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Abstract

In this report, the overall STEM system in China is briefly reviewed. The main body of the report consists of four parts: the overview of the evolution of the STEM system in China, STEM in senior secondary school, STEM in the higher education sector and STEM personnel and employment. Students' participation in STEM and teachers involved in STEM teaching have been closely examined. Strategies for improving STEM teaching and learning at different levels have also been reviewed and analyzed. The main findings of the report are two points. First, China has a larger participation of students in STEM than most Western countries at either secondary or higher education level and various initiatives have been launched by both central government and educational institutions for facilitating STEM, resulting in considerable progress of STEM system in China. Second, there are still vulnerabilities in the current STEM system in China, mainly in the way of instruction and scientific spirit cultivation. Continuous reforms are necessary for sustain the development of STEM in China and the higher education system should be further expanded in order to achieve the goals set by the Chinese central government for 2020.

1 Introduction

In the Chinese context, science refers to mathematics, basic natural science and interdisciplinary subjects. Science explores the natural law. It drives science and technology (S&T) and economic development. Amid the entire knowledge system, science serves as the foundation and directs the future, advancing the human civilization. Science education, particularly in the higher education (HE) sector bears the missions of nurturing scientific research and cultivating talents. Now the missions also involve popularizing scientific literacy among university students. The success of science education of a nation is closely related to national S&T development, economic prosperity, national security and even social progress. Science education in the HE sector influences the citizen's scientific literacy and indigenous innovation, which is the core competitiveness of a nation. It is the foundation of the whole HE system, and also plays an important role in the national innovation system. Therefore, science education has always been seen as a strategic priority in China (Science Specialty Committee of China Higher Education Society, 2009).

In general, science education consists of two major parts: cultivating science talents (specialized education) and implementing scientific education, which refers to providing basic science training to students who do not major in science and to foster the scientific literacy of all students. This is also an indispensible part of liberal education or quality-oriented education. In terms of specialized science education, it could be further divided into two groups: basic science education and applied science education. Efforts need to be made in both groups and they interact with each other. Against the Chinese context, the focus of basic science should be put on quality, targeting international standards. The primary aim of basic science education is to provide the manpower for indigenous innovation. The majority of applied science talents will be involved directly with R&D activities in different sectors, serving as the main force of S&T innovation. Meanwhile, non-science students should possess basic science knowledge, scientific spirit and qualities, in order to promote the entire nation's creativity (ibid).

2 Overview of the STEM system in China
2.1 Evolution of China’s STEM-related policies and system

After the foundation of the People’s Republic of China in 1949, the introduction of modern S&T and the establishment of a completed modern education system became the top priorities of the new government. In the 1950s, China promoted research and development centring on the fields of defence and heavy industry under the highly centralised ruling system modelling after the former Soviet Union (Song, 2008; X.-W. Zhong & Yang, 2007). With the opening up of policy in 1978, the slogan that ‘science-technology is the chief productive force, knowledge and talent shall be respected’ was proposed (Deng, 1997). For the first time in China’s history, S&T were viewed as the driving force behind economic development. The Chinese government began to shift away from the inefficient Soviet style technology innovation system to a new system that motivates the participation of all parties: research institutes (RIs), universities and the enterprises. In 1995, China’s overarching national development strategy was defined as ‘Rejuvenating China by Technology & Education’ (L.-L. Zhu, 1995).

In 2006, a new S&T development goal (2006-2020) was defined for the coming 10-20 years, covering agriculture, industry, high-tech and basic science research (China State Council, 2006). It is clear that China has positively adjusted its S&T strategies to better align with the overall national strategy and the goals for economic and social development. The important role that S&T plays in current China’s society is three fold. Fundamentally, the advancement of S&T is the radical motive of social and economic development. Second, scientific innovation will accelerate the transformation of economic development, which is the first priority of the national strategy. Third, S&T do not only mean knowledge and skills, but are also closely related to the national culture and spirit. The scientific spirit and qualities of a nation determine the future and vitality of the nation (Wen, 2011).

Over time this series of policies have laid down a crucial institutional foundation that independent agencies for S&T have been established at all levels down to counties, constituting an effective top-down science system in China (see Figure 1). Fiscal appropriations for S&T are granted through program-based competitive grant schemes, which are administered by the Ministry of S&T (MOST), Chinese Academy of Science (CAS), Chinese Academy of Engineering (CAE) and National Natural Science Foundation of China (NNSFC). The competitive grant schemes cover ten main programs, each of them including several subsidiary programs. The ten main programs are Basic Research Program, Key Technologies R&D Program, S&T Basic Conditional Construction Program, Spark Program, Torch Program, National New Products Program, Innovation Fund for Small Technology-based Firms, Agricultural S&T Transfer Fund, International S&T Cooperation Program and Special Technology Development. By 2010, a total of 218 national leading laboratories had been established. The majority of them are operated by universities and RIs, under the administration of the Ministry of Education (MoE) and CAS.
2.2 STEM in the national interest

Giant of science emerges when the society’s economy becomes extraordinarily robust by world standards. France, Germany, Britain and the U.S. are examples. An evolving multi-polar world economy is leading to multiple centres of science. As the Chinese economy has boomed in the last two decades, China has emerged as an important science power (Rogers Hollingsworth, Müller, & Hollingsworth, 2008; P. Zhou & Glanzel, 2010). In recent years, China’s economy has been growing fast. The average annual GDP growth rate was 11.2 per cent during the period 2005-2010, and reached ¥47.16 trillion (approximately AU$7.25 trillion at current exchange rate) in 2011 (National Bureau of Statistics of China, 2012). China has become the second largest economy after the U.S. China’s economic growth and social progress are inseparable from its S&T developments and policies since the relationship between S&T and the economy is interdependent and mutually enhancing (Ding, Li, & Wang, 2008; Foray, 2004; P. Zhou & Leydesdorff, 2006).

Like any developing country, the financial investment in R&D is a decisive factor for the progress of S&T in China, and government allocations play a major role. Expenditure on R&D is one of the most widely used measures of innovation inputs. R&D intensity (R&D expenditure as a percentage of GDP) is used as an indicator of an economy’s relative degree of investment in generating new knowledge (OECD, 2011a). Table 1 shows the gross expenditure on science-related R&D (GERD) in China from 2005 to 2010. China has excelled at mobilising resources for S&T on an unprecedented scale and at exceptional speed. According to OECD figures, in 2009, China’s domestic expenditure on R&D was the equivalent of 12 percentage of total OECD GERD; it was therefore the world’s third largest R&D performer (ibid). In 2010 GERD in all sectors of the economy was ¥706.3 billion (approximately AU$108.7) in China, increasing by 21.7 percentage of last year. Among the total GERD, 71.7 percentage came from the business sector, and the government (including through the HE sector and RIs) directly controlled 24 percentage of GERD. Figure 2 shows the GERD by source of funds. The distribution of

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1 In this section, all the data without specific note are sourced from NBSC, 2012, and the tables and figures in this section are summarized by the author according to the data.
investment among different sectors shows that enterprises have become the principal force of R&D activities, and universities have become a significant base for technology innovation (Song, 2008; X.-W. Zhong & Yang, 2007). The dominant role of enterprises in technology innovation is clearly a prerequisite for the transfer of S&T to productivity.

Table 1 GERD in China (2005~2010)

<table>
<thead>
<tr>
<th></th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>GERD (billion yuan)</td>
<td>245.00</td>
<td>300.31</td>
<td>371.02</td>
<td>461.60</td>
<td>580.21</td>
<td>706.26</td>
</tr>
</tbody>
</table>

Figure 2 GERD by source of funds (2010)

<table>
<thead>
<tr>
<th>Source of Funds</th>
<th>Total (billion yuan)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business</td>
<td>506.31</td>
</tr>
<tr>
<td>Government</td>
<td>169.63</td>
</tr>
<tr>
<td>Abroad</td>
<td>9.21</td>
</tr>
<tr>
<td>Others</td>
<td>21.10</td>
</tr>
<tr>
<td>Total</td>
<td>706.26</td>
</tr>
</tbody>
</table>

However, in terms of R&D intensity, China (1.70%) stood below the OECD average (2.3%). The mix of research expenditure summed across all sectors of the system was 4.6 per cent basic research, 12.7 per cent applied research and 82.8 per cent experimental development in 2010. Figure 3 shows the GERD by type of activity. Compared with developed countries, the most obvious difference is that the number of investments in basic research accounts for only a small proportion in China. This is determined by various priorities on different countries’ agendas. The top priority in a growing economy is to eliminate poverty; therefore, China has to focus its resources on applied and experimental development research (Song, 2008). There have always been arguments over this issue in the science community, with many appealing for more input into basic research. Basic research is the driving force behind the progress of civilisation, the cradle that nurtures talents. New discoveries and inventions are sources for new knowledge and technologies (ibid). As the economy grows, appropriations on basic research are likely to increase in the future. Over the past 20 years, China has made tangible contributions to biology, geology, physics, astronomy, and mathematics. Nevertheless, its major research capability in basic science is still weak compared with developed countries. The basic and applied research was largely funded by the HE sector, which contributed 30.1 percentage and 56.4 of total expenditure on these two types of research respectively. Experimental development was funded overwhelmingly by the business sector, which took up 97.5 per cent. In 2010 the total government appropriate was ¥411.1 billion (approximately AU$63.3 billion).
In 2010 the total GERD summed across all sectors varied markedly according to the field of research (see Figure 4). The priority of R&D investment was Engineering and Technology Science, which received ¥88.4 billion (approximately AU$13.6 billion), followed by Natural Science (¥18.77 billion). Total GERD on Agricultural and Medical Sciences was ¥8.47 billion and ¥4.99 billion respectively.

### 2.3 STEM in the business sector

It is found that policy changes have gradually made enterprises the focal point of the national innovation system (Ding et al., 2008). S&T back up the development of enterprises. The contributions that S&T make to the national economy are expressed themselves through the progress made by enterprises since in the market economy; the competitiveness of enterprises comes from scientific innovation (Tian, 2006). Building enterprise innovation capability has been involved in the national S&T development agenda. In 1996, for example, the central government launched the Technological Innovation Project with emphasised boosting corporate technological innovation capacity. In 1999, the Technological Innovation Funds for High-tech Small and Medium-Sized Enterprises was set up to support enterprise-based technological innovations (Ding et al., 2008).
The 2010 census data show that professionals in R&D in the business sector was 2.4 million people, accounting for 68.7 percentage of the total R&D personnel in China. In 2010, the business sector invested ¥506.3 billion (approximate AU$77.89 billion) in R&D, and 28.31 percentage of all different categories enterprises in China were involved with R&D activities. Among them, the large and medium-sized industrial enterprises ran a total number of 145,589 R&D projects that cover almost all the industrial sectors.

With emphasis on innovation capacity building in the business sector, China also aims to encourage scientific RIs and universities to undertake R&D activities in response to industrial needs and to strengthen the combination of industry, education and research. Developing linkages with universities and RIs provides an alternative approach for enterprises to be involved in S&T activities. Various forms of cooperation, such as informal consulting by university researchers to industry, technology service contracts, joint research projects, science parks, patent licensing, and University and RIs-affiliated enterprises have been promoted to strengthen the close ties between industry and academic institutions (X.-W. Zhong & Yang, 2007). The effective Chinese science and high-technology park model exemplifies the role of universities in nurturing native companies through information network and entrepreneurship training (Salami & Soltanzadeh, 2012).

2.4 STEM in the education sector

From the last section, it could be noted that the increase of investment in R&D has greatly facilitated the development of S&T in China. Large-scale R&D requires a steady supply of S&T talents, and China now has the largest supply of S&T talents in the world (X.-F. Liu, Liang, & Liu, 2012). Science education in China has a long history. The Chinese society has always attached great importance to science education and regarded it as the cornerstone of the nation state. Formal education in China is divided into basic education and higher education. Basic education includes three years of preschool and twelve years of primary and secondary school study. In order to continue their study in the general or academic rather than specialized or vocational route, junior secondary graduates must pass the entrance examination for general senior secondary schools. The examination includes subjects of Chinese, mathematics, foreign language, politics (open-book), physics and chemistry (H.-C. Sun, 2005). During the three years of senior secondary education (from Year 10 to Year 12), students need to make their decisions to take either of the two divisions of arts and science at the beginning of Year 11. Unlike most Western countries where students are entitled the right to choose the specific subjects they would like to take during the senior secondary education, the students who choose the science track in China are required to continue to study physics, chemistry and biology as compulsory subjects in the final year to make the fullest extent preparation for the highly competitive National College Entrance Examination (NECC), which determines if they can be enrolled by higher education institutions (HEIs). Mathematics is a compulsory subject for students in both of the two divisions.

All students are required to take the General Senior Secondary Unified Graduation Examination by the end of Year 11 in order to get the graduate certificate. By passing the unified graduation examination, students demonstrate that they have fulfilled the requirements of all compulsory courses according to the national syllabuses. And the examination consists of nine major subjects; among them the STEM-related subjects of physics, chemistry, biology and mathematics are compulsory (ibid). This means science
is taught as a compulsory part from Year 7 to Year 11 in China. And mathematics is emphasized throughout the whole period from year 7 to Year 12. Therefore, the number of students involved in STEM-related education in China is the largest in the world.

Since the lack of nationwide statistics about the numbers of students in two divisions in senior secondary schools, it is difficult to depict a precise picture of the pipeline of science students for the HE sector. But a rough picture could be drawn from the number of applications for the NECC in arts and humanities, and in science and engineering. In the year 2010, 8.9 million students took the NECC; among them, approximately 3.9 million took the arts and humanities branch and 4.9 million took the science and engineering pathway (see Figure 5). The ratio of science and engineering students to arts and humanities ones is 1.26. It shows that the science and engineering track is more popular among students.

Figure 5 Applicants of student take NECC in two divisions (2010)

<table>
<thead>
<tr>
<th>Division</th>
<th>Total (persons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arts and humanities</td>
<td>3,917,040</td>
</tr>
<tr>
<td>Science and engineering</td>
<td>4,897,524</td>
</tr>
<tr>
<td>Others</td>
<td>113,095</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>8,927,659</strong></td>
</tr>
</tbody>
</table>

(Source: China Educational Statistics Yearbook, 2010)

According to Su’s study (2009), seven factors influence the students’ decision on the division of the arts and science: achievement motivation, social demands, internal controlling sources, creativity, subject knowledge, interests and preferences, and family help. When choosing the pathway of the two divisions, social demands are the most important decisive factor for students. For example, the science and engineering applicants have more possibility to get enrolled by HEIs and various opportunities to be exempted from the NECC. The consideration of social demands also reflects the concern of employment. Since the choice of the arts or science track in senior secondary school will largely determine the majors the students could choose in the university, and in turn influence students’ career path in the future. The individual interests and preference of specific subjects are also influential in decision-making. Interests have been seen as the primary motive in learning and contribute to the long-term achievement of a student in academics. In addition, boys place more importance on achievement motivation and subject knowledge than girls in the consideration of track choosing. The parents who have professional knowledge have greater impacts on their child’s choice than those that have not. In general, students’ personal trait and social resources are significant correlation with the intention of the division of the arts and science.

Students usually enter HEIs after completing senior secondary study and passing the NCEE. China is similar to Canada in terms of the general pattern of HE. Students may choose short-cycle college diploma programs or pursue Bachelor, Master and Doctoral degrees. An important way to categorize HE programs is whether they belong to regular HE or adult education. These two types of education differ in many ways, including the institutions, curriculum, admission and graduation requirements, and overall quality control standards. In reality, regular education is considered to be of better quality and
therefore more highly regarded in China (H.-C. Sun, 2005). It is offered by degree-granting institutions (universities), research institutions or institutions that offer only diploma programs. In this report, the discussion of STEM-related education at HE level only limits within regular education sector.

HEIs are a key element of the national science and innovation system. They function as both human capital provider and seedbed of new firms in the emerging knowledge economy (Etkowitz, 1999). In China, the role of universities has evolved aligned with the transformation of economic development mode. In 1950, universities in China were mainly set up to train S&T talents for the government. At that time, the teaching function of universities was strengthened and seen as the priority. In contrast, the research function of universities was extremely weak and neglected. It was partly because the major research function was carried out by governmental research institutions. Since the economic reform started in 1978, universities have been regarded as an integral part of China’s national innovation system (Xue, 2006).

After more than two decades of the reform, the position of China’s universities in the national innovation system has been substantially promoted to a high level. On the one hand, the teaching function of universities has been further strengthened with an increasing gross enrolment rate for HE, reaching 26.5 percent in 2010. On the other hand, universities have also shown their great potential in knowledge innovation and industrialization of high-techs. Chinese universities have become a main force in China’s knowledge production activities. In 2010, 288,602 full-time equivalent research people were involved in S&T work in universities, spending 8.5 percent of national R&D expenditures and publishing 64.6 percent of all the papers published domestically (MOST, 2012). University research is central not only to expanding the frontier of codified knowledge through publications, patents and prototypes, it also contributes to local and national economies through research commercialization, problem solving, and providing public space for knowledge exchanges and application (Wu & Zhou, 2012; Xue, 2006). Universities are increasingly seen as a source of knowledge and innovation for technological progress. The Chinese government has invested considerable energy and imagination in promoting local universities as critical agents of technological progress (Ronald et al.). All the facts show that the role of universities in China’s national innovation system have been much more important than before.

In 2010, the number of students enrolled in Normal Bachelor Course in China was 12,656,132, among them, the students participating in STEM-related fields of education, including Science, Engineering, Agriculture and Medicine reached 6,356,936, taking over a half of the total enrolment (see Figure 6). In 2010, 3,512,563 students commenced a course at Bachelor’s level. The STEM-related fields of education held the following shares of total commencing bachelor’s enrolment: Science, 9.8 percent; Engineering, 31.6 percent; Agriculture, 1.8 percent and Medicine, 6.3 percent (Figure 7). Compared with the counterparts in Australia, a larger proportion of Chinese students chose science-related disciplines as their major.
For postgraduate study in China, HEIs provide Master and Doctoral courses. Unlike most Western universities where two different types of Master programs (by course or by research) can be chosen by students, all Master programs offered in Chinese universities require certain credits of coursework. The entrants of both Master and Doctoral levels was 538,117 in 2010, among them, 267,033 majored in science-related fields (Figure 8). From the data it can be seen that as much as 71.4 percent of new commenced doctoral students chose science-related disciplines as their major. Among all the science majors, the most favored field was engineering, followed by science and medicine. China has overtaken the U.S. as the world leader in the number of doctoral degrees awarded in natural science and engineering. The proportion of students participating in STEM majors is impressively high. A similar pattern could be found in the number of entrants at Master level.

The following figures and tables without specific note are summarized by the author according to the data from MoE, 2012.
Figure 8 Entrants of Master and Doctor’s Degree by field of education (2010)

<table>
<thead>
<tr>
<th>Field of Education</th>
<th>Doctor’s Degree</th>
<th>Master’s Degree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science</td>
<td>12,216</td>
<td>46,172</td>
</tr>
<tr>
<td>Engineering</td>
<td>23,977</td>
<td>129,727</td>
</tr>
<tr>
<td>Agriculture</td>
<td>2,831</td>
<td>12,043</td>
</tr>
<tr>
<td>Medicine</td>
<td>6,524</td>
<td>33,543</td>
</tr>
<tr>
<td>Others</td>
<td>18,214</td>
<td>252,930</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>63,762</strong></td>
<td><strong>474,415</strong></td>
</tr>
</tbody>
</table>

Various factors interact with each other in determining the majors that students choose for their university study. The most decisive factor is career prospect (Fan, 2012; H.-B. Zhao, 2004; Y.-Z. Zhao & Qian, 1999). The opportunity for employment after graduation plays a key role in students’ major selection since nowadays the graduates in China need to face really fierce competition to obtain a job. It is also closely related to the students and their parents’ expectation for the changes that HE can bring to the whole life of the student (Fan, 2012). Currently, HE in China is still at the stage of massification, for the HE age cohort, the chance to be enrolled by HEIs is relatively rare. Particularly, for the students from farmer families, they expect to gain a job that could change their life pathway through receiving HE (ibid). Another influential factor is family background (social-economic status, education of parents and the place of residence) of the student (Jiang, 2007; Meng, Li, Zhou, Zhu, & Su, 1996; Xie & Wang, 2005; D.-P. Yang, 2006; Yu, 2002; Y.-P. Zhong & Lu, 1999). According to the existing studies, urban students from advantageous family backgrounds, which means their families are richer, their parents are well-educated or have higher social status prefer to choose those majors closely related to better career prospects or those less demanding majors. In contrast, students from disadvantageous family background may choose the majors that are easier to be enrolled or the ones that have less tuition fees. In addition to the above-mentioned two factors, the interest and competence in a certain major are also considered. Similar to the arts or science track selection in senior high school, students refer to their parents’ opinions on major selection as well. According to Fan’s (2012) study, over 60 percent of students perceive that their parents’ opinions are important or very important in decision making.

3 STEM in senior secondary school
In an era where technology and the rapid flow of information dominate every major area of economic growth, innovation and excellence in mathematics and science are integral to a nation’s long-term success. All countries that have advantages in S&T place particular attention on their citizens’ science literacy, since it is closely related to the overall qualities and creativities of talents, and even the competitiveness of a nation (Y.-B. Wang, 2008b).

3.1 The senior secondary school STEM landscape

3.1.1 STEM-related courses and participation in Year 10-Year 12

As discussed in the last section, all the students in Year 10-Year 11 are required to study mathematics, physics, chemistry and biology as compulsory subjects. For students in Year 12, the mathematics is still compulsory for all students in two divisions, and the participation in physics, chemistry and biology includes the students who choose the science and engineering track. Figure 9 shows the changes of the number of students in senior secondary schools from 2005 to 2010. It stands for the number of Chinese students involved in mathematics study. The ratio of students involved in the science track and in the arts track has been maintained at around 1.2 since 2005.

Figure 9 Number of students in senior secondary schools (number of students involved in mathematics study in senior secondary schools) 2005~2010

The data shows that there were very slight changes in the number of senior secondary school students during the six years. It means the number of students participating in mathematics study remained stable from 2005 to 2010. Among them, 48.6 percent were female students, 2.8 percent fewer than the male students.
3.1.2 Teaching and learning in STEM

Science education has a long history in China. Under the influence of traditional culture, the teaching and learning in science has evolved with its unique characteristics. For example, it is teacher-centered, theory focused, national examination oriented, and homework supplemented. It also features systematic after-class activities and the active involvement of parents. Science teachers attach great importance to lesson planning and exchange of experience following systematic pre- or in-service teacher training. In this section, the pattern and features of teaching and learning in STEM-related subjects will be examined from three aspects, curriculum, teaching methods and examinations, aiming to depict a rough picture of current Chinese science education at the senior secondary level.

Curriculum

In both science and mathematics, China has national standards for what is to be taught at each of the three levels of schooling. While these standards are revised from time to time, they spell out in some detail the topics that students are expected to master (Y.-B. Wang, 2010). Textbooks, materials, teacher preparation, and professional development are all clearly aligned to these standards. The importance given to the standardized texts and teaching plans is linked to the national system of examinations. The NECC is held annually by a province or city and is closely based upon what is contained in the standard textbooks. As a result, textbooks function as the central pillar for science lessons instead of occasional references or sources in the Western countries. The curriculum in China focuses on building strong foundational knowledge and mastery of core concepts. Biology, chemistry, and physics as well as algebra and geometry are mandatory for completion of high school (Asia Society, 2006).

Teaching methods

Chinese education leaders express great concern about teacher-dominated classrooms and students’ lack of independent thinking. This instructional approach is based on deep differences in cultural attitudes between China that is influenced by Confucian philosophy, and Western societies such as the United States. The latter stress individualism and competition, valuing personal achievement and independence. Eastern culture emphasizes the social roles of individuals and classes, valuing collectivism in which individuals work toward the well being of the whole. This results in a ‘group-based, teacher-dominated, highly structured pedagogical culture’ in classrooms in China (L. Wang & Fan, 2007).

Lectures are the primary method used in teaching. In China, it is quite common for a science teacher to dominate the entire class period and to monotonously present his or her prepared lectures from the beginning until the last minute of the class (W.-J. Wang & et al., 1996). One advantage of using lectures as the primary means of instruction is that students are exposed to much information in a limited time (usually 45 minutes). This method also allows a teacher better control over the class. The shortcomings, however, are the lack of student involvement and the neglect of the differences in abilities and needs among students.

Examinations
Although the philosophy of quality-oriented education has been promoted in China, in practice, China’s education is still largely examination-driven. The promotion rate of senior school graduates to higher education (the ratio of total number of new entrants admitted to HEIs to the total number of graduates of regular senior secondary schools of the current year) is relatively high in the recent five years (see Figure 10); however, those who want to enter a prestigious HEI still need to face fierce competition in the NECC. Math and science scores attained in the NECC count highly in differentiating among students seeking college admonition. Therefore these subjects command major emphasis in the curriculum and in student effort. The examination system plays a very important role in science education in China (Asia Society, 2006; W.-J. Wang & et al., 1996).

Figure 10 Promotion rate of senior school graduates (2005~2010)

<table>
<thead>
<tr>
<th>Year</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Promotion Rate of Senior Graduates</td>
<td>76.3</td>
<td>75.1</td>
<td>70.3</td>
<td>72.7</td>
<td>77.6</td>
<td>83.3</td>
</tr>
</tbody>
</table>

It is obvious that students and parents must take these examinations seriously. Achievement will help determine the student’s future. Teachers also attach importance to them because the scores their students attain are seen as a reflection of their teaching effectiveness. School leaders and administrators at different levels regard examination results as important since they are linked directly to the reputation of the school. The NECC can help promote the level of science education and promote the students’ participation in science majors in universities (W.-J. Wang & et al., 1996).

3.1.3 Teachers of STEM

Science teachers in high schools will teach only one subject. They seldom teach other subjects, even within the realm of science. In addition, in urban schools, they often specialize in one or two year levels each year. The majority of science and math teachers in China hold degrees in their discipline. Figure 11 below shows the changes in the number of STEM-related teachers by subject from 2005 to 2010. It can be seen that the total number of teachers of STEM-related subjects increased gradually during the six years. For different subjects, mathematics had the biggest number of teachers, followed by physics and chemistry. Biology and information techniques had relatively fewer teachers.

Figure 11 Number of STEM-related teachers by subject (2005~2010)
Figure 12 to Figure 16 show the changes in the number of teachers with different levels of qualifications in mathematics, physics, chemistry, biology and information techniques respectively during the period 2005 to 2010. From the data, it could be noted that in all of the five disciplines more than 90 percent of subject teachers hold Bachelor degree and above in the subject they teach. The number of subject teachers with Master degree increased almost three times in the six years. The number of teachers who only get College Diploma dropped a half or even more. This demonstrates a solid foundation of subject knowledge that science teachers have.

Figure12 Number of mathematics teachers with different levels of qualifications (2005~2010)
Figure 13 Number of physics teachers with different levels of qualifications (2005~2010)

Figure 14 Number of chemistry teachers with different levels of qualifications (2005~2010)

Figure 15 Number of biology teachers with different levels of qualifications (2005~2010)
In addition to strong subject matter preparation, prospective teachers in China spend a great deal of time observing the lectures of experienced teachers, often in schools attached to their universities. Once teachers are employed in a school, there is a system of induction and continuous professional development in which groups of teachers work together with master teachers on lesson plans and improvement. There is also a clear career ladder in teaching, with demanding standards and salary incentives for each step (Asia Society, 2006). In China, the focus for in-service training of science teachers is on the development of teaching skills and on understanding the curriculum content. In-service activities fully concentrate on those issues instead of on the teaching and learning of more advanced knowledge in education or science. In-service training in China pays little attention to the achievement or upgrading of academic degrees for science teachers.

3.1.4 International comparisons of students’ achievement in STEM-related subjects

In terms of the scores achieved by Chinese students in internationally comparable exams like PISA, the STEM-related education in China is successful. Shanghai, as a representative of Mainland China participated in PISA 2009 and achieved the highest average results in both mathematics and science (Figure 17). And there is no significant difference between the achievements of boys and girls (Shanghai Acedemy of Education Science, 2009).
In considering the issues of math and science achievement, deeply rooted cultural factors that underlie the Chinese education system must be kept in mind. In China, schools are educational institutions rooted in a continuous cultural history dating back 5,000 years. Chinese students have a strong work ethic, partly due to this deep cultural commitment to education and because pure academic achievement is a lauded pursuit. Reflecting the strong cultural value placed on education, Chinese schools are highly academically focused, and education is highly valued by students and the whole society. Overall, Chinese students spend long hours studying in school and outside of school in homework, extra tutoring, and studying for examinations. Students are highly motivated to succeed in order to participate in the expanding opportunities that are open to those with a good education. Effort, not ability, is presumed to determine success in school (Stewart, 2006). Students whose families can afford the tuition arrange additional instruction, either by an individual tutor or by attending tutoring schools, which is a common practice in China. Furthermore, many students in China attend residential or boarding schools, which also extends their hours of study (Asia Society, 2006). All these factors contribute to the outstanding achievement of Chinese students in math and science subjects.

However, the high scores achieved by Chinese students in international assessments do not depict the whole picture of China’s science education. Conclusions of successful science education in China cannot be drawn only based on the examination results. It should be recognized that science education does not only mean the memory of subject knowledge or the ability to work out complex exercises, more importantly, scientific literacy, spirit and attitude are also indispensible components of science education. In this regard, China still has a long way to go.

### 3.1.5 Vulnerabilities in the current STEM system in secondary education

One obvious problem related to the examination-oriented science education in China is that many students perceive the purpose of learning in school is to pass examinations. To a certain extent, students are encouraged to think like this. Formulas, for example, are never provided when students take the exams so they have to memorize all the specific details from their science courses. It has been summarized that the student behavior can be characterized by ‘taking notes in class, checking notes after class, reciting notes before the exam, and throwing notes away after the exam’. When a
science teacher presents a lecture, his or her focus is always on information retention and analysis of theories that are contained in the textbook. Though science courses such as physics, chemistry and biology should focus on experiments, there is a bias toward the elevation of theory over practice. The reason is the NECC and most other tests cover only theoretical knowledge, not practical skills. Questions about experiments will appear only in the form of paper tests. As a result, teachers usually focus on teaching theory and allocate less time for experiments. Students trained in this manner know many subject facts and theories. They are good at working out difficult exercises and problems. They can achieve high scores in examinations. But they lack the ability to conduct experiments independently. Their problem-solving competence is far from satisfactory. This has been admitted in the circle of Chinese science educators (W.-J. Wang & et al., 1996). Other vulnerabilities of China’s science education lay in the disparity and inequality of education accessibility between advantaged regions (urban areas and developed cities) and disadvantaged regions (rural areas and underdeveloped cities).

3.2 Strategies for improving the quality of STEM teaching and learning

3.2.1 New Curriculum Reform—new requirements and challenges for both students and teachers

In order to address the problems that exist in the current STEM-related secondary education system, in September 2004, the MoE launched a new round of fundamental education curriculum reform, which is known as New Curriculum Reform. Four provinces (Guangdong, Shandong, Ningxia and Hainan) were involved in the first round pilot by implementing an experimental curriculum published by MoE in March 2003 (see Table 2). In the next several years, the new curriculum standards were implemented in most schools throughout the country. Until 2012, a total number of 23 areas (including provinces, centrally administered municipalities and autonomous regions) have been involved in the reform. The mission of this new curriculum reform is to shift the emphasis from transfer of knowledge in the classroom to the development of students’ scientific literacy with inquiry-based teaching.
Table 2 Senior Secondary School Curriculum (Experimental), 2004

<table>
<thead>
<tr>
<th>Study Area</th>
<th>Subject</th>
<th>Compulsory Credits (116 in Total)</th>
<th>Elective Credits I (^1)</th>
<th>Elective Credits II (^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Language and Literature</td>
<td>Chinese 语文</td>
<td>10</td>
<td></td>
<td>≥6</td>
</tr>
<tr>
<td></td>
<td>Foreign Language 外语</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mathematics 数学</td>
<td>Mathematics 数学</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Humanities and Society 人文与社会</td>
<td>Ideology and Politics 思想政治</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>History 历史</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Geography 地理</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Science 科学</td>
<td>Physics 物理</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Chemistry 化学</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Biology 生物</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Information Technology 信息技术</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>General Technology 通用技术</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arts 艺术</td>
<td>Arts 艺术</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Music and Fine Art 音乐、美术</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physical Education and Health 体育与健康</td>
<td>Physical Education and Health 体育与健康</td>
<td>11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Comprehensive Practice 综合实践活动</td>
<td>Research-Oriented Study 研究性学习活动</td>
<td>15</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Community Service 社区活动</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Social Practice 社会实践</td>
<td>6</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. Elective credits I: additional course modules designed for the compulsory subjects.
2. Elective credits II: course modules designed by individual schools based on local needs and student interest. (Source: Ministry of Education, 2003)

The experimental curriculum comes with course standards for 14 national compulsory subjects: Chinese, foreign languages, mathematics, physics, chemistry, biology, history, geography, technology, art, music, fine art, PE and health. It uses a credit system and organizes course content at three levels: study area, subjects, and modules. For the three science subjects (biology, chemistry, and physics), in Years 10 to 11, students are required to take six credits (108 hours) in each of these three subjects; additional science modules (generally two credits or some 40 hours) are optional (H.-C. Sun, 2005).

Specifically, the new curriculum standards related to science subjects are based on the beliefs of ‘developing students scientific literacy’, ‘science for all children’, and ‘teaching science through inquiry’, which collectively defines the values and goals, target population, and approaches of science teaching (X.-F. Liu et al., 2012). These philosophies are aligned not only with international trends in science education reforms, but also with the needs created by the rapid economic development and social changes in China. Updating the science curriculum content is also an important part of the new curriculum reform. The content standards are restructured with themes in order to show broader pictures of science to students (ibid). For instance, the biology content standards focus on four themes, including genetics, evolution, reproduction, and development and ecology (Ministry of Education, 2001). Inquiry is not only a teaching and learning approach, but also part of the content. Some laboratory activities are designed to help students understand how science knowledge is applied in technology. In general, two approaches are taken to modernizing the science content; one is to replace outdated science content with the latest development in science, and the other is to connect science content with technology that students encounter in their daily lives (E.-S. Liu, 2011).
With the release of the new science curriculum standards by the MoE, developing textbooks and related teaching references aligned with the new standards became an urgent task for science educators from 2001 to 2003. As an important outcome of this new curriculum reform, the MoE authorized the development of alternative (rather than only one) textbooks for the compulsory mathematics and science syllabus to allow more flexibility in teaching approaches (E.-S. Liu, 2011; H.-C. Sun, 2005). Currently, the publication of textbooks and other references is open to all commercial publishers in addition to the People’s Education Press. Many publishers from around the country build teams consisting of experienced science teachers, scientists, and college science education researchers to develop a new generation of science textbooks. As a result, a variety of science teaching materials has been developed in recent years. However, these textbooks and other references still need to meet the national standards set forth by the government.

Reformers in China also want to introduce a greater variety of instructional methods. Chinese students striving for university entrance are highly competent in factual knowledge and in ability to perform complex algorithmic operations. However, Chinese researchers and ministry officials have criticized the current system for failing to encourage creativity and the ability to carry out scientific inquiry. In their instruction, teachers need to give more consideration to individual students, encourage students in their own active learning, foster their hands-on skills by involving students in project work, and ‘teach them how to fish rather than giving them the fish’ (Y.-B. Wang, 2008b)—that is, teach students how to learn on their own and become lifelong learners. Some experienced teachers are now advocating that ‘students at the center, whereas teachers as the guide’ should be the motto that direct the nature of instruction in science. Only in this way can the teacher motivate students to actively learn. The new science and mathematics curriculum put more emphasis on critical and analytical thinking skills of the students. In 2006, the MoE issued the National Mid and Long-term Education Reform and Development Framework (2010-2020) (Ministry of Education, 2010). This framework emphasizes that the priority of senior secondary education should be to further implement the new curriculum reform nationwide, in order to improve the all-round qualities of high school students.

### 3.2.2 Teacher preparation and professional development under the new curriculum

One key challenge to implementing the new curriculum standards is teacher preparation and professional development. For China, as discussed above, science and math teachers are well prepared in subject knowledge, at least in major metropolitan areas. The need is for changing teachers’ instructional methods to match the curricula reforms being instituted, with greater emphasis on involving students in active participation through questioning, critical thinking and development of creativity. This is not an easy task, as teachers are ingrained in their traditional methods. Hence, they do not have the teaching skills to work with students using some of the reformed pedagogic strategies or to design lessons that incorporate them effectively. Moreover, teachers are concerned that their students will not perform as well as before in the examinations if they deviate from traditional teaching methods (Asia Society, 2006). During the first years of the new curriculum implementation, almost all science teachers felt that inquiry and the new content are difficult for them to teach (X.-F. Liu et al., 2012). In order to address this issue, Chinese central government has invested heavily in providing human and
financial resources. Many training workshops and peer group projects have been
developed, focusing on developing science teachers’ content knowledge and
pedagogical knowledge. Inquiry is the most common theme in teacher professional
development. Nowadays, most of the teachers have become more accustomed to the
new curricula, and some of them routinely use inquiry science teaching (ibid).

3.2.3 Special programs for STEM talents

In order to identify and cultivate the students who are talented in science subjects, in
most key senior secondary schools in China, ‘Science Experimental Class’ (SEC) is
organized as a special education program. In the beginning, the purpose of SEC was to
provide special training for the talented students to attend the International Science
Olympiad. With the evolution of SEC, it has developed into an elite education form for
individualized talent’s cultivation (Liao, 2009). Individual schools have the autonomy to
recruit students from junior secondary graduates to attend the SEC. In most cases,
students need to take extra examinations in order to get into the SEC or have good
performance in provincial or national Science Competitions at primary or junior
secondary level. They usually have superior intelligence and competence, and express
gifted talents in math, physics or chemistry. The independent thinking ability and
challenge-preferred qualities are also obvious in this group of students (Ruan & Yu,
2012).

The SEC aims at selecting the outstanding students who have great interest and
potential in natural science learning, and cultivating them into the real talents with
creativity and research capacity in the field of science (X.-N. Liu, 2012). The SEC uses
unique school designed curriculum that is different from the general senior secondary
standardized curriculum. The unique curriculum emphasizes individuality and flexibility.
Students can choose various modules to study according to their own preference and
interests. And for the students who choose the same module, they form a small group
sharing similar interest. These small interest groups facilitate the communication
between group members and create an inspiring learning atmosphere. In addition,
exploratory learning is involved in the unique curriculum. Students propose their own
research topics according to their interests and the teachers give them tasks related to
the topics. Through self-learning, group discussion and tutorials, students finish their
own topics (Liao, 2009; X.-N. Liu, 2012; Ruan & Yu, 2012). Students in the SEC are also
encouraged to attend national and international science competitions like the
International Science Olympiad. For those who perform well in the competitions, they will
be eligible for exemption from the National College Entrance Examination.

As more autonomy has been given to the universities for recruiting students, SEC has
become the shortcut to top universities. Students who attend SEC have more
opportunities to be enrolled by the elite universities through participating science
competitions, school recommendation or even self-recommendation. Regarding this,
parents make all their efforts to send their children into the SEC in order to get into top
universities. For example, student’s competence in solving Mathematical Olympiad
problems is a common criterion in SEC selection. Parents in China send their children to
attend extra tutorial on Mathematical Olympiad even from primary schools. In order to
earn extra points for getting into the SEC, students are forced to attend extra classes
regardless of their interest and competence (J. Dong, 2012; W. Wang, 2012; Y.-Y.
Zhang, 2012; J.-T. Zhou, 2012). The original purpose of Mathematical Olympiad is to
identify talented students in mathematics and provide special training to them for further
developing their talents and finally make achievements in math. In norm case, only 5 percent children who have above-average intelligence are suitable for Mathematical Olympiad learning. However, since Mathematical Olympiad has become a means to add points in the selection of SEC, an increasing number of parents require their children to learn Olympiad math, which is deviated from the original purpose of talent nurturing.

Although the SEC has made a contribution to the identification and cultivation of science talented students in China, for example, China has achieved a myriad of gold medals in the International Mathematical Olympiad competition. The students representing China to attend the competition largely consist of students from the SEC. Both educational practitioners and the public have shown concerns regarding the negative effects of the SEC on students. Since 2005, in most provinces in China, the SEC has been gradually abolished by the local government as the SEC, as a form of elite education, is inconsistent with the current prevalent philosophy of ‘education for all’. Because of the imbalanced investment in the SEC and in general classes, equal access to high-quality education resources cannot be guaranteed. In addition, the operation of the SEC deviates from the original purpose of identifying and nurturing science talented students. Since the close relation between the attendance of SEC and the enrolment of top universities, the SEC has become a means for other purposes. The majority of students who are not gifted in science and have no interest in science are also forced by their parents to attend extra tutorial classes for competing the place of the SEC. Moreover, liberal education at fundamental level has been acknowledged by educational practitioners and policy makers in China. However, the SEC over-emphasizes the learning of science subjects and preparing for science competitions, impeding the over-round development of students. All these reasons have led to the decreased popularity of the SEC in China.

3.2.4 SETM-related after-school activities

In addition to the traditional in-class learning, at least once a week, secondary school students take part in after-class activities. More than 90 percent of students get involved in these activities based on their individual interests. At the end of each academic term, unlike in the regular science course, students do not have to take a test nor do they receive grades as an evaluation of their performance. Through these activities students obtain interesting and useful knowledge and skills. They are important supplements to the regular science learning in the class so they are often called ‘after-school activities’ or ‘second classrooms’ (X.-F. Liu et al., 2012). Generally, there are two kinds of clubs providing the after-school activities. One gives emphasis to the academic subjects and is called ‘subject-related club’, while the other pays more attention to the extension of a student’s knowledge and is called ‘student-interest club’.

In conclusion, the current characteristics of STEM-related secondary education in China are closely related to the deep-rooted traditional Chinese culture. China is a country with a civilization over 5000 years. This civilization was built on agriculture and its ideological framework was Confucianism. Even today, some aspects of Confucianism still influence most Chinese people. Throughout history, teachers in China have long been seen as authority figures second only to parents. Therefore, the accomplishment of strict classroom discipline is easy in most schools. Students obey teachers’ demands unconditionally, and teaching activities can be carried out smoothly in the classroom. The side effect of this is that students always treat the teachers’ saying as the truth. They seldom doubt what teachers tell them. They do not dare to discuss problems with
teachers. In addition, Chinese people value knowledge obtained from books. However, because of the impacts of Confucianism, people respect the learning of theory but neglect practical experimental skills (L. Wang & Fan, 2007). These cultural factors help students guarantee the learning in classroom and achieve good results in exams; however, it might be an obstacle to the development of their critical thinking and creativity.

Lewin, in 1987, commented in an analysis of Chinese science education programs that:

The school science curriculum in China is characterized by subject specialization, emphasis on the physical science, infrequent practice activity by students, emphasis on content rather than process skills, and theoretical rather than applied approach to subject matter (p. 439).

Unfortunately, current science education in China does not make much improvement compared with what it looked like in the past. The examination system still has powerful impacts on China’s science curriculum and instruction. It drives the nature of what is taught in the science classes and determines the emphasis on the rote learning of a vast amount of specific information in those STEM-related subjects. With the recent movement toward new curriculum in senior secondary education and stress on comprehensive assessment of students’ capacity, it could be prospected that science teaching and learning in secondary schools in China will transform from subject knowledge intensive to all round development of students’ scientific literacy and capacities.

4 STEM in higher education

HE plays a crucial role in China’s science system. A science or related qualification from HEIs represents the gateway to the vast majority of workforce roles in the Chinese science system—from science and mathematics teachers to engineering and technology professionals, from medical practitioners to government science advisors, from agronomists to researchers. Meanwhile, the HE sector in China also serves the role of nurturing technology industries, providing talents for the companies or directly involved with the R&D activities and making contributions. It is for this reason that this section takes a detailed look at China’s HE of science, particularly focusing on domestic participation since overseas students do not take a considerable proportion in science study at HE level. The STEM-related HE system will be examined in terms of the programs and participation, science teachers, achievements and vulnerabilities. In the second part of this section, strategies for improving science teaching and learning at HE level will be explored.

4.1 Higher education landscape of STEM

4.1.1 STEM-related courses and participation at HE level

Institutions

In 2010, a total number of 1,428 HEIs in China provided degree-level programs. Among them, 316 were RIs that only offer postgraduate programs. The other 1112 were universities and colleges, of which 261 were comprehensive universities, 320 were natural science and technology universities, 41 agriculture institutions, 7 forestry
Institutions and 101 medicine and pharmacy universities. During the year 2007 to 2008, there was an expansion of HEIs, which was mainly contributed by the increasing number of Comprehensive Universities and Natural Science & Technology Universities (see Figure 18). The numbers of RIs, Agriculture and Forestry Universities maintained the same level from 2005 to 2010.

Undergraduates

Because of the rapid expansion of China’s HE system, commencing enrolments for bachelor’s students grew by 48.6 percent between 2005 and 2010. The total enrolment grew more than commencing enrolments, at 49.1 percent in the same period. The most impressive growth took place in the number of graduates, by 76.7 percent from 2005 to 2010 (Figure 19). The entrants for science-related fields grew by 44.5 percent from 2005 to 2010 against the total growth in commencing enrolments of 48.6 percent. Specific to different fields, engineering was the most popular study field among commencing undergraduates and increased by 49.9 percent. Natural science was the second popular field with a growth of 48.7 percent, followed by medicine (48.6%). Compared with other three fields, agriculture was the least favored; fortunately, more students chose it as their major in 2010, increasing by 36.4 percent. Figure 20 presents the changes of entrants by fields of study.

Figure 18 Number of HEIs by type (2005-2010)

Figure 19 Entrants, enrolment and graduates in regular HE sector
The enrolment of students in science-related fields during 2005 to 2010 shows a similar pattern to commencing enrolments (see Figure 21). The majority STEM students participated in majors of engineering, followed by natural science, medicine and agriculture. The graduates (Figure 22) in all science-related fields rose gradually in the six years. The HE sector cultivated a large number of talents to contribute to the national science and innovation system and economic development. The increase in science graduates guarantees the sustainable development of China's S&T, promising the prosperous future of China. In addition, a STEM qualification constitutes an advantage in the labor market. According to the national survey of bachelor graduates the employment rate in 2011 among the top 50 high employed majors, 27 were engineering-related with the average employment rate of 95.17 percent, 4.37 percent higher than the overall employment rate (90.8 percent). In the other 23 high-employed majors, three were medicine related and two were in the field of agriculture. Only 18 majors related to social science and humanities (Mycos Institution, 2012).
Postgraduates

With the launch of Project 211 in 1995, the Chinese government has promoted the building of global research universities. Postgraduates and the commitment to postgraduate programs are important for a HEI’s research capacity. Compared with graduates with a Bachelor degree in science-related fields, higher research degree holders in STEM are supposed to make a greater contribution to the national R&D activities and S&T development because of their specialized knowledge and advanced research skills. From 2005 to 2010, the entrants, enrolment and graduates at Master level increased considerably, particularly from the year 2008. The total enrolment of Master students rose by 62.5 percent. In contrast, students involved in Doctoral programs grew gradually in the same period with an increase rate just half that of Master students. The figure below shows the changes in the entrants, enrolment and graduates at the two levels. The overall growth of postgraduates was more than that of undergraduates. It demonstrates that research capacity construction is the current priority on the HE development agenda.
The number of doctoral entrants increased by 19.6 percent, 14.3 percent and 25.7 percent between 2005 and 2010 in natural science, engineering and agriculture respectively. In the field of medicine, however, the number grew in the first four years and then kept dropping in the later two years. In 2010, the medicine doctoral entrants were 4 percent fewer than those in 2005. At Master level, in the fields of science, engineering and agriculture, the number of commencing students grew during the six years with ups and downs. Only in the medicine study, the number had decreased since 2008 (Figure 24). Engineering was still the most popular field for postgraduates and agriculture was the least. For the graduates in science-related fields (Figure 25) between 2005 and 2010, the overall trend increased gradually at both Doctoral and Master levels with two exceptions of Master graduates in engineering that dropped slight in 2010 and Master graduates in medicine that showed a decrease from 2009. In Figure 26, it shows the total enrolment in different science-related fields. At Master level, according to the data, more students participated in the study of natural science and engineering from 2005 to 2010. The number of enrolment in agriculture peaked in 2007 and decreased after. Similar patterns can be found in the number of students majoring in medicine, which reached a peak in the year 2008 and dropped in the next two year. In the same time range, the doctoral students kept growing in natural science, engineering and agriculture. However, the students involved in medicine showed a similar decrease after 2008, aligned with the trend of Master level enrolment.
Figure 24 Postgraduates entrants in science-related fields of study (2005~2010)

Figure 25 Graduates in science-related fields of study at Doctoral and Master levels (2005~2010)
In general, the participation in science-related fields of study grew aligned with the expansion of China’s HE system. In 2010, the number of students enrolled in universities for science-related subjects reached 7.2 million, accounting for 50.7 percent of total. STEM disciplines are popular among university students; more than half of the total number of students is involved in science study at different levels. The graduates majoring in science-related fields took up 51.1 percent of the total in 2010. This means that in China there is a large science talents pool to support the development of S&T. For certain fields like medicine, the reason for the drop of participation cannot be identified with the available data. Further in-depth research and analysis is necessary for exploring the underlying reasons causing the decline.

4.1.2 STEM academics in universities

The expansion of China’s HE system also expresses itself in terms of the growing number of academics. A close examination of the number of full-time teachers serving in universities shows that the scale of academic team expanded by 40 percent between 2005 and 2010, particularly, the number of teachers who held Doctoral degrees doubled. The majority of the academic team consisted of Bachelor and Master degree holders, and the number of both grew considerably in the six years. In contrast, teachers with only Diploma or other certificates were fewer than before. This illustrates the improvement of quality of academic staff. The figure below shows the changes in the number of full-time teacher by qualifications.
Among all academic staff, the proportion of females increased from 43.3 percentage in 2005 to 46.5 percent in 2010. The overall pattern of qualifications held by female teachers was similar to the general pattern of all teaching staff (see Figure 28).

The supervisors of postgraduates are crucial for the cultivation of high-quality research students. The total number of postgraduates’ supervisors grew by 62.9 percent from 2005 to 2010, which made contributions to the enhancement of universities’ research capacity. Among them, approximately 20 percent were eligible for supervising doctoral students. The increasing rate of the number of doctoral supervisors kept in pace with the growth of total supervisors (see Figure 29).
The academic staff involved with teaching in science-related fields shows different changing patterns in specific field. The following four figures present the changes of teachers from 2005 to 2010 in the field of natural science, engineering, agriculture and medicine respectively. In these four fields, engineering had the largest academic team, followed by natural science and medicine. This was in accordance with the distribution of students in these fields. Medicine had the largest proportion of senior title teachers, taking up more than 17 percent. In contrast, academic staff with senior title in engineering accounted for only 12 percent, the smallest one in the four fields. The numbers of teachers in engineering and medicine had a relatively high growth rate in the six years, by 35.4 percent and 30.5 percent separately. Teachers in natural science and agriculture grew less, by 26.1 percent and 21.1 percent.
4.1.3 Academic achievement at HE level

Tertiary education has shifted from elitist education to massification education (HE enrolment rate exceeded 24 percent in 2009). Now, China has a large pool of S&T personnel educated at home and abroad, a group of world-class RIs and universities, and an expanding high-quality academic team. The scientific research capacity has been considerably promoted. The improvement of research capacity is also reflected in terms of academic output. In 2010, the total number of patents granted by the State Intellectual Property Office (SIPO) was 814,825, almost four times the number granted in 2005 (Figure 32). Among them, 28.8 percent came from the HE sector. In 2010, the domestic S&T papers published in the HE sector reached 343,000, taking up 64.6 percent of the total domestic published paper. Compared with the S&T paper publication in 2005, the amount grew by 46 percent (Figure 33).

Figure 32 Patents granted by SIPO (2005~2010)
Internationally, the Chinese S&T papers indexed by SCI, EI and CPCI-S was 272,000 in 2010, increasing by 77.8 percent with the publications in 2005 (Figure 34). And Table 3 shows the comparison of the S&T papers indexed by SCI, EI and CPCI-S in different countries. China was the largest contributor to the papers indexed by EI, and the second largest one to both SCI and CPCI-S, just behind the U.S.

Table 3 S&T papers indexed by SCI, EI and CPCI-S in selected countries

<table>
<thead>
<tr>
<th>Country</th>
<th>SCI Papers (Unit: 1,000)</th>
<th>Rank</th>
<th>EI Papers (Unit: 1,000)</th>
<th>Rank</th>
<th>CPCI-S Papers (Unit: 1,000)</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>122</td>
<td>2</td>
<td>112</td>
<td>1</td>
<td>38</td>
<td>2</td>
</tr>
<tr>
<td>U.S.</td>
<td>390</td>
<td>1</td>
<td>95</td>
<td>2</td>
<td>84</td>
<td>1</td>
</tr>
<tr>
<td>U.K.</td>
<td>114</td>
<td>3</td>
<td>26</td>
<td>5</td>
<td>21</td>
<td>4</td>
</tr>
<tr>
<td>Germany</td>
<td>105</td>
<td>4</td>
<td>29</td>
<td>4</td>
<td>22</td>
<td>3</td>
</tr>
<tr>
<td>Japan</td>
<td>87</td>
<td>5</td>
<td>35</td>
<td>3</td>
<td>20</td>
<td>5</td>
</tr>
<tr>
<td>France</td>
<td>73</td>
<td>6</td>
<td>16</td>
<td>10</td>
<td>14</td>
<td>6</td>
</tr>
<tr>
<td>Italy</td>
<td>63</td>
<td>7</td>
<td>16</td>
<td>10</td>
<td>11</td>
<td>8</td>
</tr>
<tr>
<td>Canada</td>
<td>60</td>
<td>8</td>
<td>20</td>
<td>7</td>
<td>5</td>
<td>14</td>
</tr>
<tr>
<td>India</td>
<td>46</td>
<td>10</td>
<td>20</td>
<td>8</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>Total in the world</td>
<td>1421</td>
<td>480</td>
<td>302</td>
<td></td>
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</tr>
</tbody>
</table>

According to SCImago Journal & Country Rank (2012), China ranked second in the total number of published papers in science-related fields in 2011. In some specific fields
such as chemistry, chemical engineering, and computer science, China even overtook the U.S., ranking first all over the world. Among all the published papers by Chinese scholars, papers in engineering took the highest proportion, accounting for 18.5 percent, followed by materials science (15 percent) and medicine (8.1 percent). All these data demonstrate the great achievement that China has made in promoting its HE sector’s research capacity.

4.1.4 Vulnerabilities in the current STEM system at HE level

China’s HE system has made great progress in educating students majoring in science-related fields and in publishing academic papers in both domestic and international S&T journals. However, a successful STEM system at the HE level cannot only be defined by the participation of students or the achievement in academic output. These indicators measure the quantitative aspects of STEM in universities, but a close examination of the qualitative facets of HE of science, it could be noted that vulnerabilities still exist. The teaching and learning of STEM at the HE level share many characteristics with those at the senior secondary level. For example, science education in universities focuses on pursuing uniform and normative answers to science problems. Like the science-related subjects teaching in secondary schools, HE of science in China also emphasized the fundamental knowledge and skills. The narrow focus results in the misunderstanding of the main purposes and goals of HE of science. Consequently, science teachers set the teaching of fact knowledge as the primary target instead of scientific attitude, methods and spirits, which should be the core of science education (J.-Y. Wang, 2008). Science itself is regarded as an instrument rather than the ultimate pursuit of truth.

In addition, textbooks and teachers are seen as the authority. Laws and rules presented in textbooks are golden and precious, beyond any manner of doubt. Science teachers in universities are the prolocutor of truth. Students are only required to learn, master and accept static knowledge. Science teachers seldom induct students on authenticity, veracity and merits of scientific knowledge (Qiao, 2009; J.-Y. Wang, 2008). In this context, some important scientific qualities like critical thinking have been neglected for a long time. These indispensible scientific qualities, to a large extent, determine the creativity and research abilities of students in their further study or career, particularly in relation to S&T. HE is exactly the most important venue for the scientific qualities’ cultivation, indeed, they are part of the key goals of HE (Slavin, 2005). However, in Chinese universities, students’ science abilities are not evaluated in terms of critical thinking or problem solving. It encourages the student to learn passively without doubting or making his or her own judgment, and finally impede the development of creativity (Qiao, 2009; X.-N. Wang & Ye, 2011). This instruction mode may lead to the loss of students’ interest in science and scientific inquiry. The practice of science education in universities shows that science education in China fails to foster students’ scientific spirits and qualities. Moreover, the content involved in science subjects’ teaching is out of date. It cannot reflect the advancement in related fields. Teachers pay less attention on the new discoveries in the field but accentuate the well-accumulated basic knowledge. As some scientists point out, students cannot obtain the most advanced knowledge in their majors even after years of university study (J.-Y. Wang, 2008).

4.2 Strategies for facilitating STEM in HE sector
Since S&T plays such a significant role in national economic and social development and to a large extent determines the overall competitiveness of a nation and the prospect of the nation and the HE sector serves as an indispensible part in the national science and innovation system, the Chinese government has developed various strategies for facilitating HE of science, launching nationwide projects, providing policy support and initiating diverse programs. In this section, the main strategies adopted to promote science education in universities will be reviewed and analyzed, including elite universities projects, collaboration among industries, universities and RIs, and the internationalisation of HE. At the end of the section, other important policies issued to strengthen university science education will also be summarized.

4.2.1 Building world-class HEIs in China — Project 211 and Program 985

In order to make universities as world-class innovative bases, China has to strengthen academic research capacity. Aimed at providing more funding to elite universities, two key national programs have been instrumental—one is Project 211 and the other is Program 985. Project 211 is jointly sponsored by the State Planning Commission, MoE, Ministry of Finance and provincial governments, aiming at strengthening about 100 HEIs and key disciplinary areas as a national priority for the 21st century. Until 2012, a total number of 112 universities have been involved in this project. It has great significance in improving HE, accelerating the national economic progress, pushing forward the development of science, technology and culture, and laying the foundation of training high-quality professional manpower mainly within the HEIs at home. The majority of efforts have been made to enhance the physical conditions and staff competence of the selected universities (CERN, 2000).

Project 211 consists of two major components: the improvement of overall institutional capacity and the development of key disciplinary areas. Specific to the science education, measures have been taken to enhance the infrastructure and laboratory facilities that are indispensible for teaching and research, thus, creating necessary conditions for training as well as attracting outstanding S&T talents. Also, initiatives have been made to enhance scientific research, and strive for the commercialization of research findings so as to accelerate the pace of transferring scientific achievement into productivity. The main thrust of the development of key disciplinary areas is to strengthen the capacity of training high-quality manpower in the frontier fields of S&T. Among the institutors with favorable conditions, efforts have been made to identify key research areas, which can exert significant impacts on S&T advancement and national defense. These areas are supposed to have the capacity to address major issues in S&T and have the prospect for breakthroughs in relevant fields. Improving the experimental facilities for the cultivation of professional manpower, efforts have been made to broaden the coverage of various disciplines, and foster the emergence of groups of disciplinary areas and research bases. Efforts have also been made to establish a system of key disciplinary areas covering major professions and sectors for national economic and social progress, facilitating the development of academic disciplines and S&T (Ministry of Education, 2007).

Project 211 was part of the 9th Five Year Plan (1996-2000). During the first phase of the project, the priorities were accorded to the upgrading and improvement of the infrastructure for teaching and research in about 25 universities, with a high concentration of key disciplinary areas. These institutions are expected to improve their training of high-quality professional personnel and have some of the key disciplines
approaching and reaching international standards. They are supposed to play a key and exemplary role among universities in China. Emphasis was placed on supporting the development of institutions and key disciplines that are closely related to the basic and pillar sectors of the industry, and on cultivating technical personnel who are urgently needed for national development. Efforts were made to strengthen about 300 key disciplinary areas that have important bearing on S&T advancement and national defense (Ministry of Education, 1995).

The State Council has set up a coordinating group for Project 211, under which an office has been established with the responsibilities of project implementation, management, review and evaluation. Since the launch of Project 211, great progress has been achieved in the universities that have been supported by the project. The overall research capacity and international competitiveness and reputation of those universities have been enhanced considerably. The quality of talents’ training has been improved and a myriad of advanced scientific achievements have been made. Some disciplinary areas have already reached international standard. The supported universities have evolved as curdles of basic research and high-tech indigenous innovation. They have also become the basement for innovative talents cultivation, the main power for driving national development (Hu, 2011).

On the heel of Project 211, the MoE launched Program 985 that aims to turn top universities in China into world-class research universities. On May 4, 1998, President Jiang Zemin declared that ‘China should have a number of first-rate universities of international advanced level’, in this context, Program 985 was launched. In the initial phase, 9 universities were included in the program and received funding from the central government. The second phase, started in 2004, expanded the program, and until now the number of funded universities reached 39 (CERN, 2012). The initiatives of building world-class research universities have been integrated into the overall national development strategy. These elite universities have made great contributions to the cultivation of talents and to the improvement of China’s S&T competitiveness.

4.2.2 Collaboration between industries, universities and RIs

Universities/RIs and companies are main actors of the national innovation system (Lundvall, 1992; Nelson, 1993). Knowledge is generated and diffused among these organizations. The knowledge transfer between universities/RIs and industries widely affects the development of the national innovation system (Chen & Kenney, 2007; Motohashi & Yun, 2007). Since the onset of economic reforms in 1979, China’s strategies for enhancing indigenous research and innovation capacities have in part involved the promotion of university-based research and commercialization, particularly by elite institutions to which the central government provides the most funding (Wu & Zhou, 2012). The initial results have been promising. Enterprises affiliated with universities and RIs were among the earliest non-government high-tech producers in the 1980s and 1990s. Some of the most successful high-tech firms, such as Lenovo and Founder, stemmed from such roots (Y. Zhou, 2008). Encouraged by such success, the Chinese leaders hope to use the leverage that can be gained from research universities to acquire innovation and technological capability in more of its industrial sectors. During the collaboration of universities/RIs and industries, partners in each sector benefit from the intensified linkages. For universities and RIs, the cooperation with companies could be thought as a method to conduct a user-oriented innovation, which will improve the teaching, learning and research in S&T-related disciplinary areas. The universities have
acquired a new mission in addition to science teaching and learning—the third mission—as key agents for commercializing technology. For companies, universities and RIs function as the intelligence tank, offering professional human recourses for the development of companies and cutting down companies’ R&D cost.

Many research universities have developed closer links to industries through various forms of collaboration, including university-affiliated technology enterprises, technology transfer contracts, patent licensing, joint-authored publication and university science park (X. Liu & Lundin, 2007; Wu & Zhou, 2012; Ying, 2012). Among them, the university science parks and university-affiliated enterprises are the dominant forms of University-Industry Linkages (UILs). University science parks in China as incubators of university-affiliated enterprises and high-tech firms play an important role in university’s social service function. Until 2011, 86 national university science parks have been established in China (Ying, 2012). Science parks associated with universities are meant to be a main mechanism for linking HE and science research with production and economic development—one of the key requirements of post-1978 HE and science policy reform (Ma, 2004; Xue, 2006). Successful endeavors in science parks can help fund university operations, university science research, and drive local economic development as well as attract high-skilled overseas Chinese back to the mainland. Other initiatives have also made great contributions to both universities/RIs’ research capacity building and companies’ innovation and competitiveness enhancement. Since different forms of collaboration cannot be elaborated in the report, here, one of the most successful cases of UILs, the Brainbridge Program is provided to serve as an example.

The Brainbridge Program is operated by Royal Philips Electronics, which is famous for its open innovation strategy. Philips has cooperated with some Chinese universities such as Shanghai Jiaotong University, to set up joint laboratories and projects as a prime aspect of open innovation approach. Besides the research collaboration in 2005, Philips signed a research and education agreement with Zhejiang University and Technical University of Eindhoven (Netherland), aimed at fostering a new culture of technical excellence through the creation of a ‘brain bridge’ between universities in different countries and companies, and at supporting China’s efforts in creating high-quality, home-grown scientists and engineers that the country will need to sustain its growing economy. The collaboration is called the Brainbridge Program. According to the memorandum of understanding of partners, the three parties will concentrate on research and education in health science, information technology and electronic engineering. The technology and science related to the healthcare is the center of the cooperation. Philips supports the joint research projects among three parties, and provides a research platform for the exchange students of the program. Students will also be able to conduct part of their research at the Philips research laboratories in the Netherlands, Germany, and Asia. In addition, professors from the two universities conduct research projects granted by Philips according to the Philip’s strategic plans. The cooperation between Philips at China and Zhejiang University includes joint research projects, personnel exchanges, and cooperation between the science park of Zhejiang University and the innovation campus of Philips in China (Jin, Wu, & Chen, 2011).

The Brainbridge Program is only one of the innumerable collaborations between universities/RIs and industries. Other cooperative programs may involve more than one university and develop extensive collaboration between HEIs and companies. The Microsoft Joint Master Programs is another example. Microsoft China Company
cooperates with many Chinese universities to set up joint software programs. Microsoft Company designs courses for such kind of programs with universities. When a student joins such a program, he or she will join Microsoft projects and work at Microsoft for a semester or more. Many students will attend the Microsoft certificate exam, and excellent students will stay to work at Microsoft after graduation (ibid).

The strengthened collaboration between industries, universities and RIs represents the co-development of HE policy and S&T policy. China is now crafting policies intended to encourage an environment conducive to indigenous innovation as a mechanism for moving up the global production value chain. HEIs have multiple roles to play in this newly emerging vision of China as a world-player in cutting-edge scientific research and technology development and the knowledge-economy, as both knowledge creators and knowledge communicators.

4.2.3 Internationalization of the HE system and scientific research

HE in China embarked on internationalisation from the late 1970s onwards, when China adopted its Open Door policy and undertook economic reforms (Huang, 2007; R. Yang, 2002). The Chinese treat internationalisation as a strategy to develop China’s HE (D.-Y. Liu, 2007; R. Yang, 2002). It is a practical means of lifting China’s HE and research towards international standards and continuously enhancing quality (Y.-B. Wang, 2008a; Welch & Cai, 2011). In this context, recent emphasis on the internationalisation of China’s HE is mainly a result of increasingly fierce global competition (D.-Y. Liu, 2007; Y. Wang, 2008). The Chinese government recognizes the importance of an educated workforce to economic growth, innovation and competitiveness, and has tried very hard to promote the internationalisation of domestic HEIs (Bi & Huang, 2010). The National Mid-Long-term Education Reform and Development Framework accentuates the internationalisation of HE as a national strategy (Ministry of Education, 2010). From 1985 until now, China has been the country with the largest number of students studying abroad. Between 1978 and 2010, an estimated 1.3915 million Chinese students travelled abroad to study (C. Dong, 2011). In recent year, Chinese government initiated various measures in order to attract overseas Chinese students to come back home. The figure below shows the changes in the numbers of Chinese student going abroad for study and the ones who return after graduation. These talents may be employed in S&T industry, directly making contributions to the S&T development in China. In other cases, they may work and teach in universities, conducting research or educating more Chinese talents.
Great progress has also been made in developing transnational education programs in China. By 2004, the number of joint programs provided in Chinese HEIs in collaboration with foreign partners had reached 745 (Welch & Cai, 2011). In addition, internationally cooperative research projects and internationally co-authored publications have been promoted. According to OECD statistics, in 2007, China’s share of internationally co-authored scientific articles took up almost 25 percent of total articles, exceeding the world average (see Figure 36). Compared with the proportion in 2002, the number doubled in five years. Among China’s international partners, the U.S., Japan, Germany, the U.K. and Canada took major part of China’s international publications. Over 71 percent of China’s internationally co-authored publications are jointly written with authors from the above five countries (Figure 37). Mutual collaboration links between China and Australia have also been enhanced.

Figure 36 Share of internationally co-authored scientific articles, 2007 as a percentage of total articles

(Source: OECD, 2009)
International collaboration partly contributes to China’s scientific output. International collaboration also compensates China’s deficiency of field research. China follows the basic paradigmatic pattern of the former socialist countries with pronounced research in chemistry and physics and less activities in the life sciences, in the mean time research is also remarkable in mathematics. Publication activities in China’s international collaboration are the opposite with clear activities in neuroscience and behavior, clinical and experimental medicine, biomedical research, and agriculture.

4.2.4 Summary on national strategies for promoting STEM in HE sector

In addition to the three national strategies discussed in the last section, other programs, projects and policies have also been initiated in order to advance the reform of HE of science. For example, in 2005, the MoE launched the *HE of Science Reform and Practice Program*, focusing on the reforms of diversification of the cultivation of S&T talents, evaluation of science education, co-construction of science curriculum, and management of science education in universities. This program consists of 14 subsidiary programs, which cover the construction of national model basements for S&T talents cultivation, intensifying the collaboration between industries and universities/RIs and fostering application-oriented manpower, implementing English-teaching science programs and developing the evaluation system for science education in universities jointly with industrial associations. The priority has been given to the information, biology, materials and energy fields (Ministry of Education, 2005).

Nowadays, universities in China have more autonomy in student’s recruitment and in program design. Almost all top quality universities, especially the research universities, have run various special programs for students who are outstanding in science and engineering (D.-W. Sun, Sun, & Liu, 2012; W. Zhang, 2008; Y.-J. Zhu, 2011). Students enrolled in the special programs will go through different pathways compared with ordinary students. Although the name and form of these specially designed programs are various, they share many characteristics. The basic difference between the special program and general undergraduate program is the major decision. For general undergraduate courses, students are required to decide their majors at the beginning of their courses. However, for all special science and engineering programs, students need to learn a range of fundamental courses at the first two years in order to strengthen the knowledge of math, physics and chemistry, which will serve as the cornerstone of
specific major learning. At the end of the second year, students can make the decision about the field they would like to further devote in the following two years rather than a specific major. Since the new emerging disciplines are most inter-disciplines that require a broad range of knowledge of related subjects. The development of high-tech also require the talents acquire wide range of knowledge of inter-disciplines. It is similar to the ‘Melbourne Model’ that combines narrow and specific majors into broader fields. Students have more flexibility in choosing the area they would like to develop. For those who would pursue a research higher degree, the transform in different majors will not be a barrier.

The recruitment and management of these special science or engineering programs are independent to a full extent. Students in the science and engineering special programs will be allocated a supervisor throughout the four years. For general courses, only in the last year, students can have a personal tutor who will guide the writing of dissertation. The supervisors for the special programs consist of professors and senior academic staff who have extensive knowledge in the field and can provide the best support for student’s development. For some of the special programs, students have the right to choose double majors for study and the proportion of graduates who pursue a Master degree in special program is higher than other courses. Here, a brief summary of the national strategies for improving HE of science is provided, including the national programs, policy incentives and organizational- rated innovations (Table 4).

Table 4 Summary of national strategies for improving science education in HE sector
<table>
<thead>
<tr>
<th>Program</th>
<th>Agency</th>
<th>Start date</th>
<th>Key focus</th>
</tr>
</thead>
<tbody>
<tr>
<td>National Programs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project 211</td>
<td>MoE</td>
<td>1995</td>
<td>Improve overall institutional capacity and develop key disciplinary areas in selected universities</td>
</tr>
<tr>
<td>Program 985</td>
<td>MoE</td>
<td>1998</td>
<td>Build world-class Chinese universities</td>
</tr>
<tr>
<td>Science Education Reform and Practice Program</td>
<td>MoE</td>
<td>2005</td>
<td>Science talents cultivation, evaluation of science education and science curriculum development</td>
</tr>
<tr>
<td>Policy incentives</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>National Mid and Long-term Education Reform and Development Framework</td>
<td>MoE</td>
<td>2010</td>
<td>Intensify the collaboration between industries and universities/RIs; improve the laboratory and scientific research and enhance the basic and applied research</td>
</tr>
<tr>
<td>Guidelines for Strengthen Basic Research in HE Sector</td>
<td>MoE</td>
<td>2012</td>
<td>Implement Changjiang Scholar Plan, Innovative Team Development Plan and New Century Talents Support Plan; develop the evaluation system of basic research; attract overseas talents and expand the investment on basic research</td>
</tr>
<tr>
<td>Organizational innovation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>National Technology Transfer Centers</td>
<td>MoE</td>
<td>2001 (first six)</td>
<td>East China University of S&amp;T, Tsinghua University, Sichuan University, Shanghai Jiaotong University, Xi’an Jiaotong University and University of S&amp;T of China</td>
</tr>
<tr>
<td>University Enterprise Reform</td>
<td>MoE</td>
<td>2001</td>
<td>Streamline relations between universities and affiliated enterprises through ownership and management reform</td>
</tr>
<tr>
<td>University Science Park</td>
<td>Various</td>
<td>Various</td>
<td>Municipality provides free land allocation, infrastructure, and facility support</td>
</tr>
<tr>
<td>Science and Engineering Special Programs</td>
<td>HEIs</td>
<td>Various</td>
<td>Nurturing outstanding STEM talents, special designed curriculum and personal tutors for undergraduates</td>
</tr>
</tbody>
</table>

5 STEM personnel and employment

China has become one of the world’s biggest reservoirs of R&D personnel. The number of scientists and engineers almost doubled between 2005 and 2010 (Figure 38). In 2010, more than 3.5 million people were involved with various kinds of R&D activities. Among them, 20 percent held higher research degrees. The full-time equivalent accounted for 62.1 percent of the total. Despite this feat, the density of researchers in China remains lower than that of developed countries, even if China is rapidly closing the gap. In 2010, there were 336 R&D personnel per thousand employments in China, compared to 1490 in France, 1390 in Japan and 1310 in Germany (OECD, 2011a). But the lower density of R&D personnel in China also means great opportunity for improvement. Since with the expansion of HE, more youth can get access to HE and contribute to the S&T development of China. According to the National Mid and Long-term Education Reform and Development Framework (2010-2020), Chinese government sets the target of 40 percent gross enrolment rate for HE sector to achieve in 2020, and till 2020, 90 percent of the new labor force will hold HE degrees (Ministry of Education, 2010). Another point needs to be noticed is that among all the R&D personnel, only 25.3 percent were female,
much lower than the male counterpart. It means that the female talents were underdeveloped in S&T. Like the low density of R&D personnel, if the female talents could be further explored, more remarkable progress might be made in S&T development.

Figure 38 R&D personnel (2005~2010)

These R&D personnel were distributed in different performing sectors. The majority of them conducted R&D activities in enterprises, taking up 70 percent, followed by HE sector, accounting for 15 percent (Figure 39). And the full-time equivalent personnel were engaged in different types of activities (Figure 40). Approximately 80 percent of them were involved with experimental development. It is because the majority of R&D activities conducted in China belong to experimental research.

Figure 39 R&D personnel by performersFigure 40 R&D personnel by activity type

With the increasing international cooperation in S&T and in the HE sector, a large number of Chinese students go overseas for study and more of them return to China after their graduation because of the improvement of experimental facilities and research conditions. From the figure below, it can be noted that the returnees were almost four times in 2010 in comparison with the number in 2005. The returnees, to a large extent facilitate the exchanges between China and other countries in terms of S&T.
development, and strengthen the links between different countries. Because of the personal connection they made during their overseas study period, they also partly trigger the travelling of foreign scientists to China. The latest available data of foreign scientists travelling to China was the number in 2008 when a total of 99,950 scientists came to China to attend international conferences and to participate in international collaborative research.

![Figure 41 Overseas Chinese students and returnees (2005~2010)](image)

6 Conclusion

China has done a remarkable job in reforming and implementing education, science education and S&T policies, but there are still vulnerabilities existing in science education at both secondary and higher levels. Therefore, it must continue to reform and improve science education; meanwhile, to expand the HE sector. Families count on the opportunity for education as a key to enhancing their economic prospects and improving their social status. Chinese industries also need an educated workforce to move beyond being the world’s factory and to realize indigenous innovation. As the Chinese government tries to achieve a more balanced HE system throughout the whole country, in order to fulfill the 40 percent gross enrolment rate of HE in 2020, the economic prosperity and investments in education need to be spread to the disadvantaged parts of China. China’s ability to keep its dramatic economic growth and to take a leadership position in the world economy depends on its ability to improve and expand its HE system. Science education, as the foundation of the whole HE system requires more attention in the future to keep furthering reforms and improving quality. It has been widely acknowledged that a nation’s competitiveness largely relies on the S&T innovation, and the key of S&T innovation is human resource. Education bears the role of training various specialized talents to sustain the development of S&T. Science education is the cornerstone of all other majors’ learning and also closely related to the entire nation’s scientific literacy and civilization.

Compared with other countries, especially the Western developed countries; science education in China has the advantages of large participation in both secondary and higher education. The emphasis has been placed on mathematics and other basic science subjects’ teaching and learning, which lays a solid foundation for Chinese students to pursue specialized science learning and research. In addition, with the expansion of the HE system in recent years, considerable progress has been made in
promoting the scientific output in terms of patents, publications and other research achievements. Through the indicators of citations it could be noted that the international influence of research conducted by Chinese scientists and researchers has been remarkably improved. Initiatives at both national and institutional levels have been launched to facilitate the development of science education in China. Particularly, science education and research have no longer been isolated from industrial development. Through the diverse cooperation between universities and industries, scientific knowledge has been successfully transferred to productivity and directly contributes to the national economic growth. During the process of HE system expansion, the international collaboration has been intensified as a means to lift China’s HE to international standards. Though there are still weakness existing in China’s science education system such as the over-focus on basic knowledge and the neglect of scientific spirits’ cultivation, it could be foreseen that with the continuous reforms in science education, China could become one of the world’s science giants in the near future.
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