2006	505,895	79,482	6.36	280,232	43,998	6.36
2007	574,343	80,528	7.13	304,733	44,607	6.91
2008	577,844	81,266	7.11	293,735	43,736	6.71
2009	572,567	82,640	6.92	328,184	46,372	7.07
2010	646,207	85,152	7.58	382,665	47,030	8.13
2011	784,913	86,368	9.08	439,232	46,975	9.35
Year	Medicine/Pharmacy			Social sciences		
2005	113,489	10,877	10.43	562,218	92,095	6.10
2006	125,545	12,530	10.01	642,354	97,285	6.60
2007	129,426	13,497	9.58	729,775	99,228	7.35
2008	131,597	14,371	9.15	791,741	99,267	7.97
2009	139,011	14,688	9.46	789,575	95,534	8.26
2010	198,222	17,953	11.04	885,014	97,493	9.07
2011	228,413	20,750	11.00	1,074,893	97,649	11.00

Note. A: Number of applicants; B: Number of admitted students; C: Enrolment rate. Applicants could have applied for multiple institutions.

Source: Jin et al. (2012)

Overall, the ratio of new students in science and engineering out of all new students has gradually increased (see Table 14).

Table 14. Number of new students enrolled in science and engineering and their ratios

	2005	2006	2007	2008	2009	2010	2011
Students	133,505	136,070	138,092	139,373	143,700	150,135	154,093
Ratio	40.9	40.5	40.3	40.6	41.3	60.1	42.6

Source: Jin et al. (2011)

Statistics from Tables 15 and 16 show a constant decrease in the ratios of students in the natural sciences and engineering, particularly in engineering. On the other hand, those in the social sciences have continued to increase in both size and proportion. Table 15 indicates the total population of college students by field of study who were attending four-year institutions each year from 2005 to 2011. Table 16 indicates college students who graduated from four-year institutions each year by field of study from 2005 to 2011.

Table 15. Number of students attending four-year institutions by field of study and their ratios

	Total	Engineering		Natural sciences		Humanities		Social sciences	
		Number	%	Number	%	Number	%	Number	%
2005	1,859,639	519,300	27.9	235,045	12.6	251,466	13.5	522,941	28.1
2006	1,888,436	514,544	27.2	235,548	12.4	251,634	13.3	544,879	28.8
2007	1,919,504	512,682	26.7	236,637	12.3	253,873	13.2	566,938	29.5
2008	1,943,437	513,188	26.4	235,234	12.1	255,230	13.1	584,245	30.0
2009	1,984,043	518,975	26.1	238,604	12.0	261,171	13.1	599,485	30.2
2010	2,028,841	526,193	25.9	243,441	11.9	267,549	13.1	613,973	30.2
2011	2,052,026	533,087	25.9	245,593	11.9	269,495	13.1	618,862	30.1

Source: Jin et al. (2012)

Table 16. Number of graduates from four-year institutions by field of study and their ratios

	Total	Engineering		Natural sciences		Humanities		Social sciences	
		Number	%	Number	%	Number	%	Number	%
2005	268,833	69,419	25.8	36,441	13.5	39,258	14.6	69,926	26.0
2006	270,546	67,838	25.0	36,112	13.3	39,036	14.4	72,367	26.7
2007	277,858	69,176	24.8	35,500	12.7	39,100	14.0	75,614	27.2
2008	282,670	67,535	23.8	35,695	12.6	38,484	13.6	79,221	28.0
2009	279,059	65,103	23.3	35,653	12.7	37,655	13.4	79,759	28.5
2010	279,603	65,442	23.4	35,049	12.5	36,808	13.1	80,842	28.9
2011	293,967	69,846	23.7	35,816	12.1	37,939	12.9	86,809	29.5

Source: Jin et al. (2012)

These trends can also be confirmed in Table 17, where an increase in medicine and pharmacy is more evident here.

Table 17. Proportion of natural sciences and engineering in tertiary education

	2005	2006	2007	2008	2009	2010	2011	2012
Natural sciences/ Engineering	38.7	37.9	37.3	36.8	36.3	36.1	36.0	36.0
- Natural sciences	12.0	11.9	11.8	11.6	11.6	11.6	11.6	11.7
- Engineering	26.7	26.1	25.5	25.2	24.7	24.5	24.4	24.2
Medicine/Pharmacy	3.4	3.4	3.5	3.6	3.7	3.9	4.2	4.5
Humanities/ Social sciences	42.2	42.6	43.0	43.5	43.8	43.7	43.5	43.2
Common	0	0	0	0	0	0	0	0
Other	15.7	16.1	16.2	16.2	16.2	16.3	16.3	16.4
Industry (Open)	0	0	0	0	0	0	0	0
Total	100	100	100	100	100	100	100	100

Source: NTIS (2012)

However, the proportion of Korean college graduates in the natural sciences and engineering is relatively high when compared to other countries (see Table 18).

Table 18. Proportion of college graduates in the natural sciences and engineering by country

	Korea	Japan	UK	USA	Germany
Natural sciences and engineering	36.89	24.06	22.51	14.7	27.22
- natural sciences	10.92	4.47	13.87	8.68	12.97
- engineering	25.97	19.59	8.63	6.02	14.25

Source: NTIS (2012); OECD, Science and Technology Industry Scoreboard

Graduate education

According to Table 19, the number of people with advanced degrees in science and engineering has increased. However, Table 20 shows that the proportion of master's degrees in science and engineering has decreased, while that in humanities and the social sciences has increased. On the other hand, the proportion of doctorates in science and engineering has increased altogether with those in other fields of study, as shown in Table 21.

Table 19. Number of graduates with advanced degrees in science and engineering

	2008	2009	2010	2011	2012
Master's degree holders in engineering	12,539	13,124	13,123	14,429	14,216
Doctorates in engineering	2,078	2,112	2,308	2,935	3,050
Master's degree holders in the natural sciences	5,829	6,048	6,278	6,538	6,693
Doctorates in the natural sciences	1,592	1,703	1,830	2,157	2,242
Total	22,038	22,987	23,539	26,059	26,201

Source: NTIS (2012)

Table 20. Number of master's degree holders by field of study and their ratios

	Total	Engineering		Natural sciences		Humanities		Social sciences	
		Number	%	Number	%	Number	%	Number	%
2005	68,439	13,470	19.6	6,209	9.0	7,157	10.4	15,726	22.9
2006	69,834	12,698	18.1	5,985	8.5	7,526	10.7	16,674	23.8
2007	70,092	12,160	17.3	5,638	8.0	7,909	11.2	16,914	24.1
2008	72,924	12,539	17.1	5,829	7.9	8,670	11.8	18,698	25.6
2009	75,685	13,124	17.3	6,048	7.9	8,688	11.4	20,036	26.4
2010	77,328	13,123	16.9	6,278	8.1	9,416	12.1	20,509	26.5
2011	79,430	14,429	18.1	6,538	8.2	9,633	12.1	20,953	26.3

Source: Jin et al. (2012)

Table 21. Number of doctoral degree holders by field of study and their ratios

	Total	Engineering		Natural sciences		Humanities		Social science	
		Number	%	Number	%	Number	%	Number	%
2005	8,602	2,138	24.8	1,531	17.7	759	8.8	1,222	14.2
2006	8,909	2,201	24.7	1,613	18.1	811	9.1	1,403	15.7
2007	9,082	2,104	23.1	1,515	16.6	790	8.6	1,472	16.2
2008	9,369	2,078	22.1	1,592	16.9	814	8.6	1,620	17.2
2009	9,912	2,112	21.3	1,703	17.1	854	8.6	1,860	18.7
2010	10,542	2,308	21.8	1,830	17.3	1,037	9.8	2,027	19.2
2011	11,645	2,935	25.2	2,157	18.5	1,064	9.1	2,120	18.2

Source: Jin et al. (2012)

Nevertheless, Lee, J. et al. (2008) pointed out that Korea still has a low level of doctorates in STEM, particularly in the natural sciences, compared to the OECD average. This finding can be confirmed with statistics in Table 22.

Table 22. Number of doctorates in science and technology per 1,000 population by country

	Korea	USA	Switzerland	Germany	Canada	Australia	Portugal
	2005	2003	2003	2003	2001	2001	2004
Doctorates per 1,000 population	4.9 (3.7)	8.4	23.9	15.4	6.5	5.9	2.1
Doctorates per 1,000 working population	6.5 (4.8)	10.7	27.5	20.1	8.2	7.8	2.6

Source: KISTEP (2007) & OECD (2007) cited in Lee, J. et al. (2008)

Female students

The proportion of female students in the natural sciences and engineering in Korean higher education is very low, at 28.5% in 2010 (MEST & WISSET, 2012). This rate tends to decrease as the level of education advances: 30.1% in undergraduate, 26.6% in master's, and 23.9% in doctoral programs. Moreover, the number of female graduates with undergraduate and graduate degrees in the natural sciences and engineering decreased from 226,169 in 2006 to 190,496 in 2010. Their proportion remained the same, at 28.2%, although it had decreased to 26.7% back in 2008. In

other words, female students in science and engineering majors are fairly underrepresented in Korean higher education.

Faculty

The faculty-student ratio per full-time faculty member by field of study in Korean higher education tends to be very high overall, as shown in Table 23. The ratio in engineering is particularly high above the average.

Table 23. Faculty-student ratio per full-time faculty member by field of study (2010)

	Humanities/Social sciences	Natural sciences	Engineering	Medicine	Arts/Sports	Total
Faculty-student ratio	48.9	33.2	48.4	3.4	49.2	38.2

Source: Center for Education Statistics/Korean Education Development Institute (CES/KEDI) website

Despite the lack of full-time faculty, departments have been established indiscriminately in Korean higher education. In the natural sciences and engineering, nearly 80% of departments have full-time faculty below 10, and a third have below 5. This environment makes it difficult to provide a high quality of education in the trend of expanding, specializing, and merging different majors (Park et al., 2011). According to the WEF (World Economic Forum) Global Competitiveness Report, the quality of math and science education in Korean higher education has improved from 23rd in 2006 to 10th in 2007 and to 11th in 2008, but down to 18th in 2009.

1.4 The role of STEM disciplines in both general education and vocational and occupationally-specific programs in education and training

In Korean society, people who do not have college diplomas or those who are not white-collar workers often receive little respect. Technicians and engineers, and even vocational high school students have been treated unfairly or disregarded due to this bias in Korean society. Vocational high schools, the pillar of Korea's industrial and economic growth, have also been subject to this prejudice over the last fifty years. Nonetheless, policies and strategies designed to revive these schools and students have produced no tangible results yet; in fact, some of them have even been counter-productive.

Meister High Schools (2010-)

Accordingly, the Korean government has made huge efforts to revitalize vocational high schools. It has tried to support students to find out and develop their aptitudes and specialties so that they can realize their dreams without college diplomas.

The Meister High Schools, special vocational high schools, a representative attempt of STEM education from the 1st Master Plan for Educating and Supporting Human Resources in Science and Technology (2011-2015), offer an alternative way in this regard. Students in the Meister High Schools are provided with diverse training

programs that help them attain in-demand skills, which in turn, enable them to get decent jobs after graduation. The introduction of the Meister schools demonstrates a 'positive change' in secondary education in Korea. The popularity of the Meister High Schools has spread to other high schools specializing in vocational and technical education. More financial firms are hiring high school graduates, and cooperation between vocational high schools and companies is on the rise. In other words, the Meister High Schools has brought about a boom in vocational education at the secondary level of education, and students appear to have received opportunities to find their strengths and nurture their dreams without being pressured to go to college (Lee, J. et al., 2011).

STEAM and experiential education

Additionally, a number of extracurricular science programs, including hands-on science educational programs, will be linked with STEAM education to expand it into an experiential/research program. To achieve this, the Global Hands-On Science Education program for middle and high school students will be expanded, and they will be provided with opportunities to make field trips overseas to the high-technology sites, as well as to research institutes, such as the National Aeronautics and Space Administration (NASA) and the Conseil European pour la Recherche Nucleaire (CERN).

Two-year colleges for vocational and occupationally-specific programs: Case studies

MEST launched the World Class College (WCC) program in 2011 to strengthen the global competitiveness of local vocational colleges. Under the WCC program, the government supported seven colleges in 2011 and selected four colleges in 2012. The government anticipates that the selected colleges will become the best examples of academy-industry cooperation and will help improve the social reputation of vocational colleges.

Case 1. Korea Lift College

Korea Lift College, which is the only higher education institution in the world specializing in lifts, was established in Geochang County, Gyeongsang Province in 2010. The college is located near the Lift Industry Cluster Complex and the Lift Industry R&D Center. The college is managed by the Korea Elevator Safety Institute. Korea Lift College reflects the curriculum demanded by companies, including the departments of elevator mechanical design, elevator electric design, elevator mechatronics, elevator maintenance, and elevator safety control. The college plans to help more than 20% of graduates get hired overseas every year. To this end, they set up specific programs that include practical English education and curricula for overseas elevator certificates. The admission rate in 2012 was 4.2:1 for 320 enrolments, and the employment rate of its graduates was 85.9%.

Case 2. Ajou Motor College

Ajou Motor College is located in Boryeong, South Chungcheong Province, which is the heartland of the western coast automobile industry belt regions and the production center of the Korean automobile industry. The college has six majors related to automobile design and technology. It became a certified authorization institute of automobile maintenance certificates of British NVQ (National Vocational Qualification) by the British Automobile Industry Institute in 2012. The Competitive edge of its curriculum is the order-made curriculum in collaboration between industry and the school. They offer courses related to jobs requested by industry sites. People from industry also participate in its education. The admission rate in 2012 was 4.9:1 for 520 enrolments, and the employment rate of its graduates was 64.5%.

Case 3. Kyungbuk College

Kyungbuk College is located in Yeongju city, North Gyeongsang Province. When the college was selected for the WCC program, it was celebrated as a local event. Yeongju city has been called the 'backwoods' in North Gyeongsang Province because there are no commercial enterprises or industrial complexes. The regional headquarters of the Korail (Korean Railways) for North Gyeongsang Province is located in Yeongju. Taking advantage of its location, Kyungbuk College established a Railroad Division, which has departments related to the railway business. The division consists of the Departments of Railroad Electricity, Railroad Management, Railroad Administration and Computer Systems, and Railroad Electronics. As a result of these efforts, Kyungbuk College has made a 'grand slam' among competing vocational colleges from the government, by winning the Educational Capacity Enhancement Project for higher education (2008-2012) and the Evaluation and Accreditation for Two-Year Colleges in 2011, and WCC in 2012. The admission rate in 2012 was 7.1:1 for 1,100 enrolments, and the employment rate of its graduates was 64.6%.

1.5 Student uptake of STEM programs and factors affecting student performance and motivation.

As described in 1.1, Korean students show mixed attitudes toward STEM. Their responses to STEM programs and education, as well as factors affecting their performance and motivation need more examination, especially regarding the recent STEAM education curriculum. Moreover, the existing research on these topics often lack academic rigor.

Findings from a handful of studies on the effectiveness of STEM/STEAM education programs have indicated positive results on students' self-efficacy and creativity. For example, Kim (2010) showed that STEAM education benefits students' motivational development: interest, self-efficacy, scientific attitudes, achievement, divergent thinking, and even enrolment. In Song and Lee (2010), a group using an educational robot for STEM integration education accomplished a higher level of achievement

than a textbook-based instruction group. Similarly, Kwon et al. (2012) showed that contents using an educational robot for an integrated subject study program model yielded a positive effect for improving elementary school students' self-efficacy and creativity. On the other hand, Sung and Na (2012) noted no significant effect between an integrated STEM education and technology education curriculum in science self-efficacy, but STEM education had a statistically positive effect on students' attitudes toward engineering. Overall, the integrated instruction of the STEAM curriculum and classroom lessons is expected to improve students' academic achievement and satisfaction with classes in math and science.

The study findings also imply that STEAM education requires more effort from teachers. The literature has shown that high school teachers in science are influential in students' decision to study science and engineering at college, in addition to their self-interest and that of their parents. Therefore, the professional development for teachers' using integrated instruction must be developed and conducted to build up teachers' motivation toward STEAM education. To this end, the government has started to support teachers' study groups.

1.6 Access of STEM graduates to the labour markets, and labour market take-up of STEM knowledge and skills.

1.6.1 Access of STEM graduates to the labour markets

According to a study using longitudinal data on college graduates' occupational mobility between 2006 and 2008, STEM graduates showed differences in their access to the labour markets and later career paths, according to their majors: the natural sciences and engineering (Hong & Jung, 2011). First, regarding employment and unemployment, only those from the natural sciences majors showed lower rates of participation in economic activities than those from engineering majors, as well as the average rate (see Tables 24 and 25). On the other hand, those who studied engineering showed the highest participation rates in economic activities across all academic fields.

Table 24. Rate of college graduates' participation in economic activities by field of study

	Humanities	Social Sciences	Education	Science & Engineering	Natural Sciences	Medicine & Pharmacy	Arts & Sports	Total
2006	81.5	87.5	84.9	88.3	81.7	91.9	88	86.7
2007	83.1	88.7	86.8	90.7	83.5	91.6	88	88.1
2008	84	89.4	90.2	91.5	84.5	91.1	86.2	88.8

Source: Hong & Jung (2011, p.9)

Table 25. College graduates' unemployment rate by field of study

	Humanities	Social Science	Education	Science & Engineering	Natural Sciences	Medicine & Pharmacy	Art & Sport	Total
2006	9.1	7.6	4.5	8.1	11.1	3.9	8.3	7.9
2007	5.5	5.7	1.7	5.5	5.4	2.5	6.0	5.2
2008	4.1	3.6	1.0	3.5	3.4	1.8	4.2	3.3

Source: Hong & Jung (2011, p.10)

Secondly, the rate of changing jobs in science and engineering was 6.8%, far lower

than the total average, 16.7%; however, it had increased to 10.2% in 2009 (KISTEP, 2009). Those from the natural sciences showed a higher rate of changing jobs (31.9%) than those in engineering (25%) in 2008 data (Hong & Jung, 2011). The main reason for changing jobs appeared to be due to pay raises, both in the natural sciences and engineering fields, but those from the natural sciences tended to get new jobs unrelated to their majors, compared to those from engineering. In other words, those who studied the natural sciences experienced more difficulty in findings jobs related to their majors.

Thirdly, for those who graduated from STEM majors, whether they had initial jobs in the STEM fields or not was decisive in the kinds of jobs they had for later careers (Hong & Jung, 2011). Those who had their first jobs in the STEM fields continued to stay in STEM two years later in 2008, but those with jobs outside of the STEM fields had difficulty moving into STEM, and continued to stay in non-STEM jobs. Those from engineering majors tended to work for jobs within the natural sciences and engineering field more often than those with natural science majors (Jin et al., 2012; Park et al., 2011).

One important recent change is the increase of temporary jobs, which was already high with doctorates in the natural sciences and engineering when compared to other countries in 2004 (KISTEP, 2012; Lee & Chun, 2012). Moreover, female doctorates had three times more temporary jobs than males (see Table 26).

Table 26. Proportion of temporary jobs among doctorates earned between 2000 and 2004

	Korea (2006)	Switzerland (2004)	Germany (2004)	Portugal (2004)	Argentina (2005)
Total	17.0	21.1	12	73.5	7.4
Males	12.6	19.3	10.3	71.6	-
Females	36.3	25.9	15.7	75.8	

Source: Lee & Chun (2012, p.253)

In addition, those who pursue expert careers in the STEM fields in Korea tend to be males, unmarried, graduates of higher education institutions located in Seoul or other regions related to industries, majoring in science and engineering rather than the natural sciences, and high academic achievers (high GPAs) (Hong & Jung, 2011).

One positive change, however, is that more STEM graduates advance to top positions in companies, as seen in Table 27. This is noteworthy, along with a government policy to hire STEM graduates for jobs in central government bodies and public service, and its subsequent positive results (see Table 28).

Table 27. Distribution of CEO by field of study among 100 major Korean companies

	STEM (%)	Business/ Social science (%)	Other (%)
2003	35.9	59.2	4.9
2004	36.9	58.2	4.9
2005	39.9	55.8	4.3
2006	43.2	53	3.8
2007	46.4	50	3.6

Source: www.ntis.go.kr

Table 28. Employment target rate of STEM graduates for jobs in central government bodies and public service, and its results

		2004	2005	2006	2007	2008	2009
Central government (Level 4 or higher)	Target	27.9	29.1	30.6	32.3	34.2	-
	Result	28.9	29.5	29.6	32.3	30.9	-
Central government (Level 5 or higher)	Target	26.8	30.1	33.4	36.7	40.0	-
	Result	50.1	50.4	34.7	29.2	38.9	-
Public service	Target	-	56.3	57.4	58	59.3	60.9
	Result	-	60.3	61.6	59.7	56.8	56.1

Source: www.ntis.go.kr

1.6.2 Labour market take-up of STEM knowledge and skills

According to KISTEP (2009), employers generally prioritize academic majors (e.g., knowledge), job-related knowledge (e.g., certificates), and job performance/capability (e.g., logical thinking) in hiring STEM graduates. It is more evident that the academic major and knowledge are key factors for hiring STEM graduates when compared to data on non-STEM graduates. Similar results have been found in the assignment of job duties. These results indicate that employers consider it important to utilize STEM graduates' knowledge and skills related to their academic majors.

Mismatch of between STEM graduate's jobs and their knowledge and skills: 'Difficulty of employing qualified people amongst difficulty findings jobs'

The level of match between academic major and job is generally better with STEM graduates than those from the humanities and social sciences, but not those from medicine and pharmacy (Park et al., 2011). The match is also better with college graduates from engineering majors than those from the natural sciences (Lee & Chun, 2012). However, according to a recent study, only 42.4% of STEM college graduates were working for jobs in the natural sciences and engineering (Jin et al., 2012). This result gets better only with those with advanced education: 64.7% for master's degree holders and 90% for doctoral degree holders in the natural sciences and engineering.

However, the issue of 'difficulty of employing qualified people amongst difficulty in finding jobs' has been raised, which may be related to a lack of qualified human resources in science and technology in the future (Seo, Jang & Pereira-Mendoza, 2004, p.191). Kim (2010) pointed out that employers in the industrial sector reported experiencing difficulty hiring qualified people they want despite the oversupply of STEM graduates. He explained that the curriculum of science and technology majors in Korean higher education focuses on the manufacturing industry, which is currently 'old-fashioned'. Consequently, STEM graduates cannot meet the needs of industry, which is switching to a service industry based on a manufacturing or tertiary industry. It has been reported that more than the half of employers consider STEM graduates not to have adequate competence to match what companies require for jobs (see Table 29).

Table 29. Level of matching between new employees' (college graduates) ability and demand from employers (%)

		Very close	Somewhat close	Somewhat different	Very different	Don't know	Total
Korean higher education institutions	Humanities/Social sciences	1.7	20.3	51.9	18.4	7.7	100
	Natural sciences/Engineering	2.9	31.1	48.1	8.1	9.8	100
Overseas institutions		2.0	18.0	23.9	4.1	51.9	100

Source: Chae et al. (2006)

Moreover, Kang (2011) predicted an imbalance between demand and supply of human resources in science and technology due to avoiding the natural sciences and engineering, along with an aging population. Even with current statistics, Korean higher education has a very high proportion of students in the natural sciences and engineering, compared with those in other countries (see Table 18 in 1.3). On the other hand, the proportion of science and technology-related jobs in the Korean job market was low, at below 20% in 2008, while those in the UK, France, and Germany were 24.4%, 29.5%, and 33.7% in 2007, respectively.

Shortage of STEM human capital in the future

Regarding the issue of a shortage or oversupply of human resources in science and technology in the future, the literature has offered mixed prospects. For example, Jang et al. (2009) anticipated an oversupply of about 250,000 people in science and technology between 2008 and 2018. However, Kang (2011) and Byun et al. (2010) provided results that predicted a shortage of qualified personnel in science and technology based on analyses prior to 2005. As Song et al. (2008) pointed out, this is a complicated task to analyze, but it appears that there will be a need for doctoral-level human resources in science and engineering for the future Korean economy.

1.6.3 Females in labour market: Access and take-up

According to a report on the status of women in science and engineering by MEST & WISSET (2012), women participating in economic activities after graduating from science and engineering majors accounted for 61.4% in 2010, which was lower than that of males at 91.4%, and even that of women overall, at 62.8%. Similarly, among all R&D personnel in science and technology, women represented 17.3% of them, 36,360 out of 210,685 in 2010. Women in science and technology were employed in 16,834 regular jobs, and 19,526 were employed in irregular ones. While the proportion of women working for regular jobs in R&D science and technology has increased slightly after the mid-2000s, more than half of them still work in temporary jobs.

More significantly, women in science and technology tend to discontinue their careers after pregnancy, childbirth and child rearing, similar to general female workers in Korea (Lee, H. et al., 2011). However, women in science and technology show a lower rate of returning to the labour market than other females who tend to return to work after their mid or late 30s. Especially those from engineering show a much lower rate than those from the natural sciences after their mid-30s, contrary

to their higher levels of economic activity in their mid-20s.

A decline of women working in science and technology by age group is more evident when compared by gender and age, as illustrated in Figure 3. In their 20s, both males and females show high levels of economic activity by 70~80% in the 2010 data. However, while men stayed economically active throughout their lifespans, above 85% and up to 95%, women tended to go down to 50% in their 40s. Women in the natural sciences dropped down even to 30% in their participation in economic activities; however, on the contrary, women from engineering increased to 66%.

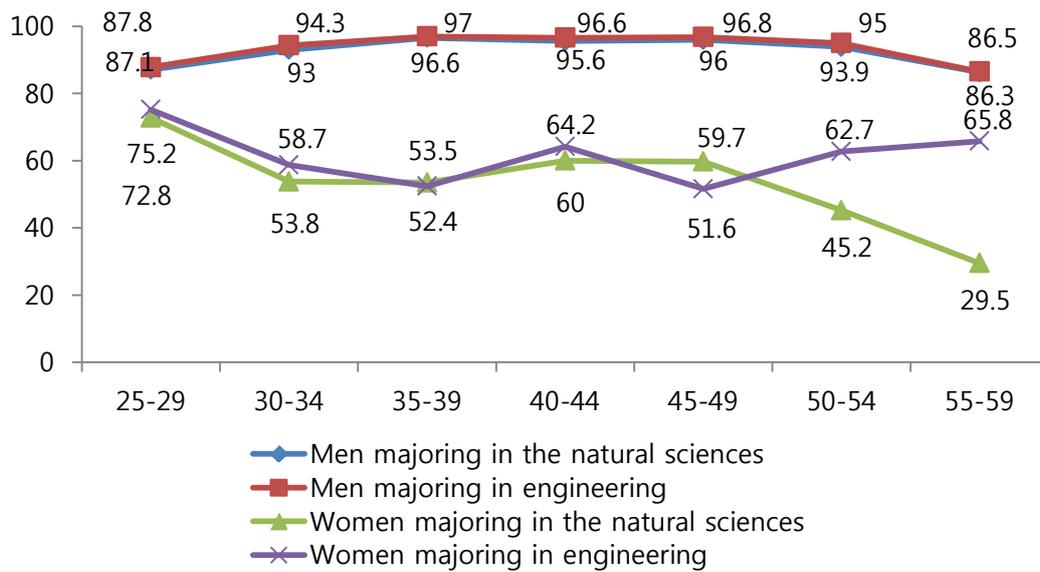


Figure 3. Participation rate in economic activities by human resources from the natural sciences and engineering majors by age group and gender (MEST & WISSET, 2012, p.109)

1.7 Strategies, policies and programmes used to enhance STEM at all levels of education, and judgment concerning the success of those programmes

1.7.1 STEM policy history prior to the 2000s

1960s~1990s policy history for STEM education

As summarized in Table 5 of the previous section, 1.2.1., the Korean government established detailed policy programs and strategies for technology development, according to its goals for economic development every five years from the 1960s through the 1980s (Hong et al., 2010). More plans for science and technology also followed afterwards. In the 1960s, with the science and technology section of the 1st economic development 5-year plan (1962~1966), the government focused on educating technicians to promote light industry. Its strategies included increasing the number of vocational high schools and trying to increase their quality, and providing technical and vocational education to manual laborers and technicians at a low level. In the 2nd economic development 5-year plan (1967~1971), the government

increased the enrolment quota of colleges and universities in science and technology, and increased classes and schools in industry and fisheries.

After the 1970s, the government focused on educating human resources specialized in different industries (e.g., mechanical, electrical, and chemical engineering) and at different levels, according to national economic plans to promote the heavy chemical industry (Hong et al., 2010). In the 1980s, the advancement of the industrial structure progressed rapidly in Korea, and demand for highly qualified and specialized human resources in science and technology intensified. Accordingly, the government built systems for educating qualified people in science and technology by setting up the Korea Advanced Institute of Science and Technology (KAIST), Korea Institute of Technology, and science high schools, as well as boosting graduate education in science and technology. By this time, the government switched its focus of higher education policy from undergraduate education to graduate education to meet changing trends in the structure for human resource demands in the 1980s. Enrolment quotas, which are controlled by the government in Korean higher education, were expanded in the science and engineering fields, including those in local universities to meet the demands of regional industries.

With an increase in governmental investment in R&D and projects to build research-intensive universities, a supply of highly qualified human resources in science and technology was successful in the 1990s (Hong et al., 2010). The government supported higher education institutions, especially graduate education, using the 'selection and concentration' strategy (Byun et al., 2012). However, the issues of imbalance between demand and supply, as well as quantity and quality of human resources in science and technology, difficulty of finding employment in science and engineering fields, and the phenomenon of avoiding science and engineering emerged. In the 2000s, a need for highly advanced human resources increased with the advent of the knowledge-based economy, but issues from the 1990s still persisted in addition to a decrease in the number of high school graduates in Korea and a mismatch between university education and the demand from industry.

Accordingly, the government has initiated policies and programs to encourage people to participate in science and engineering, and to enhance the competitiveness of science and technology in Korea. Such initiatives include the First Master Plan for Educating and Supporting Human Resources in Science and Technology and other programs that will be described below.

These policies for STEM education prior to the 2000s can be considered as successful, considering that Korea placed 22nd in the IMD World Competitiveness Ranking in 2012 (see Table 3 in 1.2). Nonetheless, they have also been criticized for their quantity-oriented development strategies, neglect of basic research, brain drain, and lack of cooperation between industry and academia (Kim, 2010).

Korea Advanced Institute of Science and Technology (KAIST)

Among the STEM education-related policies earlier in Korea, KAIST is noteworthy for its role and success. The Korean government established KAIST in 1971, a graduate school specialized in science and engineering, operating under an independent legal system. The government felt a need to educate highly qualified people in science and technology domestically instead of sending them abroad, and it invested in creating advanced technologies and educating qualified human resources without resorting to overseas institutions and other mature economies (Byun & Jon, 2011; Hanson, 2006). KAIST received ample financial support from the government to recruit Korean scientists from abroad, recruit talented students, and provide top facilities at that time. Students were provided with scholarships, dormitories and particularly exemption from military duty for male students, which is a very exceptional occurrence in Korean society.

KAIST produced 5,483 master's and 904 doctorates between 1975 and 1990, and KAIST graduates played a pivotal role in the science and technology sector, as well as in the industrial sector (Hong et al., 2010). Between 1975 and 1981, KAIST graduates were more than 30% of graduate degree holders in science and engineering in Korean higher education (Byun & Jon, 2011). The success of KAIST motivated Seoul National University to focus on its graduate education, and also influenced the establishment of another highly regarded institution specialized in science and technology, POSTECH, which was established by the company POSCO (Pohang Iron & Steel Company) in 1986.

The triumph of KAIST is proved by its international university rankings, 68th in the 2012-2013 Times Higher Education World University Rankings, and research outcomes, 564.5 papers published in the Social Science Index (SCI) and SCOPUS journals in 2012. Nevertheless, Park et al. (2011) pointed out that KAIST still has a large discrepancy in its scores with top universities in engineering, such as MIT, Stanford University, and the University of California, Berkeley.

Korea Institute for the Advancement of Science and Creativity (KOFAC)

KOFAC, a government-affiliated organization, was created to promote culture for science in Korean society, initially in 1967 and was reorganized in 2008 into its current form. It emphasizes communicating with the public about science and facilitating their understanding of science. Its previous forms were involved in a National Science Campaign in the 1970s, as well as a Science Korea Campaign in the 2000s. Particularly since the 1980s, it has focused on science and technology-related cultural activities, including a 'national movement to read books in science for students'. KOFAC has provided various classes, activities, and camps for students to experience and learn science and math, and has supported government programs for science education, including the recent STEAM curriculum.

Its recent programs in 2012 include Science Saturday Talks, a Christmas Science Concert, STEAM Classes in Our Daily Lives for teachers, Science Evening Dinner with

Science for adults at work, and a Science Integration Contents Fair for college students and businesses. It has also expanded programs for low-income families and students. KOFAC also started college students' international volunteer programs for students in a developing country. While the influence of numerous programs by KOFAC is difficult to evaluate appropriately in this report, KOFAC is considered to have played an important role in supporting STEM education in Korean society.

1.7.2 Master Plan for Educating and Supporting Human Resources in Science and Technology: For creative power Korea with human resources in science and technology (2011-2015)

The National Science and Technology Commission (NSTC, 2011) announced the Second Master Plan for Educating and Supporting Human Resources in Science and Technology (2011-2015), following up on the first plan (2006-2010). These master plans are initiated every five years, based on the Special Support Act for Science and Engineering for Improving National Competitiveness in 2004, which shows the importance of science and engineering in Korean governmental policy (Lee et al., 2008).

This second plan emphasizes educating human resources for a creativity-based economy. For education, its strategies include promoting STEAM education for primary and secondary education and providing a research-friendly environment to enhance research competence for tertiary education by supporting the World-Class University project, the Global Ph.D. Scholarship, and supporting four specialized institutions in science and technology –KAIST, GIST, DGIST, and UNIST as a research hub (see Figure 4). The plan also includes supporting women in science and technology in collaboration with the Korea Advanced Institute of Supporting Women in Science, Engineering, and Technology (WISET).

Detailed programs and strategies for supporting human resources in science and technology will be explained further below.

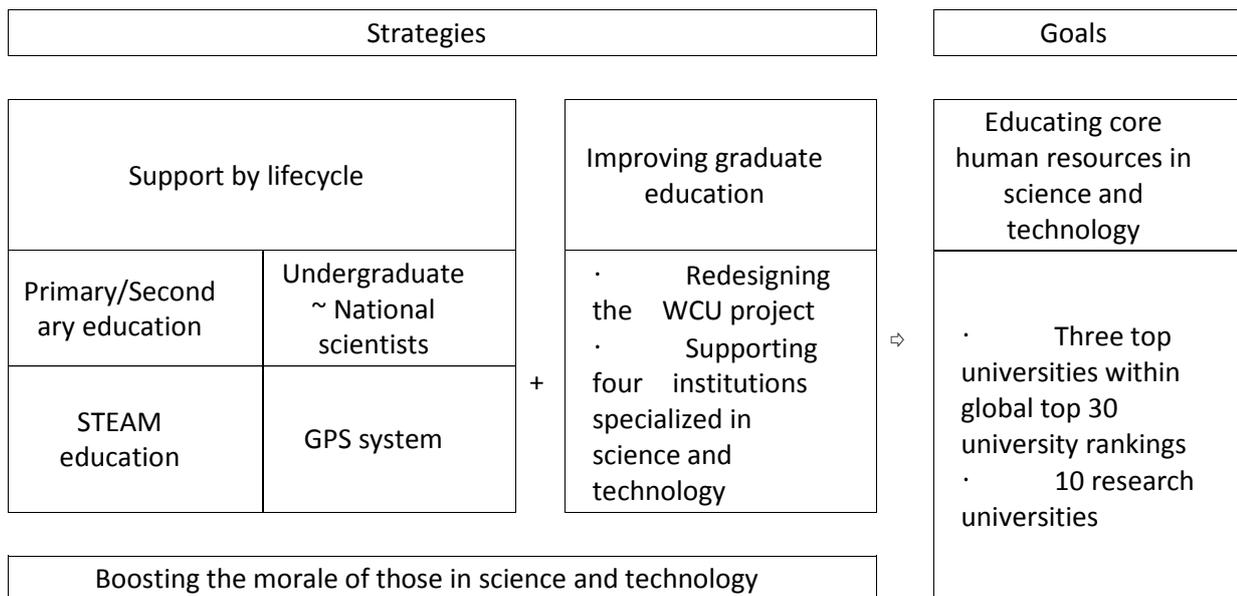


Figure 4. Directions for educating global human resources in science and technology

Source: MEST (2011) cited in Park et al. (2011, p.27)

1.7.3 All-lifecycle system for educating, training, and supporting human resources in science and technology (2007-)

The KISTEP announced a plan, ‘System to educate and support human resources in science and technology throughout their lifecycle’ with the Ministry of Science and Technology in 2007 (Lee et al., 2008). This plan provided a new paradigm so that policy for human resources in science and technology needs could be reviewed from beneficiaries’ all-lifecycle perspectives in its planning, implementation, and evaluation.

As illustrated in Figure 5, this system consists of four stages of Education, Employment, Research, and Retirement. The stage of education is divided into early childhood, elementary and middle school, high school, undergraduate education, and graduate education (see Figure 6).

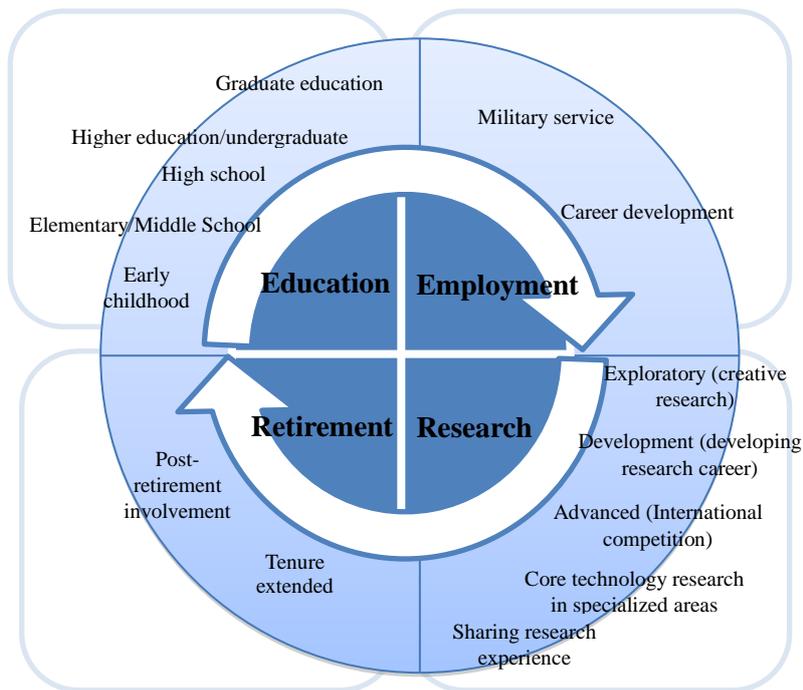


Figure 5. All-lifecycle system for educating and supporting human resources in science and technology (I)
 Source: Revised from Lee et al. (2008, p.149)

Among the previous government policies for human resources in science and technology, the Global Ph.D. Scholarship is close to this system at best, which plans to encompass undergraduate education through postdoctoral careers. Some of the programs for women in science and engineering have involved the lifecycle support system. However, a policy that reflects this system fully has not yet been implemented.

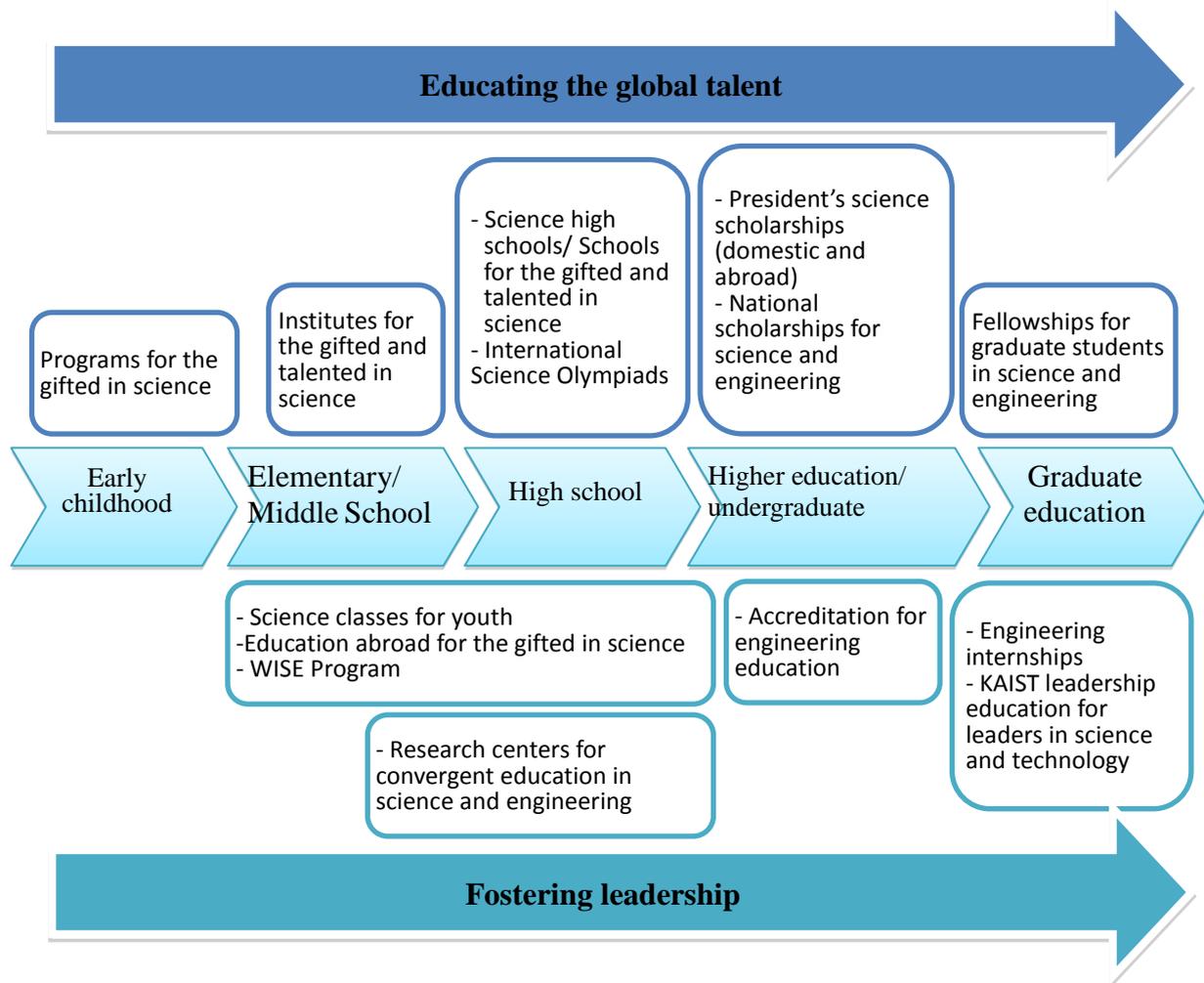


Figure 6. All-life-cycle system for educating and supporting human resources in science and technology (II)
 Source: Revised from Lee et al. (2008, p.149)

Furthermore, there is still a dearth of research on human resources in science and technology from all-lifecycle perspectives, and research outcomes on each stage have not been well connected (Lee et al., 2012). Nevertheless, this idea of organic support for human resources in STEM seems useful. It is hoped that this system will be more actively reflected in prior policies and strategies and in the development of future policies for STEM.

The most recent government initiatives on STEM education and judgment of their levels of success are discussed below.

1.7.4 Educating human resources in science and technology at the level of secondary education

Educating talented and gifted students in science

The government established a Comprehensive Plan for Discovering and Educating Talented and Gifted Youth in Science (2008-2012) in 2007, following previous plans with the same purpose. Science high schools began to be built from the 1980s, and among students between 1983 and 1992, a total of 2,202 students entered KAIST in its undergraduate programs. In addition, 85% of these students graduated from science high schools in two years, which shows the successful settlement of educating talented students in science (Hong et al., 2010). Kim et al.'s (2010) national study also showed that about 76% of graduates from science high schools chose the natural sciences and engineering for their academic majors at college. The number of schools for gifted and talented students in science increased from 172 in 2003 to 233 in 2006, and the number of students having received relevant education increased from 17,599 in 2002 to 36,818 in 2006 (Lee et al., 2008).

In addition, students studying in high schools specialized in science generally felt satisfied with their education, and the majority of them planned to continue studying in science and engineering in future academic and professional careers (Jin et al., 2012; Kim, 2010; Lee, W et al., 2011). They also decided to choose schools for science, considering their aptitudes for science and with their own will.

Despite the need to educate talented students in science appropriately, however, schools for them tend to be considered as a shortcut to top universities in Korean society. This misunderstanding has led to the spread of private tutoring to enter schools for the gifted and talented in science (Byun et al., 2010). Graduates from science high schools also criticize their own schools for focusing on students' entering top universities (Kim et al., 2010). They believed that such a focus can obstruct students' creative knowledge and balanced thinking.

During the presidential election campaign in 2012, the abolishment or reform of high schools specialized in foreign languages or science was one of the important issues raised by the presidential candidates. While expensive tuition for science high schools has been recently raised by the media, there still seems to be agreement in Korean society that there is a need for elite education in science at the secondary level of education. Therefore, this elite educational system for science needs to continue, along with efforts to improve the problems discussed here.

STEAM (2011-) - Why STEAM (Science, Technology, Engineering, Arts, and Math)?

As discussed above, Korea started to face a crisis in science and engineering: students' disinterest in science and math, and brain drain within Korean society from science and engineering to medicine or other areas. This phenomenon has happened, despite Korea's remarkable economic development and advancement in science and technology, as well as President Obama's frequent praise of Korea's educational system. Korea has built a strong basis generating innovation in science

and technology, led by the Ministry of Science and Technology. Following this trend, Korea is currently taking a leap to become the 'Powerhouse of Talents' (Lee, 2012). In this context, the Korean government began to ask the question: 'What is the reason for students' low level of interest in math and science, despite their high grades in these fields?' The main factor is that both math and science education are too far removed from real-life applications. For math education, classes are quite difficult and boring for students, and fail to draw students' interests. Educational experts and researchers claim that it is necessary to look at STEM education from a whole new way of solving problems. Moreover, the keywords for the new perspective are 'creative thinking' and 'academic convergence'. In current science education, 60.7% of classes are given in lecture format, and they lack opportunities for students to build an understanding of scientific thought processes (Lee, J. et al., 2011). If science and technology are integrated with other subjects, even the arts, it could lead to increased curiosity and interest in students.

In 2011, MEST launched Science, Technology, Engineering, Arts, and Math (STEAM) education as a main policy for reorganizing the curriculum (see Figure 7). The core of STEAM is to overcome the obstacle of the existing strict curriculum, promote divergent thinking, and ultimately aim at being the powerhouse of creative talents. Steve Jobs, the founder of Apple, repeatedly emphasized that 'the reason Apple is able to create products like the iPad is because we always try to be at the intersection of technology and liberal arts'. In this context, STEAM education is expected to contribute to fostering creative and artistically literate talents, such as Leonardo da Vinci or Steve Jobs.

What is the Korean model of STEAM?

As mentioned above, the second master plan for educating and supporting human resources in science and technology includes promoting STEAM, and the government and its research bodies have conducted various research programs to establish the basis of a Korean model for STEAM education (MEST, 2010). STEAM Education fosters integrative STEM education from artistic perspectives. By merging various subjects and applying it to real life, STEAM intends to develop students' divergent thinking and their excitement about learning. The purpose of this interdisciplinary education is to attract students' understanding, interests, motivation, and potentials in science and technology, as well as to increase their creativity.

The Revised Educational Curriculum announced in August 2011 reflects these changes and is directed toward transforming math education from one based on memorization and calculation to one of critical thinking by reinforcing math courses to incorporate the practice of more problem-solving, deduction, and communication skills (see Table 30). Not only that, the amount of material that the curriculum covers has been reduced by 20% in order to provide time for students and teachers to think about and discuss the matters at hand and to enable a more creative learning environment, decreasing the pressures of having to progress quickly through the curriculum in order to cover all of the material.

Moreover, MEST is planning to strengthen public education and reduce the burdens of students and parents for excessive private education. It intends to establish a highly desirable, sound math education culture through strengthening the professionalism of math teachers, vitalizing math classes for each level, expanding support for underachieving students, and conducting math classes for parents.

In order for STEAM to succeed, teachers are the most critical factor. In this regard, MEST is in the process of creating the phased teacher training system for math, science, and technical teachers at all stages of the teaching experience.

For example, the government and KOFAC have hosted symposiums, conferences, forums and events like the STEAM fair in order to spread the concepts and contents of STEAM education among educational subjects. Researchers have created the curriculum and have also visited cities and provinces 24 times to promote, explain, and facilitate an understanding of the curriculum, as well as to provide support in the form of training, lectures, and orientations to teachers (Lee, J. et al., 2011). To share the know-how of applying STEAM education, there were 64 instances of open classrooms for 4 months and workshops bimonthly with the municipal government all across the country (MEST & KOFAC, 2012).

Table 30. Direction for reorganization of STEAM subject curriculum

	Direction for Reorganization of Curriculum
Mathematics· Science	Reduce the rote memorization type of learning -math: calculating skill with speed oriented → problem-solving, creativity oriented -science: theory oriented → inquiry-centered laboratory class
Technology· Home Economics	Restructure the curriculum regarding the high-technology and actual life e.g.) smartphone, satellite, skyscrapers, etc.
Linked to Arts	Apply teaching techniques of the arts to combined subjects e.g.) the development of the team-teaching model for chemistry & arts, physics & music

Source: MEST (2012)

In addition, MEST plans to set up two new secondary schools: Science and Arts Schools for the Gifted' in Incheon and Sejong City, offering cross-disciplinary education. For the first time in Korea, these schools will offer students cross-disciplinary education opportunities in science, technology, engineering, arts and math. There will be no grade ranges for students, but they are required to complete a certain number of course credits for graduation. The first STEAM school will open in March 2015 in Sejong City, South Chungcheong Province, where the ministries and a number of central administrative organizations are to be relocated. The second cross-disciplinary school will open in 2016 in Incheon.

Case studies: STEAM Leader Schools and Teacher Study Groups

MEST and KOFAC extended their support for teachers' study groups that convene to develop teaching materials and lesson plans for the new curriculum, and facilitate teacher-centered collaborative research.

A teacher study group is a collaborative research team that consists of about 7 members including teachers, professors, and research staff. The groups were selected by MEST and KOFAC based on a research proposal in 2011. At the same time, the 'STEAM Leader School' project was initiated by MEST and KOFAC. A STEAM leader school is required to apply integrated STEAM subjects to organizing and teaching their lessons. The schools were selected from all levels of education primarily by local offices of education.

After the first year and its positive responses, MEST announced that the government would select more leader schools and study groups in 2012 (16 leader schools in 2011 to 80 in 2012, 47 teachers study groups in 2011 to 150 in 2012).

STEAM Education Research Map

Conceptualization

STEAM Education Frameworks

Lesson Model for School Level and Type	Elementary school level	Middle school level	High school level general type	high school level S&T type	Science and Technology (S&T) career-related advanced course
	Use block scheduling and creative experience activities within subject	Use STEAM related subject's lesson or creative experience activities, and after-school time	Use STEAM related subject's lesson or creative experience activities, and after-school time	Science High School Science Core School Specialized Vocational High Schools	

Application of Lesson Models

Teachers Study Groups: 47(2011)→170(2012), Leading School: 16(2011)→80(2012)

Support System	1	Development of educational contents	Lesson Model for School Level and Type	Creative experience activities, donation for education program	Out-of -school donation for education	
	2	Reinforcement of teachers' competency	Workshop for the leading teachers	Introductory (cyber) in-service training	Basic course in training	Advanced S&T training center for teachers

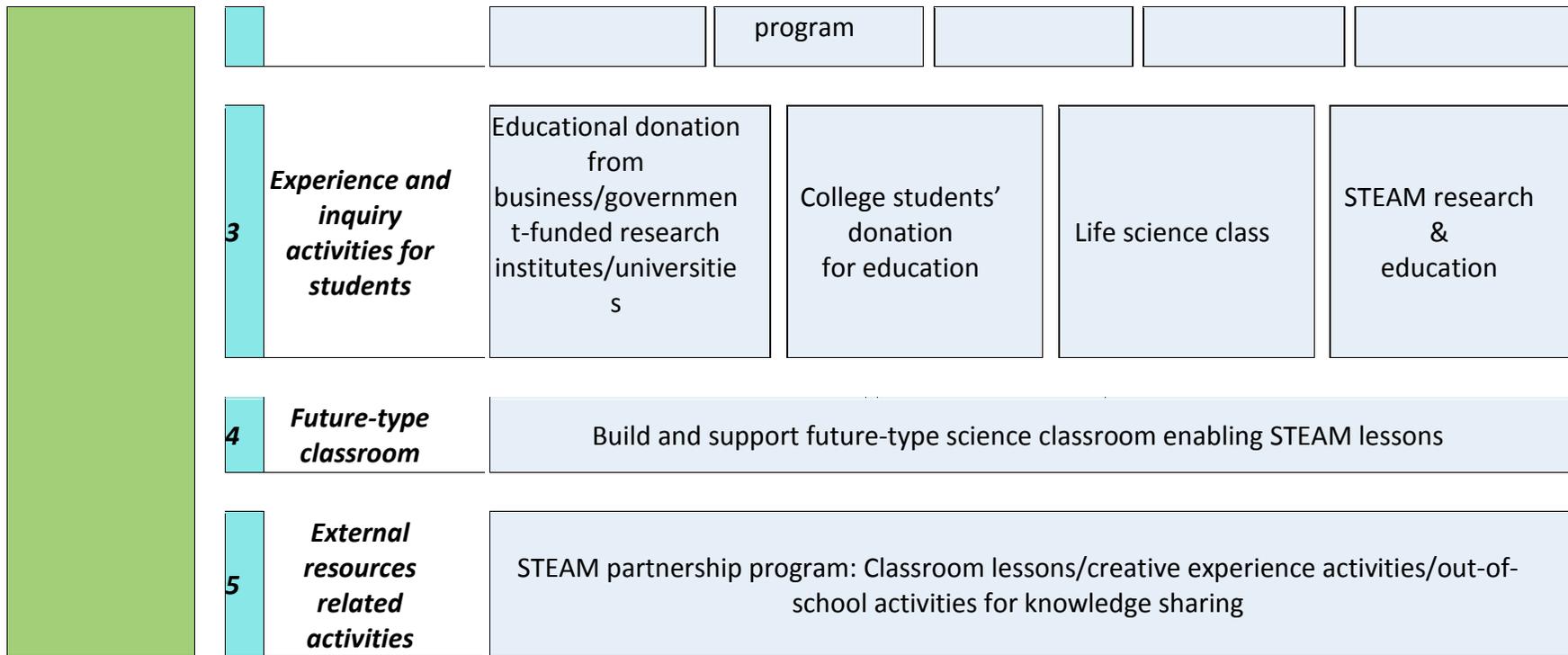


Figure 7. STEAM: Policy, Research, and Education (MEST & KOFAC, 2012)

Case 1. Shinan Middle School in Anyang, Gyeonggi Province

In November 2012, Shinan Middle School received a citation from the Minister of MEST for outstanding performance as an excellent STEAM school at the 2012 STEAM Education Performance Announcement. Shinan Middle School, located in Anyang city, Gyeonggi Province, runs a 'STEAM UP Project for developing the creativity of students'. For this project, 80% of teachers at this school took in-service training courses related to STEAM education. They then organized a 'Shinan STEAM study group' around science, technology, home economics, art, music, and mathematics teachers and conducted integrated lessons. In addition, this school holds a 'STEAM Day' and 'STEAM Week' using creative experience activities. From these efforts, teachers, students, and even parents have shown a high level of satisfaction with STEAM education.

Shinan Middle School has convened 'STEAM education field consulting' for teachers in Gyeonggi Province. For example, in a science class, students create artworks using sounds from vibrating speakers, and by observing the movement of marbling, they learn that they can make great artwork by using sound.

Case 2. Dokjeong Elementary School in Yongin, Gyeonggi Province

Dokjeong Elementary School was selected as a STEAM leader school in 2011. Teachers launched a task force and analyzed the curriculum by school year and subject so that they could tease out the factors of each subject for integrated lessons. STEAM lessons in Dokjeong Elementary School are applied within 20% of the curriculum. Examples include 1) mathematics in traditional art, where students measure the size of the angle between two lines as a math class and learn the beauty of the perpendicular form from artworks as an art class; and 2) making oxygen from potatoes, where science and art classes are integrated together.

Responses and prospects

Regarding STEAM education, several studies have been conducted on the perceptions of elementary and secondary schoolteachers. Overall, teachers have positive attitudes about STEAM education. There is general agreement that STEAM education will be an alternative teaching and learning method. (Geum & Bae, 2012; Han & Lee, 2012; Lee, H. et al., 2012; Shin & Han, 2011; Son et al., 2012). They mostly understood the core concepts and the necessity of STEAM well, but some of them showed misunderstanding or confusion with other educational approaches.

Moreover, most teachers have used little integrated education in their classes, due to insufficient time in actual presentations and a lack of knowledge and expertise in teaching- learning material for STEAM education (Lee et al., 2012; Geum & Bae, 2012). They have presented several needs to facilitate STEAM education: development of a lesson model for the STEAM program, administrators and staff in mind, sufficient financial support, productive in-service training and consulting with educational experts (Shin & Han, 2011). Meanwhile, according to Son et al. (2012), prospective teachers' awareness of

STEAM education was considerably high due to the information acquired from their university classes related to science education; also, they acknowledged the necessity of convergence education, showing the intent to apply it to their actual teaching. It should be noted that STEAM education has quite a short history of application, beginning in 2011. Teachers and students may feel confused, but it also seems that students enjoy this new method of learning. STEAM education needs to include systematic evaluations, effective strategies to benefit student learning, and support, in collaboration among the government, researchers, teachers, and people in science and engineering.

Supply and quality of STEM teachers

Supply of STEM teachers

In Korea, the government controls the supply of teachers, both at the primary and secondary levels of education. It also controls the enrolment quota at teacher training institutions and programs, as well as the quota for each subject for teacher qualification examinations. Teachers are public officials in Korea, except for those working at private schools.

Teachers in the Korean education system are educated in two ways. Primary school teachers are trained mostly at national universities of education, and secondary school teachers receive training at colleges of education, take courses elected for teacher-training, or attain a master's degree at a graduate school of education at four-year institutions. Then public school teachers are selected and appointed based on the teacher qualification examination conducted by metropolitan/provincial offices of education. This national examination is two-tiered: the primary examination is a written test on education (20%) and special areas (80%), and the secondary examination consists of a practical test, essay writing and interview. Teachers hired by private schools do not need to take a national exam for teacher qualifications.

Accordingly, the supply of STEM teachers is also controlled by the government. Being a teacher is one of the top popular occupations in Korean society, and its competition rate for qualification exams is very high for all subjects. For example, the competition rate for English teachers in the Seoul area was 15.5:1 to select 56 people, mathematics at 22:1 for 21 people, physics at 9.4:1 for 10 people, chemistry 15.1:1 for 9 people, biology at 18.3:1 for 11 people, and earth science at 7.1:1 for 9 people. Mathematics usually takes the top quota among all subjects only after English or Korean language and literature in most areas in Korea. However, each science subject receives a small part of the quota or none, presumably due to the curriculum reform and the national exam for college entrance (KSAT; Korean Scholastic Aptitude Test), which provided students with options to study only a couple of science subjects at different levels instead of studying all of them. As a result, these changes have led high school students to elect only a few subjects that were needed or advantageous for their scores on the national exam for college entrance or high school GPAs. For similar reasons, science teachers who teach less popular subjects may teach a small number of hours at school and may also teach the same subject at

neighboring schools because a teacher for the same subject has not been hired there.

Quality of STEM teachers

Regarding the quality of teachers, a variety of in-service training programs are provided by different training institutes and educational organizations designated by MEST. Programs include subject-specific ones, and providers include a KOFAC-affiliated in-service teacher training institute, which provides STEM-specific programs, as well as online ones. The completion of such programs can be factored into their scores for promotion. However, Kim et al. (2012) pointed out that teachers have a negative view of in-service training programs for science education. They maintain that those programs cannot satisfy what teachers want to learn for teaching in class.

Teachers' career structures in Korea are very simple, as long as they stay at school: a teaching track to remain as teachers or an administrator track to become vice principals and principals. The government introduced the Head Teacher program in 2011 as an additional teaching track. Those with more than 15 years of teaching experience can apply for this track, and can have their course load reduced, along with a raise in their salary. Their roles involve assisting other teachers' in their teaching and research, as well as educating students. The purpose of this track was to create an atmosphere to respect teachers, and the allocation per subject is considered when selecting Head Teachers. This track is still very recent, and its scope is still small. The judgment for the success of this program needs more time.

Change of teachers' status in Korean society

A very serious current issue in Korean society is that respect for teachers based on the traditional Korean value system has significantly deteriorated, along with teachers' self-esteem. Students tend to invest their time and energy only in subjects considered to be important for college entrance exams. Students also depend on private tutoring and education outside of school for their education. In this respect, science teachers may find students to be uninterested in their classes, especially when they can select only a few science courses for the college entrance exams. Mathematics is an important subject, but students may pursue advanced learning outside of school (e.g., private tutoring) rather than in public school classrooms.

1.7. 5 Educating human resources in science and technology at the level of tertiary education

Both BK 21 and WCU targeted increasing the global competitiveness of Korean higher education, especially focusing on research, and investing the majority of its funding in science and technology (Byun, Jon, & Kim, 2012)

Brain Korea 21 (BK 21) (1999-2005; 2006-2012)

The Korean government launched the BK 21 project in 1999 to educate qualified human resources in science and technology. This was the first and largest project in financial terms for the educational sector with its goals of contributing to economic development and national competitiveness. Its first phase continued to 2005, and the second phase lasted from 2006 through 2012. BK 21 had a particular focus on supporting graduate students, and most of the funding was concentrated on the natural sciences and engineering fields. Its vision, 'stronger with enhanced human capital', with extensive investment from the government, has yielded significant results in terms of research productivity (Byun et al., 2012).

First, more Korean institutions were ranked high in international university rankings, especially those specialized in science and technology. In the recent Times Higher Education World University Rankings (2012-2013), POSTECH (50th), Seoul National University (59th), and KAIST (68th) appeared in the top 100. KAIST moved from 160th in 2004 to 68th in 2012, and POSTECH moved up from 233th in 2006 to 28th in 2009. Second, BK 21 is evaluated to have contributed to a radical increase of research productivity, although its growth rate was similar to other countries (Byun et al., 2012; Shin, 2009). The number of papers published in SCI journals jumped from 10,739 in 1998 to 39,843 in 2010. In detail, the number of papers published in SCI/SCIE journals increased by 15.7% among participating faculty, 38.1% among junior scholars, and 62.8% among graduate student participants over the second phase of BK 21 (MEST, 2012b). The Impact Factor of journal articles published also increased by more than 30%. A total of 45,353 student participants obtained graduate degrees during the second phase of BK 21. The government evaluation report also emphasized that the employment rate of graduate student participants increased, while that of general graduate students decreased. In addition, the number of patents in science and technology increased; domestic ones from 3,536 in 2006 to 4,352 in 2012, and international ones from 429 in 2006 to 667 in 2012.

BK 21 was not free from criticism for its quantity-oriented performance measures, but most importantly, it is regarded to have contributed enormously to changing attitudes toward research. It has created an environment that values research and has planted the notion that research is necessary for the survival of Korean higher educational institutions.

The World Class University (WCU) Project (2008-2012)

The WCU project (2008-2012) planned to create world-class universities by recruiting internationally renowned faculty, such as Nobel laureates, thereby leading to creating world-class departments, and eventually world-class universities. It encouraged creating new academic majors and departments, as well as collaborating on research projects between international and Korean scholars. It has invited more than 200 scientists from overseas, including Nobel laureates.

This project needs more systematic evaluations in the future, but it is considered to have spent a considerable amount of budget without thorough preparation (Kang, 2011). It also

appears to have sacrificed supporting junior scholars in favor of inviting international faculty (Kim, 2012). It seems that the post-BK and WCU project has considered these shortcomings of the WCU project, and future plans intend to focus on supporting domestic scholars, especially graduate students.

Post-BK & WCU project: Global EXCEL (Excellence and Competitiveness Endeavor for Leading Universities) (2013-2019)

The government plans to begin a follow-up project of BK21 and WCU (2013~2019), the Global EXCEL project (Kim, 2012; MEST, 2011b). Its budget will be twice that of the total of BK21 and WCU. This project aims to increase the number of Korean institutions among the top 100 global universities to seven.

The Global EXCEL consists of three types: 1) global leader teams (30%), 2) interdisciplinary teams (10%), and 3) innovative teams for graduate education (50% in the natural sciences and engineering and 10% in the humanities and social sciences). The Global EXCEL focuses on supporting graduate students by increasing funding for doctoral students, but eliminating the program for international faculty from the previous WCU project. It also concentrates on supporting the natural sciences and engineering, but decreases funding for the humanities and social science fields.

This new project is anticipated to be similar to the previous BK21. Improving quantity-oriented indicators and competition-based evaluation, and supporting researchers and graduate students from a long-term perspective will enable the continued success of BK21.

Global Ph.D. Fellowship (GPS) (2011-)

In 2011, the Korean government initiated the Global Ph.D. Fellowship (GPS), which aims at educating doctorates at the global level to lead the national competitiveness of Korea (MEST, 2012c). It also has the ambition to advance the level of science and technology of Korea by producing Nobel laureates. The GPS funds doctoral students so that they can focus on their academic studies only without concerns about tuition and living expenses. This has a heavy focus on cultivating core human resources in science and technology. In 2011, a total of 295 doctoral students were selected with 233 in science and engineering and 62 in the humanities and social sciences, with plans to recruit new applicants at a ratio of 2 to 8 for humanities/social sciences/education/arts and sports versus the natural sciences/engineering/medicine in 2012.

Through GPS, the Korean government plans to build a comprehensive system for supporting human resources in the natural sciences and technology, which has been widespread (Kim et al., 2011). The GPS system consists of 1) President's science scholarships for undergraduate students, 2) Global Ph.D. scholarships for graduate students, and 3) President's Post-doc fellowships.

The evaluation of its first-year implementation showed that GPS led talented students to pursue graduate education in domestic institutions, expanded research opportunities for

them, and helped them concentrate on their studies (MEST, 2012c). This program is desirable in providing graduate students with an environment to focus on their own studies, considering the fact that graduate students' lives can involve other non-academic jobs in Korean higher education. The GPS system is also expected to reflect the all-lifecycle system for supporting scientists and engineers.

1.7.6 Supporting women in science and technology (2009-2013)

The recent governmental policy initiatives for women in science and technology include the first and second master plans to foster and support women scientists and engineers (2004~2008; 2009~2013) (Lee, H. et al., 2011). The first plan focused on increasing female students in the natural sciences and engineering, developing women scientists and engineers' competence, and building an infrastructure and social atmosphere friendly to women in the field. The second plan has more of an emphasis on female students in engineering, who are relatively less represented than those in the natural sciences. The first plan was successful in improving its targeted areas between 2004 and 2007 (NSTC, 2008); for example, the proportion of female doctorates in the natural sciences and engineering increased from 16.3% to 19.5%; the participation rate of women in governmental committees related to science and technology increased from 27.8% to 33.7%; and the ratio of female faculty in the natural sciences and technology increased from 15.4% to 16.1% and from 2.4% to 3.3%, respectively.

In both master plans for women in science and technology, the major policy programs for education include 4W projects –WISE, WIST, WIE, and WATCH21, by the Korea Advanced Institute of Supporting Women in Science, Engineering, and Technology (WISSET). WISSET was created to support policies and programs for women in science, engineering, and technology (SET) fields, commissioned by the Ministry of Science, Education, and Technology of the Korean government. As described below, the 4W programs are evaluated to have been highly successful. They have contributed to encouraging female students to seek their studies and careers in SET and to developing women's careers in SET. Several tracer studies about these four programs have been conducted, and their results are explained below together (Lee, H. et al., 2011). These programs and their achievements are also explained below.

WISE (Women Into Science and Engineering; 2002~)

The WISE program focuses on a mentoring program between renowned women in SET and female students from elementary school through college. The program also provides opportunities to explore and experience future careers in science through internships, career academies, science research camps, and conference participation. The number of participants increased from 27,732 in 2004 to 142,096 in 2010, and the level of satisfaction increased from 75% in 2004 to 91% in 2007.

In 2010, WISSET surveyed WISE participants between 2007 and 2009 in its mentoring program for a junior science thesis and national research presentation conference for female high school students. They responded that their experience in the WISE programs

influenced their decision for future study and careers (53%), and 64% of them decided to stay or pursue graduate study in the natural sciences and engineering fields.

WIE (Women in Engineering; 2006~)

THE WIE program aims at supporting the development of female students' competence in engineering school and expanding their career paths in their engineering majors. The program consists of improving the curriculum in engineering, which considers gender differences, strengthening academic competence in engineering majors, and providing practical experience for confidence in future engineering careers. Examples include a program that analyzed factors affecting female students' dropout rates in engineering programs and conducted preventive programs that yielded positive results. The curriculum involving strategies to promote gender awareness and equity in engineering education also resulted in positive attitudes and outcomes, for both female and male students.

The WIE program can be evaluated as successful, as shown in Table 31. Not only did female students' employment rate and that in the engineering field increase over the years, but the satisfaction levels of participant students, faculty, and employers with the WIE program also had increased to more than 85% in 2010.

Table 31. Performance indicators (2006~2010)

Performance indicators		2006	2007	2008	2009	2010
Improving engineering curriculum from gender perspectives	Developing new courses	12	20	20	10	5
	Improving preexistent courses	5	25	23	65	74
Improving adjustment capability in the field	Developing competence in major	8	11	20	22	34
	Developing job competence	6	11	13	13	14
Programs for industry-university cooperation and employment	Industry-University cooperation and exchange	5	9	11	16	18
	Employment supporting program	7	12	15	13	14
Employment rate of female students from engineering school		11	15	39	37	37
Employment rate of female students from engineering school in their academic major field		66.1	70.2	76.8	76.2	75.9
Level of satisfaction about WIE program	Industry					
	Female students in engineering school					
	Faculty in engineering school					

Source: Lee, H. et al. (2011, p.108)

WIST (Women in Science and Technology; 2004~)

The WIST program supports the career development of women in SET, including those who are working and seek to return to work in the field. The program also conducts policy research, provides information online, and supports group activities for women in SET. Participants in its educational programs have increased from 135 in 2004 to 2,145 in 2010,

and their level of satisfaction has consistently improved from 4.0 in 2005 to 4.4 in 2010 on a scale in which 5 indicates maximum satisfaction. The level of satisfaction with its web service for a personnel database and information has also grown from 73% in 2006 to 95.7% in 2010.

WATCH21 (Women’s Academy for Technology Changer in the 21st Century; 2004~)

The goal of the WATCH21 program is to educate female college students in engineering school for their relevant competence and leadership. It also aims to motivate female high school students to choose the natural sciences and engineering for their majors and help them increase creative problem-solving capability through joint research activities. About 2,553 students and 360 teams participated in this program from 2004 to 2010. In 2011, WISET surveyed WATCH21 participants between 2009 and 2010, and results showed very positive outcomes. As shown in Table 32, their satisfaction level was high, and programs were highly influential for their decision to pursue future study and careers. Many of them were seeking academic study or careers in SET.

Table 32. Survey results for WATCH21 programs with past participants (N=476)

	High school students	College students	Graduate students
(Very) Satisfied with WATCH21 programs	76%	68%	72%
Programs influenced my decision for future study and career	94%	85%	91%
Chose the natural sciences and engineering for my study/career	81% ^a	85% ^a	97% ^b
What programs helped	Interest in the field	Leadership and management of assignments	Management of assignments

Note. ^a: with only those who are currently college students; ^b:with only those who are currently employed

Overall, Lee, H. et al. (2011) evaluated that the policy programs to foster females in SET were successful to a certain degree. The discrepancy between male and female high school students in pursuing the natural sciences and engineering decreased from 26.0% in 1999 to 18.9% in 2009. However, female high school students choosing the natural sciences and engineering still stayed low, below 30%. Nevertheless, the authors repeated an explanation by PISA, in that Korean female students’ scores in math and science improved by introducing women-friendly science education programs in the 2000s. The gap between male and female students in math scores has continued to decrease, and female students continue to excel in science scores.

Again, however, female students’ interest in math and science has not improved as much, and the proportion of female college graduates in the natural sciences and engineering has gradually decreased from 19.1% in 2003 to 17.2% in 2009 from engineering programs, for instance. Although the WIE program and other programs have been successful, the number of schools involved in the program was still small, and more policy support to elicit female students’ interest in science and engineering in middle and high schools is needed.

References

*All references were written in Korean. The English titles were either taken from original copies or translated by authors.

- Byun, K. & Jon, J.-E. (October, 2011). *Quest for building World Class Universities: Lessons from Korea's experience*. Presented at the 4th International Conference of Higher Education Policy Research Institute at Korea University, Seoul, Korea.
- Byun, K., Jon, J.-E., & Kim, D. (2012). Quest for building world-class universities in South Korea: Outcomes and consequences. *Higher Education*. DOI 10.1007/s10734-012-9568-6
- Byun, S., Kim, J., Heo, D., Ko, Y., Shim, J., Song, A., & Ha, H. (2010). *Highly-talented HRST policy issues and future tasks*. Seoul: Korean Institute of S&T Evaluation and Planning.
- Center for Women In Science, Engineering, and Technology (WISET). (2012). *2011 Korea report on women in science and technology*.
- Chae, C., Choi, Y., Oh, H., Kim, S., Ok, J., & Jung, J. (2006). *Young people's labor market entry and human resources development (II)*. Seoul: Korea Research Institute for Vocational Education and Training.
- Cho, H., Lee, Y., Kang, H., Seo, J., & Han, E. (2007). *Planning for improving social value through technology innovation*. Seoul: STEPI.
- Cho, J., Ok, H., Lee, S., Lim, H., Cha, S., Kim, D., & Lim, J. (2012). *Educational policies for improvement based on international student assessment results*. CRE 2012-1, Seoul: Korea Institute for Curriculum and Evaluation.
- Choi, D., Choi, S., & Kwak, M. (2011). Relationship between PISA 2006 Scientific Literacy and related variables according to tracks in high schools. *The Journal of Vocational Education Research*, 30(1), 247-266.
- Choi, S., & Park, H. (2006). Through Reporting in Children and Teenagers Supporting Trend Analysis of Corporate Social Responsibility Activities. *Korean Nonprofit Organization*, 5(2), 131-157.
- Geum, Y., & Bae, S. (2012). The Recognition and Needs of Elementary School Teachers about STEAM education. *Korean Institute of Industrial Education*, 37(2), 57-75.
- Han, H., Hong, I., Lee, S., Yoo, G., & Kim, J. (2012). A study on the perceptions of teachers and students on the implementation of the intensive course completion system in mathematics courses. *Journal of Korean Society for Mathematics Education*, 51(4), 317-335.
- Hanson, M. (2006). Transnational corporations as educational institutions for national development: The contrasting cases of Mexico and South Korea. *Comparative Education Review*, 50(4), 625-650.
- Hong, S., & Jung, H. (2011). Expanding STEM college graduates' career development paths in their early labor market. *STEPI Insight*, 77. Seoul: Science and Technology Policy Institute.
- Hong, S., Hwang, Y., Bae, Y., Hong, S.-B., Jung, S., Lee, S., ... Huh, H. (2010). *Role of science and technology in leading the economic development of Korea and its implications for developing countries*. Seoul: Science and Technology Policy Institute.
- Jang, C., & Kim, S. (2002). Factor analyses for the avoidance of science & technical engineering colleges and policy implications in Korea. *The Journal of Vocational*

- Education Research*, 21(2), 115-140.
- Jang, C., Lee, S., Hwang, G., Kim, C., Min, J., & Yoon, Y. (2009). *Prospect of the national long-term supply and demand for human resources: Prospect of supply and demand for human resources in science and technology. A policy research report submitted to MEST*. Seoul: Korea Research Institute for Vocational Education and Training.
- Jang, M., Kim, J., & Min, S. (2010). A performance analysis of policy for Meister School. *The Journal of Vocational Education Research*, 29(4), 215-235.
- Jin, M.-S., Song, C., Chu, H., & Yoon, H. (2012). *Planning educational policies based on the analysis of STEM-avoiding phenomenon*. Seoul: Korea Research Institute for Vocational Education and Training.
- Kang, T. (2011). *Strategies to attract global human resources in science and technology in consideration of population change in 10 years. A report submitted to the Presidential Advisory Council on Science and Education*.
- Kim, B., Yoo, H., Baek, S., Hong, H., & Kim, J. (2011). *Plans to reform higher education system to respond to change in educational environment*. Seoul: National Science and Technology Commission.
- Kim, H. (2012, March 6). Global EXCEL following BK21-WCU. Investing 4.4trillion Korean Won for the third cycle of the higher education research project over the next seven years. *Donga-Ilbo*.
- Kim, Y. (2010). A study on the policy guideline on the re-structurization of social position for scientific technologists through the analysis of the avoidance of engineering course. *Research in Human Resource Management*, 17(2), 183-202.
- Kim, J. Kim, K., Lee, J., Hwang, M., & Kim, J. (2012). Effect and recognition of peer instruction in training of in-service science teachers. *Journal of Science Education*, 36(1), 84-93.
- Kim, J., Kim, Y., Kim, H., Nam, S., Park, K., Park, Y., ... Hong, M. (2007). *A follow-up study of plans to develop the quality of life based on technology. A report submitted to the Presidential Advisory Council on Science and Education*. Korea Research Institute of Standards and Science.
- Kim, M., Lee, H., Seo, Y., Choi, K., Choi, Y., & Kim., I. (2010). *Research for comprehensive strategies to develop and educate gifted people in science and technology at the age of 15 through 45 (II): Analysis of science high school graduates' academic and career paths*. RR 2010-13. Seoul: Korea Educational Development Institute.
- Kim, S., Han, K., Kim, D. (2009). *A policy study for improving specialty in science and technology policy*. Pohang: POSTECH.
- Korean Institute of S&T Evaluation and Planning (KISTEP). (2009). *A 2009 report on human resources in science and engineering*. Seoul: MEST & KISTEP.
- Korean Institute of S&T Evaluation and Planning (KISTEP). (2011). *A 2010 report on human resources in science and engineering*. Seoul: MEST & KISTEP.
- Korean Institute of S&T Evaluation and Planning (KISTEP). (2012). *A 2012 report on human resources in science and engineering*. Seoul: MEST & KISTEP.
- Korea Foundation for the Advancement of Science and Creativity (KOFAC). (2011). *A 2010 report on Koreans' understanding of science and technology*. KOFAC & Gallup Korea.
- Korea Foundation for the Advancement of Science and Creativity (KOFAC). (2012). *2011 Annual statistics on science and creativity*. Seoul: KOFAC.
- Korea Science Foundation. (2004). *Study of the national survey on the students' recognition*

- toward science and technology*. Korea Science Foundation.
- Kwon, S., Nam, D., & Lee, T. (2012). The effects of steam-based integrated subject study on elementary school students' creative personality. *Journal of the Korea society of computer and information*, 17(2), 79-86.
- Lee, B. (2007, July). *Right people desired by companies and human resources management*. Presented at the Korean Science and Technology Conference.
- Lee, G., & Chun, S. (2012). *A comparative analysis of creative systems to educate human resources in science and technology by advanced countries. A policy research report submitted to MEST*.
- Lee, H., Park, Y., Moon, M., Kim, J., & Sohn, J. (2011). *Performances and future prospect of policies for the support and cultivation of women scientists and engineers*. A policy research report submitted to MEST. Seoul: Center for Women In Science, Engineering, and Technology.
- Lee, H., Son, D., Kwon, H., Park, K., Han, I., Jung, H., ... Seo, B. (2012). Secondary teachers' perceptions and needs analysis on integrative STEM education. *Journal of Korea Association for Science Education*, 32(1), 30-45.
- Lee, J., Hong, S., Bae, S., Kim, Y. C., Kim, Y. G., Han, S., ... Lee, J. (2011). *Powerhouse of Talents*. Seoul: Korea Economic Daily & Business Publications Inc.
- Lee, J., Ko, Y., Heo, D., Shim, J., Kim, J., Kim, H., & Do, G. (2008). *A study on the future's strategy of human resources in S&T*. Seoul: Korean Institute of S&T Evaluation and Planning.
- Lee, J., Lee, M., Seo, Y., Kang, B., & Oh, J. (2011). *Research for comprehensive strategies to develop and educate gifted people in science and technology at the age of 15 through 45 (III): Development plans for STEAM education in science high schools and schools for gifted and talented students in science*. RR 2011-11. Seoul: Korea Educational Development Institute.
- Lee, W., Yang, S., Kim, J., Lee, K., Lee, S., Lee, C., Bae, J., & Park, E. (2011). *Research on the actual condition of self-awareness of people in science and engineering fields. A policy research report submitted to MEST*.
- Ministry of Education, Science, and Technology (MEST). (2010). *The Second Master Plan for Educating and Supporting Human Resources in Science and Technology (2011-2015)*.
- Ministry of Education, Science, and Technology (MEST). (2012a). *Accomplishments of Lee, M.-B. government's science and technology policies: Science and technology opens the future of Korea* [Electronic mailing].
- Ministry of Education, Science, and Technology (MEST). (2012b). *Evaluation results and outcomes of the second phase of BK 21*. MEST materials for media.
- Ministry of Education, Science, and Technology (MEST). (2012c). *2012 Global PhD Fellowship plan*.
- Ministry of Education, Science, and Technology (MEST) & Korea Foundation for the Advancement of Science and Creativity (KOFAC). (2012). *2012 STEAM: Policy, Research, and Education*. Seoul: Korea Foundation for the Advancement of Science and Creativity.
- National Science and Technology Commission (NSTC). (2008). *The Second Master Plan for Educating and Supporting Women in Science and Technology (2009~2013)*.
- National Science and Technology Commission (NSTC). (2011). *Master Plan for Educating and Supporting Human Resources in Science and Technology: For creative power Korea*

- with human resources in science and technology (2011-2015).*
- Oh, Y.-I. (2012). *A 2012 study on Koreans' understanding of science and technology & a comparative study on the perception of science cultures among Korea, Japan, and China.* Presented at the 2012 Science & Creativity Conference, Seoul, Korea.
- Park, K., Min, C., Hong, J., Song, C., & Woo, S. (2011). *Strategies for global competitiveness in science and engineering education.* Seoul: Science and Technology Policy Institute.
- Park, S., & Cho, M. (2011). Realities of national Meister High School's curriculum and its tasks. *The Journal of Educational Research, 9*(3), 155-176.
- Russell, M. (2002). South Korea scrambles to fill Ph.D. slots. *Science, 295*(15), 1991-1992.
- Seo, H. (2007). Science education at the primary and secondary levels of education and education for gifted students in science. In HRST Joint Research Center (Ed.), *Human resources in science and technology in Korea* (pp. 35-87). Seoul: Korea Research Institute for Vocational Education and Training.
- Seo, H., Jang, S., & Pereira-Mendoza, L. (2004). *Direction of science education based on factors affecting high achievers' choices of careers in science and engineering.* Seoul: Korea Educational Development Institute, OR 2004-5.
- Seo, Y.-M., Shim, S.-O., Kim, E.-K., & Choi, J.-I. (2012). An empirical study for the cognition of the convergence human resources for the companies: Focus on the firms in Deajeon region. *Journal of the Korea Academia-Industrial cooperation Society, 13*(5), 2045-2053.
- Song, C., Jin, M., Lee, S., Hwang, G., Chun, J., Park, K., & Um, M. (2008). *Policy responses for crisis in science and engineering: Focusing on qualified human resources in science and technology.* Seoul: Korea Research Institute for Vocational Education and Training.
- Shin, Y., & Han, S. (2011). A Study of the Elementary School Teachers' Perception in STEAM (Science, Technology, Engineering, Arts, Mathematics) Education. *Elementary science education, 30*(4), 514-523.
- Shin, H., & Jung, J. (2009). The new direction of Meister High School policy and its tasks in future. *The Journal of Vocational Education Research, 28*(4), 157-182.
- Shin, J.-C. (2009). Building world-class research university: The Brain Korea 21 project. *Higher Education, 58*(5), 669-688.
- Son, Y., Jung, S., Kwon, S., Kim, H., Kim, D. (2012). Analysis of prospective and in-service teachers' awareness of steam convergent education. *Journal of Humanities & Social Science, 13*(1), 255-284.
- Song, J., & Lee, T. (2010). The effect of stem integration education using educational robot on academic achievement and subject attitude. *Journal of the Korean Association of Information Education, 15*(1), 11-22.
- Sung, E., & Na, S. (2012). The effects of the integrated stem education on science and technology subject self-efficacy and attitude toward engineering in high school students. *Journal of Korean Technology Education Association, 12*(1), 255-274.
- United Nations. (2012). *E-government survey 2012: E-government for the people.* United Nations Department of Economic and Social Affairs.
- You, E., Seo, J., & Lee, M. (2011). *Ways to activate citizen-oriented science and technology.* Seoul: Science and Technology Policy Institute

Hyundai Mobis (2012) www.mobis.co.kr

International Association of Public Transport (UITP) www.uitp.org

Korea Foundation for the Advancement of Science and Creativity (KOFAC) www.kofac.re.kr

National Science & Technology Information Service www.ntis.go.kr