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Stability of Academic Performance Across Science Subjects Among Chinese Students

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Stability of Academic Performance Across Science Subjects Among Chinese Students

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Thesis

A thesis submitted in partial fulfillment of the
requirements for the degree of Master of Science in the
College of Education
at the University of Kentucky

By

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Lexington, Kentucky

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Lexington, Kentucky

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ABSTRACT OF THESIS

STABILITY OF ACADEMIC PERFORMANCE ACROSS SCIENCE SUBJECTS
AMONG CHINESE STUDENTS

With data describing 110,520 eighth grade students from 592 junior high (middle) schools in China, a three-level hierarchical linear model was developed in this study to create a multivariate multilevel environment to examine (a) the effects of student-level and school-level variables on science achievement in four subject areas (science inquiry skills, biology, earth science, and physics) and (b) the consistency or stability of academic achievement across the four subject areas among students and among schools. Results indicated that (a) student characteristics, including gender, parental SES, time spent in learning, and the type of family separation, were related to high academic achievement in each of the four science subject areas, (b) no school characteristics were found to be significant factors to affect students' academic performance in any of the four science subject areas, (c) both students and schools with high academic achievement in one subject area also showed high academic achievement in other subject areas, and (d) the consistency or stability of science performance over the four subject areas did not depend on student characteristics and school characteristics.

KEYWORDS: School Effectiveness, Hierarchical Linear Model, Student Characteristics, School Characteristics, China

Meng Fan

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STABILITY OF ACADEMIC PERFORMANCE ACROSS SCIENCE SUBJECTS
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Chapter 1 Introduction

Education in China

Cultural context. China has a long tradition of valuing education. For over 1,000 years in imperial China, education was seen as the major pathway to power and higher social hierarchy. Learning geared toward examinations has been entrenched in Chinese culture and society (Dello-Iacovo, 2009). This history explains why the Chinese culture stresses the high value attached to education as well as the basis for their reliance on examination-oriented learning.

Beginning in the sixth century, a system was in place to select state officials based solely on their performance on the Civil Service Examination (CSE) conducted every three years (i.e., Keju). Other criteria (i.e., societal extraction) were largely ignored (Yu & Suen, 2005; Organization for Economic Cooperation and Development [OECD], 2010). The role of government servants was considered the most honorable and worthwhile, providing office holders with many benefits, such as high salary, social prestige, and political power (Schirokauer, 1981). Unsurprisingly, the stakes to pass these examinations were incredibly high. As a result, a very competitive educational system was established. Because this system was open to all, it solidified the critical importance of examinations as the principal instrument for social mobility.

CSE was a three-tiered system of prefectural, provincial, and joint examinations. The prefectural examination (i.e., Tongshi) was conducted every two years locally. The provincial examination (i.e., Xiangshi) was conducted every three years in a provincial palace. The joint examination (i.e., Huishi and Dianshi) was referred to as the palace examinations, and was held in the nation's capital. Examinations tested knowledge of mostly Confucian themes and writing skills. Candidates reaching Dianshi were placed in

front of the emperor for the final examination (Yu & Suen, 2005). Prefectural and joint examinations lasted one day while the provincial examination was far more strenuous. During the prefectural examination candidates were placed in an examination room for nine days and supplied with food.

Understanding the role and impact of CSE helps place China's educational system and explains the prevalence of standardized testing as an intrinsic characteristic of Chinese educational system. CSE was abolished in 1905, and the National College Entrance Examination (NCEE) (i.e., Gaokao) was introduced in the 1950s (Yu & Suen, 2005). Although it is difficult to compare the two systems (one for the entry-level examination for civil service and the other for academic selection to pursue higher learning at universities), the perceived role of education as the principal allocator of social status (thus the fixation on examinations) is demonstrated throughout Chinese history. Today, the large investments of families on children's education are simply a reflection of this deeply-rooted tradition and value for education in China (Zhang & Akbik, 2012). According to the Ministry of Education of People's Republic of China (MEPRC, 2003), family expenditure on education amounted to about 13% of the family income surpassing both housing and clothing to become, after food, the second highest expenditure in Chinese cities.

In the hierarchical Confucian society, social status and political power were generally reflected by gaining official appointments through higher performance on the CSE. The value of success in these examinations has long been well-integrated into Chinese culture (Yu & Suen, 2005). Thus, high parental and social expectations on

children's education continue in the contemporary Chinese society, as witnessed by the massive investments of parents in their children's education (Yu & Suen, 2004).

Educational system. Traditional Chinese education takes rote memorization and recitation as the standard learning methods and students' learning focuses mainly on future examinations (Pepper, 1996). This educational orientation has been widely criticized, leading to some attempts to reform the system to produce well-rounded educated individuals (Dello-Iacovo, 2009). China's recent history displays the efforts of moving beyond its Confucian heir to conform its educational system with (modern) international standards (Zhang & Akbik, 2012).

In 1980, China paid tribute to its citizens' desire to establish local schools in their villages, paving the way for decentralization measures in 1986 (Ming, 1986). The *Decision on the Reform of the Educational Structure* (MEPRC, 1985) and the *Compulsory Education Law of the People's Republic of China* (MEPRC, 1986) allowed different timetables for different regions to achieve a goal of nine-year universal education and served as the basis for further reforms. Most significantly, a framework was established for decentralized local school finance and governance. This immediately led to huge regional disparities in textbook quality due to differences in local economies. After many debates and adjustments about the degree of decentralization, the *Revised Law of Compulsory Education* was enacted in 2006. This law authorized the disbursement of subsidies from the central government to regions with lower economic capacities. This marked the government's determination to sustain universal basic education, and hence prepared the way for more energetic reforms within Chinese educational system (OECD, 2010a).

Figure 1 shows China's current educational system. The nine-year compulsory education covers six years of primary education and three years of junior secondary education. Students can then continue three years of senior secondary education, divided into secondary professional school, vocational high school, and senior high school. While senior high school has experienced an increased enrollment, the other schools have seen a decline in enrollment (OECD, 2010a). Less attention has been paid to the tertiary and informal (lifelong learning) system offerings (e.g., evening programs, correspondence studies, and self-study examinations). The tertiary education, in particular, has come under increasing pressure to reform, with the new national education reform initiative for 2010 to 2020 focusing primarily on the formal higher education system (MEPRC, 2010).

Examination system. The Chinese educational system contains various examinations for almost all vertical educational transitions. Admission by examination is required to enter prestigious junior high schools and senior secondary education institutions. The High School Examination (i.e., Zhongkao) assesses six subject areas (Chinese, mathematics, physics, chemistry, foreign language, and political education) as well as requires students to meet physical education requirements (Lam, 2010). The Ministry of Education allows local education departments to set up these examinations (MEPRC, 2012). Senior secondary education also culminates with a graduation examination (i.e., Joint Graduation Examination or High School Academic Proficiency Test).

NCEE was originally introduced in the 1950s, put on hold during the Cultural Revolution from 1965 to 1976, and resumed in 1977. NCEE consists of three

compulsory subject areas (Chinese, mathematics, and foreign language) and six optional

subject areas (physics, chemistry, biology, geography, history, and politics). NCEE has

been operating in a "3 + X" format since 1994, with 3 representing the three compulsory

subject areas and X consisting of a group of subject areas that differ for students

depending on what major they pursue in college (Liu & Wu, 2006; Davey, Lian, &

Higgins, 2007). For example, those pursuing liberal arts take geography, history, and

politics while those pursuing engineering take physics, chemistry, and biology. Except

for the Shanghai municipality (which was allowed to pilot its own version of NCEE),

before 2000, NCEE employed identical tests throughout China. By 2006, a total of 16

provinces, municipalities, and autonomous regions independently implemented their own

NCEE examinations under the national curricular guidelines in order to accommodate

regional differences in economy and education (Wang, 2006).

Educational conditions. Table 1 shows the number of students enrolled at each

level of educational institutions in 2010, and Table 2 shows the student to teacher ratios

from 2001 to 2010. According to MEPRC (2012), in 2010, primary schools alone

enrolled 17,396,364 students with a ratio of students to teachers as about 22 to 1. To

improve educational conditions in China, efforts have focused on what is referred to as

"three matters" (Levin & Lockheed, 1993; Wang & Zhou, 2002). *Growing participation*

targets enrollment, completion, and achievement; *becoming more effective* to decrease

dropout and repetition; as well as, promote positive learning outcomes; and *increasing*

resources boosts more expenditure per student, annual recurrent public educational

expenditure, qualified teachers, facilities, equipment, and textbooks (MEPRC, 1998).

Although the vast majority of schools have electricity, water, and roads (linking to major

highways) (Cheng, 1993), educational conditions in China are still poor in rural regions (Tsang, 2000).

Classrooms in China are often so crowded that there is barely walking space in the aisles. Circular seating is common in kindergartens, but classrooms in primary and secondary schools often have double desks or fixed desks with four to six seats (Jin & Cortazzi, 1998). The proportions of primary schools reaching national standards in terms of sports (playground and gymnasium), musical instruments, artistic instruments, and mathematics and science equipment were about 49%, 38%, 36%, and 49%, respectively (MEPRC, 2003). According to Yang (2001), less than 1% of the national total, dangerous buildings amounted to a total of 13 million square meters across schools in China, mostly distributed in the rural areas of Central and Western China. For instance, in Ningxia (an autonomous region in China), the proportion of dangerous buildings was about 5% among both primary schools and junior high schools.

Academic performance of Chinese students. Given the critical importance of success on the CSE in ancient history and the NCEE in recent history, it is not difficult to believe that, among all the critical issues of education in China, the most prevalent and significant is academic performance. The historical examination-oriented philosophy of Chinese education appears to work well in producing top-performing students. Both international academic competitions (e.g., International Mathematical Olympiad [IMO]) and international comparative studies (e.g., Program for International Student Assessment [PISA]) rank Chinese students' academic performance among the very best in the world.

Founded in 1959, IMO is one of the most competitive and highly intellectual activities for high school students in the world. Problems come from various areas of

secondary school mathematics. Success in finding solutions for these problems requires exceptional mathematical ability and knowledge. China sent a team of two students to IMO for the first time in 1985. Since 1986, China has been sending a team of six students to IMO. Chinese students have achieved great success in IMO since its formal participation in 1986. Table 3 shows the performance of Chinese students in IMO in the past 10 years. Chinese students have also demonstrated outstanding academic performance in international academic competitions in science (e.g., International Chemistry Olympiad). Bin and Yee (2006) attributed the outstanding performance of Chinese students in IMO to the heavy emphasis of the Chinese educational system on basic fundamental skills in mathematics.

Coordinated by OECD, PISA measured reading, mathematics, and science literacy of 15-year-old students, with an emphasis on the functional skills (to "survive" in the modern society) that students need to have as they come near the end of compulsory education. First initiated in 2000, PISA is conducted every three years. Shanghai, a provincial equivalent, participated in PISA for the first time in 2009. The representative sample of more than 5,000 students demonstrated stellar academic performance. The overall performance was at the top of all participating countries in reading, mathematics, and science. For science, about 15% of students in Shanghai achieved the highest level of proficiency, compared with the international average of about 4%. Table 4 shows the academic performance of students in Shanghai in mathematics and science in PISA 2009 (OECD, 2010b).

Theoretical Framework

As it relates to the historical references to Chinese education discussed above, this study aimed to explore the correlation of academic performance among Chinese students and schools across subject areas in science based on the mainstream theoretical framework of school effectiveness and school improvement (Teddlie & Reynolds, 2000). This framework has been applied internationally for more than four decades, examining mainly the relationship between schooling inputs (e.g., student characteristics, teacher characteristics, and school resources) and learning outcomes (e.g., academic achievement, self-concept, and career aspirations). One of the principal goals of this work is to identify schools that are exceptional in performance and determine whether variation between these schools and those less exceptional is explainable by schooling factors that can be manipulated by school policies and practices (Willms & Raudenbush, 1989).

In terms of research methodology, many empirical studies from the early days of research on school effectiveness and school improvement are considered methodologically inappropriate (e.g., ANOVA or Regression) because of their inability to take into account the within-school variation in learning outcomes (e.g., Willms & Cuttance, 1985). To resolve this problem, the technique of multilevel modeling (also referred to as hierarchical linear modeling) has been developed for data analysis to accommodate the hierarchical nature of educational data (e.g., students nested within schools). Multilevel modeling represents a significant advancement in the research methodology for school effectiveness and school improvement.

Willms and Raudenbush (1989) have identified the lack of adequate statistical control over school characteristics as another major limitation in many earlier studies. In

other words, they have criticized data analysis on school effects done without any understanding of schooling processes at the school level. Ma, Ma, and Bradley (2008) describe schooling processes as school-level variables (i.e., school characteristics) associated with schooling that affect learning outcomes either directly or indirectly. These researchers have classified schooling processes into two sets of variables. One set describes the context of a school (e.g., school size, school location, teacher experience, and characteristics of student intakes). The other set of variables is referred to as evaluative variables that portray the inner working of school life, or the climate of the school (e.g., classroom practice; school leadership; interpersonal relationship; and attitudes, values, and expectations of students, parents, teachers, and administrators).

Ma, et al. (2008) described their logical and analytical position or strategy concerning empirical studies on school effectiveness and school improvement:

School effects research usually focuses on school climate because it is under the direct control of parents, teachers, and administrators. For example, administrators can use school policies to create, amend, or reform school climate to provide teachers and students with a positive environment to engage in teaching and learning. In contrast, school context is out of the direct control of parents, teachers, and administrators. Although school contextual effects are informative to educational policy, most researchers use them as a control for refining the influence of school climatic variables. In other words, the effects of school climate may be adjusted for school context, reducing the dependence of educational policy implications on school context. (p. 60)

This study adopted a similar logical and analytical strategy, guiding the selection of variables at the student and school levels; as well as, the specification of multilevel models.

Research Purposes

Most existing research in school effectiveness and school improvement concentrates on five countries (United States, United Kingdom, the Netherlands, Australia, and Canada) (Teddlie, 2004). Very few studies have been conducted on (mainland) Chinese students and schools (Sun, 2003). Given the unique Chinese educational heritage and the superb performance of Chinese students in international comparative studies and academic competitions, an empirical study of Chinese school effects can be important and informative internationally. This study attempted to conduct a comprehensive empirical analysis (likely among the first in the research literature) of school effects in China.

Overall, it investigated the academic performance in some subject areas in science (science inquiry skills, biology, earth science, and physics) of students attending middle schools in China. This study has two purposes. One is to identify characteristics of school climate of effective Chinese schools that demonstrate high academic performance in the four subject areas in science with statistical adjustments for student characteristics and characteristics of school context. The other purpose is to determine the correlates of academic performance across the four subject areas in science with statistical adjustments for student characteristics and characteristics of school context and climate. Specifically, four research questions were examined: the first two pertain to the first purpose, while the latter two refer to the second purpose:

1. What characteristics of school climate are related to high academic performance in each of the four subject areas in science (inquiry skills, biology, earth science, and physics)?

2. Are there common characteristics among school climates that produce high academic performance across the four subject areas in science?

3. Do schools (students) have stable or consistent academic performance across the four subject areas in science? That is, do schools (students) with high academic performance in one subject area also show high academic performance in other subject areas?

4. After adjusting for student and school characteristics, do schools (students) have stable or consistent academic performance across the four subject areas in science?

Research Significance

Teddlie (2004) has argued that several regions of the world are under-represented in the research literature on school effectiveness and school improvement and that a continued absence of these regions in the international research database on school effects may produce skewed results overall. China is one of these regions. It is expected that the results of this study can fill some gaps in the research literature.

A shortage for the global workforce equipped with a high level of proficiency in science (S), technology (T), engineering (E), and mathematics (M) has been identified and referred to as the STEM challenge (e.g., Straffon, 2011). In the United States, about five million people work directly in science, technology, and engineering, representing only about 4% of the nation's workforce (National Science Foundation, 2010). It is hard

to imagine that this small group can maintain the nation's economic innovation and productivity in the 21st century (U.S. Department of Labor [USDL], 2003). USDL (2007) called for significant, coordinated steps to address this shortage. Calls like this across the world (see, for example, Straffon, 2011 for the case of the United Kingdom) have placed a tremendous amount of importance on science education today. Many education systems around the world strive to improve knowledge and skills of students in science to prepare them to meet this ever-growing challenge (Rowlands, 2008).

What is unique about science education is the many independent subject areas within the science study (e.g., physics, chemistry, biology, ect.) more than any other school subject. What has been ignored as a research issue is the stability or consistency of students' and schools' academic performance across subject areas in science. Previous studies examined the stability or consistency of academic performance across school subjects (e.g., mathematics, science, reading, and writing) (Luyten, 1994; Ma, 2001; Sammons, Thomas, & Mortimore, 1997; Thomas, Sammons, Mortimore, & Smees, 1997). This study attempted to examine the stability or consistency of academic performance within one of the core content areas (i.e., school science). Stability or consistency is an indicator of balanced development in basic scientific knowledge and skills. One major characteristic for both effective learners (students) of science and effective teachers (schools) of science is a balanced progress across all subject areas of science. This position is a direct implication from many researchers investigating the issue of correlates of academic performance across school subjects (e.g., Ma, 2001).

This study made a specific and critical improvement over previous studies on the stability or consistency of academic performance across school subjects. Earlier studies

either included no school characteristics at all or employed only characteristics descriptive of school context. This study included variables descriptive of school climate in addition to variables descriptive of school context. This effort helped this study to achieve more adequate statistical control over school characteristics when examining the correlates of academic performance across subject areas in science.

Chapter 2 Review of Literature

Chinese Education in an Era of Fast Economic Development

  Decentralization and marketization. Since the implementation of the policies

on reform and openness in the late 1970s, China's education has experienced substantial

changes due to the impact of market-oriented economic reforms and other social

developments (Ngok, 2007). Educational decentralization and marketization are

regarded as prominent strategies in China's educational reform (Zhao, 2012).

Specifically, decentralization (in education) refers to the relinquishing of central

government control and assigning responsibility for the provision and management of

education to the local levels, and educational marketization refers to the establishment of

an educational market where private individuals and social organizations can compete

with public schools for clienteles (even for profit) (see also Agelasto & Adamson, 1998).

Overall, the state has relinquished its monopolistic role in education and allowed room

for non-state social forces to become involved (Ngok, 2007). Zhao (2012) insisted that

there are two major driving forces to decentralize the authority of education and establish

educational market. The first is the pragmatic considerations of financial stringency.

China is still a developing country, and the central government does not have enough

financial resources to materialize many ambitious goals embedded in Chinese education.

The other driving force is the concern over educational quality. The central

government's excessively tight control is seen as a barrier to innovative ideas and

strategies (often thriving with more local autonomy) that improve the quality of education.

  Like other governments in developing countries, the Chinese government adopted

the two strategies of decentralization and marketization (Robertson, 1992), which are

embodied in two key government documents. The first document, entitled *The Decision of the Central Committee of the Communist Party of China on the Reform of the Educational Structure* issued by the Chinese Communist Party Central Committee (CCPCC) at the National Education Conference in May 1985 (hereafter referred to as "The 1985 Decision"), marked the first critical step taken to restructure Chinese education. The 1985 Decision admitted that rigid government control of schools resulted in inefficient management in education. Under the principle of linking education to economic reform, the document called for the devolution of power to lower levels and the reduction of rigid government controls over schools. While the central government, through its educational administration, would continue to monitor the process and provide basic guidelines for educational development, local authorities b the power to administer elementary education (CCPCC, 1985). As a result, local authorities bore more financial costs of education, multiple methods of financing education were encouraged, and the establishment of schools run by the non-state sector was also allowed (Ngok, 2007). Overall, with decentralization, a multilevel administration of basic education, with local authorities (counties) assuming the main responsibility, has been universally implemented in China (Zhu, 1997).

The second document, *The Program for Education Reform and Development in China,* which was released in 1993, explicitly stated the government's intention to market education and provided more specifics on how it should work. The government declared that "the national policy is to actively encourage and fully support social institutions and citizens to establish schools according to law and to provide correct guidelines and strengthen administration" (cited in Masemann & Welch, 1996, p. 557). This re-affirmed

the central government's 1985 commitment to refrain from direct control of education by resorting to legislation, funding, planning, and advising in order to manage education. The 1993 program also claimed that in order to fulfill the need for setting up a socialist market economy and promoting political reforms and scientific advancements, the pace of educational restructuring and development needed to accelerate so as to train more technical personnel for socialist modernization (Ngok, 2007).

Overall, the use of the strategies of decentralization and marketization in the Chinese context is highly instrumental (Ngok, 2007). First, the Chinese government intended to use these strategies to improve its financial situation and enhance the efficiency and effectiveness in the use of its resources in the face of financial stringency. Second, the adoption of these policies reflected an attempt to make use of market forces and new initiatives from the non-state sectors to mobilize more educational resources and create more learning opportunities for its citizens. Third, the increasing responsibility of local governments for educational investment has reduced the role of central government and increased the power of the provincial and county governments in educational planning and administration.

Universalization of Nine-year Compulsory Education. The *Compulsory Education Law of the People's Republic of China* established in 1986 requires each child in China to have nine years of formal education. Specifically, each child is required to finish primary education and junior secondary education. There are two available systems for students. The 5-4 system has five years of primary education followed by four years of junior secondary education. The 6-3 system has six years of primary

education followed by three years of junior secondary education. Currently, the 6-3 system is replacing the 5-4 system as a unified structure of compulsory education.

China's *Compulsory Education Law* is a very authoritative legal framework for the assurance of children's equal rights to basic education based on a national curriculum. Primary schools are to enroll children from nearby communities, regardless of the children's family socio-economic backgrounds; and what is often referred to as "key-point primary schools" where students are admitted for high ability (performance) were abolished to promote educational equity in admission criteria, resource inputs, and performance standards (Zhou & Zhu, 2007). As a result, opportunities of education have been enlarged, and the size of education has been expanded rapidly (see Table 5).

For elementary education, by the end of 2005, 99% of school-age children were enrolled in primary schools, and 95% of graduates from primary schools had a chance to study in junior high schools. Compulsory education has initiated a chain reaction in Chinese education, eventually promoting the nation's higher education. In 2005, the number of students in all kinds of higher education institutions exceeded 23 million, with the gross enrolment ratio of higher education reaching 21% (MEPRC, 2006). By 2010, almost all school-age children attended primary education, effectively eliminating the gender gap at this level (MEPRC, 2012a). Although the fulfillment of universal attendance beyond six years' primary education had encountered tough difficulties (Cheng, 1995), more than 98% of primary school graduates currently can move on to junior secondary school (MEPRC, 2012a).

Curriculum reforms of basic education. China has undertaken two rounds of curriculum reform for basic education since the late 1970s. After a long period of

ferment during late 1970s and early 1980s, a curriculum reform for elementary and

secondary schools was initiated in 1986. Six years later (in 1992 and revised in 1994),

the central government issued a new curriculum for compulsory education (elementary

and junior high schools) (State Education Commission, 1994). A new curriculum for

senior high schools was issued in 1996 (and revised in 1999) (MEPRC, 1999).

Curriculum reform is seen as an effort of China to seek a new balance between the design

of school curriculum and the need of Chinese society, culture, and economic

development. This motivation became clear in a further (new) round of reform.

In 1996, the central government began to undertake a nationwide investigation as

preparation for further reform within basic education. In 1999, the so-called "Expert

Group on Curriculum Reform for Basic Education" was created, marking the formal

beginning of the second round of reform. This expert group explored five aspects of the

reform agenda, including (a) background, (b) current conditions, (c) guiding thoughts and

essential tasks, (d) general principles, and (e) policies and strategies (Department of Basic

Education, 1999). At the same time, MEPRC (1998) released a critical document entitled

An Action Project for Education Vitalization: Facing the 21st Century which mandated

main tasks for curriculum reform: (a) establishing a new framework and a set of

standards for a modernized curriculum for basic education; (b) reforming educational

content, teaching methods, and learning experiences; (c) exploring a new system of

educational evaluation; (d) strengthening teacher education; and (e) initiating educational

experiments on the new curriculum. The results were expected to be a set of unified new

teaching and learning materials for a national curriculum on basic education, with the key

document entitled *Guidelines for Curriculum Reform of Basic Education* approved and

published by MEPRC (2001a). Overall, China's curriculum reform aimed to achieve six specific objectives (Feng, 2006):

Shifting from a narrow perspective of knowledge delivery in classroom instruction to a perspective concerned with learning how to learn and developing positive attitudes; shifting from isolation among subjects to a balanced, integrative, and selective curriculum structure; shifting from out-of-date and extremely abstruse curriculum content to essential knowledge and skills in relation to students' lifelong learning; shifting from students learning passively to students developing capacities to process information, obtain new knowledge, analyze and solve problems, and communicate as well as cooperate with others; no longer viewing the exclusive functions of curriculum evaluation to be identification and selection, but adding the promotion of student growth, teacher development, and instructional improvement as additional functions of curriculum evaluation; and shifting from centralization in curriculum control to dividing curriculum into three levels of control: central government, local authorities, and schools. (p. 132-133)

Science Education in China

The general goal of education in China is to raise the educational level of the whole nation. Education is viewed as an approach to train the skilled personnel needed to transform China into a more prosperous, powerful, and modern socialist country. Science education, as a part of general education, provides people with a solid foundation of knowledge about the natural world and equips them with certain skills in problem analyzing and problem solving. Therefore, science education is seen as an important

component in achieving the general goal of education for this country (Wang, Wang, Zhang, Lang, & Mayer, 1996). A brief history of science education and recent science education reform in China will be introduced in the following paragraphs.

A brief history of science education in China. According to Liu, Liang, and Liu (2012), Chinese science education can be dated from 1904 when the Chinese government of the Qing Dynasty released a school regulation specifying that physics, chemistry, and nature were to be taught as separate subjects in schools. In 1922, the warlord government (Beiyang Government) issued the *School System Reform Plan* announcing that integrated science subject, or natural science, should be taught in the secondary school science class. Later on, integrated science syllabi and textbooks were published. It was the first time in the history of Chinese science education that integrated science was taught in Chinese schools instead of separate science subjects (Wang & Fan, 2007). However, in the following 25 years, due to the Anti-Japanese War and the Civil War, science curriculum frameworks kept changing. Integrated science gradually disappeared from school curricula, and separate science subjects (e.g., physics, chemistry, and biology) continued to be taught in most schools (Liu et al., 2012).

After the foundation of the People's Republic of China in 1949, the government carried out several major education reforms in science subjects across the nation. During the early years of the new government (1950s—early 1960s), the Chinese basic and higher education systems, including science curriculum and teaching pedagogy, were mostly modeled after those of the former Union of Soviet Socialist Republics (USSR) (Liu, 1996). Elementary schools offered science as an integrated subject course called Nature; while junior high and senior high schools provided with discipline-based science

courses including biology, chemistry, and physics. Such science curriculum structure remained in effect until the late 1980s (Liu et al., 2012). In 1988, as a reform experiment, Shanghai city and Zhejiang province, as the most developed regions in China, started to develop and pilot a new integrated science curriculum, while the rest of the country continued to teach science as separate, discipline-based subjects (Chen & Fang, 2007).

In 2000, *The Guideline for General Education Reform was released by* the MEPRC, which stipulated that science should be taught as an integrated subject in elementary schools, either as integrated or separate subjects in junior high schools, and separate subjects in senior high schools (MEPRC, 2000). According to this reform policy, school science starts in primary grade 3. It is an integrated course. Two types of science courses are offered for junior secondary students: teachers can decide whether they present the integrated science or, physics, chemistry and biology as usual. In senior secondary level, science includes three subjects, and each subject includes a number of modules. Some modules are compulsory and some are elective. After completing the compulsory modules, students can make a decision on their own if they keep on going to the elective modules

According to Chen et al. (2007), within a few years, the curriculum and textbooks aligned with this guideline were either developed or revised from existing ones for implementation throughout the country. However, during the recent decade, most of the secondary schools still preferred to offer science classes as separate subjects to junior secondary students over integrated science. Offering junior secondary students integrated science in China remains an exception rather than the norm. For instance, integrated science is taught only in schools located at Shanghai city, Shenzhen city, and Wuhan city.

Zhejiang is the only province where integrated science has been adopted and implemented in all schools (Liu et al., 2012).

Recent science education reform. In recent years, China has tried to achieve four modernization goals, one of which is the modernization of science and technology. This goal cannot be realized without significantly improving the existing science education for the next generation. Like the U.S., China is also facing the challenge to close the gap between rhetoric and reality in providing quality and equal science education for all students (Su, Su, & Goldstein, 1994). At the beginning of 2000, China started with a new round of education reform with the idea that education must be oriented toward modernization, the world, and the future (Liu et al., 2012). Within one year, the new science curriculum standards for Grades 1 through 9 were released by MEPRC (MEPRC, 2001b). Two years later, high-school science curriculum standards were released (MEPRC, 2003b, c, d). According to MEPRC (2003b, c, d), the new science curriculum standards were based on beliefs of "developing student scientific literacy", "science for all children", and "teaching science through inquiry". Within the new curriculum standards, values and goals, target population, and methods of science teaching were specifically defined. In the following several years, the updated science curriculum standards were implemented in most schools across the country. The mission of this science education curriculum reform was to shift the emphasis from transfer of knowledge in the classroom to development of students' scientific literacy with inquiry-based teaching (Bing, 2005).

In addition, this curriculum reform also involved updating the science curriculum content. The content standards were structured with themes in order to show greater

pictures of science to students. For instance, the biology content standards focus on four themes, including genetics, evolution, reproduction, development and ecology (MEPRC, 2001b). Inquiry was not only a teaching and learning approach, but also part of the content. It was the first time that technology was also integrated into a science curriculum as a part of the content. Students were offered many laboratory activities to promote their understanding of how scientific knowledge was applied in technology. In general, two approaches were taken to modernizing the science content: one was to replace outdated science content with the latest developments in science, and the other was to connect the science content with technology that students encounter in their daily lives (Liu, 2011).

Teacher's professional development became one major challenge to implementing the new science education standards during the first few years (Liu et al., 2012). The majority of science teachers felt it difficult for them to teach inquiry and the new content. To address this issue, the central government of China invested heavily in providing human and financial resources. Many training workshops and teachers-helping-teachers projects were started to focus on developing science teachers' content knowledge and pedagogical content knowledge.

Furthermore, the State Council of China released the national mid-term and long-term education reform and development framework (2010–2020) (MEPRC, 2010) which states specific objectives for reforming both basic and higher education standards through 2020. In January 2012, the MEPRC issued the revised edition of science curriculum standards for Grades 1 through 9. In the new 2012 standards, beliefs and goals were kept

the same while the big ideas of science were further highlighted as an important part of the content standard (MEPRC, 2012b).

Aligned with the earlier-mentioned major reform initiatives for science education, in 2002 the Chinese People's National Congress adopted the *People's Republic of China's Science and Technology Popularization Law* (The State Council, 2002). Later in February 2006, the central government released the *Outline of A National Action Plan for Scientific Literacy for All Chinese Citizens: 2006– 2010–2020* (The State Council, 2006). This outline describes specific measures to be taken immediately, mid-term (by 2010), and long-term (by 2020) by Chinese government agencies and society to help all Chinese citizens of pre-adult age, government leaders/public servants, city/township workers, and rural peasants achieve scientific literacy.

School Effectiveness

The definition of an effective school varies. Some definitions contain single sentences, while others elaborate more in relation to policy or procedures (Johnson, 2008). Reid, Hopkins, and Holly (1987) have indicated that there is no agreement on what makes a school effective. OECD (1994) adopted the following effective school definition with a global approach: "An effective school promotes the progress of its students in a broad range of intellectual, social, and emotional outcomes, while considering socio-economic status, family background and prior learning" (p. 1). In this section, the classical school effectiveness studies both in the western countries and China are introduced.

School effectiveness research in western countries. Intensive school effectiveness research began approximately 40 years ago after the publication of

Coleman and his colleagues' (1966) research on the equality of schooling in America. This milestone study entitled *The Equal Educational Opportunity Survey* is commonly known as *The Coleman Report*. Coleman and his colleagues collected data from more than 4,000 schools and analyzed the results of standardized tests of ability and achievement for 645,000 students. The results were used to examine the relationship between school resources and student achievement. The principal finding in this report was that academic achievement was more related to factors such as family background, school demographics, teacher's literacy level, and student background than the quality of school operation. This report was considered as the major impetus for development of school effectiveness research (Reynolds, Creemers, Stringfield, Teddlie, & Schaffer, 2002). According to Verdis, Kriemadis and Pashiardis (2003), school effectiveness research has experienced two generations of growth. The first generation of school effectiveness research started after the release of the *Coleman Report*.

Ronald Edmonds was one of the important pioneers in school effectiveness research. He was one of the researchers who criticized the research methodology of the *Coleman Report*. His study with the title of *Effective Schools for the Urban Poor* had an influential effect both on this research area and education policies (Verdis et al., 2003). Edmonds (1979) studied schools serving poor, mostly minority, inner-city children in Detroit, Michigan. His research claimed that instructionally effective schools for poor children did exist. Based on his own research, the re-analysis of the data from the *1966 Equal Educational Opportunity Survey*, and a literature review, he proposed characteristics of effective schools as strong instructional leadership, a strong

instructional focus, teacher behaviors that convey high expectations, frequent monitoring

of student achievement, and a safe and orderly school environment (Lezotte, 1997).

Brookover and Lezotte (1979) conducted a study of 68 elementary schools to

examine expectation levels, academic norms, sense of academic ineffectiveness, and

other factors of schools as they related to student achievement. They conducted survey

studies in Michigan and case studies in four low-SES urban schools. A list of

characteristics of successful schools was also provided including: instruction took up the

majority of time; there were little differentiation among students in their instructional

programs; few write-offs and high academic expectations of all students; students were

able to perceive the high expectations for them, felt that they had control over their

academic work, and believed that teachers cared about their academic performance;

students were rewarded and encouraged; and principals were involved in instruction (see

Liu, 2006).

During the same period of time, a British study on school effectiveness was in the

early stage (Teddlie et al., 2000). Power (1967) investigated variations in effectiveness in

terms of social behavioral outcomes of students. Brimer *and his colleagues* (1978)

published a book entitled *Sources of Differences in School Achievement for* the National

Foundation of Educational Research. However, the most influential early school

effectiveness study in Great Britain was *Fifteen Thousand Hours*, in which Rutter *and his*

colleagues (1979) completed a longitudinal study to determine if school inputs accounted

for variances in student achievement. They spent more than four years observing classes,

coding and recoding the activities of teachers and students at 12 urban secondary schools

in London. They paid much attention to whether teachers were attending to the subject

matter, to students' behaviors, to social activities, or to administrative matters. Meanwhile, they recorded the teachers' interactions with individual students, and with the whole class, rates of on-task academic engagement, and instances of off-task behaviors. Their study identified the existence of effective schools in terms of higher achievement levels and fewer behavior problems (Liu, 2006). Using standardized test scores, Rutter et al. (1979) found that there was a correlation of 0.76 between the school input defined by number of exams and student achievement.

The second generation of school effectiveness studies started in the mid-1980s (Reynolds, et al., 2002), such as the *School Matters* in London (Mortimore, Sammons, Stoll, Lewis, & Ecob, 1988) and *Louisiana School Effectiveness Study* (LSES) (Teddlie & Stringfield, 1993). In order to examine the size of school effectiveness, the differentiation of school effectiveness, and factors that enhance school effectiveness, Mortimore et al. (1988) conducted the study of *School Matters* involving 2000 children in 50 randomly selected London primary schools over four years. This study was one of the first group of studies to take advantage of a powerful new statistical technique over the studies mentioned earlier (Verdis, et al., 2003), and it was also the first school effectiveness study in the United Kingdom focusing on classroom practices (Liu, 2006). Meanwhile, Teddlie et al. (1993) initiated the LSES in the United States. This study was a longitudinal design, from 1980 to 1992, using both qualitative and quantitative techniques to collect data from school and classroom levels. Teddlie et al. (1993) focused on the SES of student bodies and discovered various school effectiveness characteristics for middle schools with low SES: the enhancement of educational

expectations; principal leadership style; usage of external reward structures; the emphasis on school curriculum; parental involvement; and the experience level of teachers.

During this generation of school effectiveness research, methodological advancement was abundant including many new statistical algorithms (Reynolds et al., 2002). Moreover, new techniques were also used for data collection. In addition to questionnaires, researchers in the 1980s started to apply direct observations and behavior checklists. Researchers also began to consider the context and the social organization of the schools in more depth, constructing scales for measuring administrative issues and developing more sensitive output measures (Verdis et al, 2003).

Teddlie et al. (2000) believed that the current trend of school effectiveness research is to move toward the internationalization of the field. Teddlie (2004) stressed the significance of internationalization and diversification of school effectiveness research. First, during the past four decades, the majority of studies have been conducted in industrialized countries, especially in the United States, the United Kingdom, the Netherlands, Australia and Canada. More voices need to be heard from under-represented areas of the world. Second, different findings from new studies conducted in other countries will enrich the knowledge base of this field.

School effectiveness research in China. School effectiveness studies in China have been quite limited. Tang (2005) not only defined school effectiveness as the extent to which a school has effects on its students, seeing school effectiveness evaluation as a process of both assessing of the size of the effectiveness and judging of the value of the effectiveness. He used a three-level model combining classical school effectiveness studies with the context of the "quality-oriented education" in China. The three levels

consist of student-level, school-level, and context-level. Each level includes different types of indicators. Three domains including cognitive domains, behavioral domains, and affective domains that the new curriculum standards, advocate are incorporated into the student-level outcome indicators; the school-level indicators include management factors, teaching factors, and quality factors; and the context factors, which cannot be controlled by the school but affect students, involve students' gender, SES, school location, and the grade span of schooling of that school. Tang (2005) claimed that this model can be used to conduct school effectiveness evaluation research in China.

Another study on school effectiveness research in China was conducted by Liu (2006). In her doctoral dissertation, mixed methods were utilized to collect both quantitative and qualitative data simultaneously to identify the processes used by effective schools in China. This study involved 12 schools and based its conclusions on 300 classroom observations, 60 teacher interviews, and quantitative data. The result indicated processes of effective schools in China are similar to those described in the international school effectiveness literature including: effective leadership, effective teaching, a pervasive focus on learning, a positive school culture, high expectations for students and staffs, and staff development. Overall, this study presented a profile of Chinese elementary schools. To some extent, it introduced new methods for conducting research on school effectiveness and school improvement.

Consistency in academic performance. According to Scheerens and Bosker (1997), consistency or stability is operationally defined as the correlation between two rank orderings of schools. For instance, schools may be ordered according to their performance in one year and then compare this with the rank order for the following year

(stability); or, one might rank them on the basis of their output in mathematics and correlate this with their output in chemistry (a consistency measure). Scholars in educational effectiveness research note that studies on stability have important implications for theory development within the field (Kyriakides & Creemers, 2008).

There is a historical conception of schools as "classic bureaucracies". Effectiveness was considered to be a consistent and stable school characteristic and one-dimensional (Luyten, 1994). Schools can be expected to have stable or consistent performance because of classic bureaucracies' procedural effectiveness. According to Bossert (1988), a classic, mechanistic model of bureaucratic organization underlies much of the thinking about effective schools. Typical features such as strong educational leadership, comprehensive coordination, and frequent evaluation and adjustment usually increase productivity and effectiveness.

This concept of effective schools was challenged by Weick (1979) and Mintzberg (1979), who characterized schools as "loosely coupled systems" and "professional bureaucracies." Essentially they perceived classrooms as isolated workplaces where teachers are quite autonomous in doing their job. Weick has argued that teacher autonomy and loose internal coordination do not result in mere negative consequences. Loose coupling result in an organizations becoming more flexible due to the fact that several autonomous actors in the organization can react to changing circumstances in various ways. In addition, as a result of less time and money spent on coordination, loosely coupled organizations might also be relatively inexpensive to run. A loosely coupled system consisting of several autonomous units provides considerable room for self-determination by the actors. In addition, Mintzberg mentioned that it is very difficult

for administrators to reform or control the functioning of professional bureaucracies for the reason that teachers or other professionals are generally against strict planning and external evaluation of their work. According to Luyten (1994), Mintzberg's view on the flexibility of schools is more consistent with the general experience in the field of educational innovation that it is difficult for schools to make a change. Even this theoretical perspective does not deny that schools can be quite stable or consistent.

Earlier studies concluded that schools that were successful in one subject were also successful in other subjects consistency (e.g., Cuttance, 1987; Sammons, Thomas, & Mortimore, 1997; Thomas, Sammons, Mortimore, & Smees, 1997; Luyten, 1994; Willms & Raudenbush, 1989). Among these studies, the one by Willms and Raudenbush (1989) is noteworthy for its investigation of Type A and Type B school effects. Specifically, Type A refers to the differences between an average student's performance in a particular school and the average performance of the entire school system, and Type B refers to differences between an average student in a particular school and the performance of schools with similar SES composition. They examined Type A effects using both regression and HLM and Type B effects solely using HLM. The authors found significant Type A and Type B effects.

In addition, Luyten (1994) investigated the stability of schools across both years and subjects in Dutch secondary education. Not only was instability across years and subjects established, but also their interaction. In particular, the finding showed that differences between subjects within schools are fairly stable, largely corroborating studies stressing the important role of departments in secondary schools.

There are also studies showing that schools are differentially effective in different subject areas (e.g., Darandari & Green, 2001; Ma, 2001; Mandeville & Anderson, 1987; Matthews, Soder, Ramey, & Sanders, 1981; Secker & Lissitz, 1997). Ma's (2001) investigated correlates of academic performance across mathematics, science, reading, and writing among students and among schools with data describing 6,883 students in Grade 6 in 148 schools from the New Brunswick School Climate Study. A multivariate multilevel model with statistical adjustments for student characteristics and school context and climate characteristics was utilized. Three primary findings included: (a) students were differentially successful in different subject areas (mathematics, science, reading, and writing); (b) schools were differentially effective in different subject areas; (c) and the differential success was more obvious among students than among schools.

Darandari and Green (2001) conducted a two-level HLM analysis based on data from schools in a medium-sized county in Florida. Schools from elementary, middle, and high school levels were included in the analysis. The results showed that the schools were differentially effective in mathematics and reading.

Mandelville and Anderson (1987) examined the stability of school effectiveness indices (SEI) across grades levels and subjects in elementary schools with the residual scores after a regression analysis. The index was stated small but in mathematics, and fell in reading from Grade 1 to Grade 4. They also found that achievement in a school one grade level, after controlling for prior achievement and SES, was weakly associated with achievement in other grade levels.

Some school-level variables may mediate stability and consistency of performance. Mandeville and Kennedy (1993) found many of the indicators of school

relate to achievement discrepancies across subject at a given point in time (see also Lee, 2000), School location and the stability of the student population (in particular the percentage of low SES children in a school) were significant predictors of change in performance over time. Webster, Mendro, Orsak, and Weerasinghe (1998) indicated that the elementary schools have a large number of relatively homogenous schools, thus strengthening stability or consistency in performance, while middle schools have a small number of relatively heterogeneous schools, thus tending to reduced stability or consistency in performance. Heistad (1999) discovered that the school effectiveness indices reflecting students' performance at each grade level are unstable. Overall, no consistent findings across subject areas, school levels, and time periods have been confirmed yet.

Chapter 3 Method

Sample and Data

Data came from the Student Academic Achievement Evaluation (SAAE), a large-scale student assessment that focuses on core content areas (i.e., Chinese, mathematics, and science) in Grades 3 and 8 in China (see SAAE Research Group, 2009). The SAAE is a new venture in Chinese education. Organized by the National Center for School Curriculum and Textbook Development (under MEPRC), SAAE is the first large-scale student assessment in China, administered annually in principal provinces since 2005. The SAAE uses a random probability sampling approach that representatively selects schools in principal provinces. All third and eighth grade students in sampled schools participate in the evaluation. The present study employed data from the 2011 SAAE with a sample of 110,520 eighth grade students from 592 junior high (middle) schools.

Based on the current national school curricula, the SAAE aims to (a) evaluate the quality of learning in core content areas of students in elementary and junior high (middle) schools and (b) explore effective (school) educational policies and practices that promote students' learning outcomes in core content areas (MEPRC, 2012). The SAAE has received professional support from institutions and organizations across the globe, with long-term cooperation with the Curriculum, Evaluation and Management Center (at Durham University in the United Kingdom) and the United Nations Educational, Scientific and Cultural Organization (UNESCO). In addition, the Programme for International Student Assessment (PISA), Pearson Education, the Hong Kong Examinations and Assessment Authority, and McGraw-Hill have also provided professional guidance for the development and implementation of the SAAE.

Variable Selection

The selection of variables in this study were based on the mainstream theoretical framework of school effectiveness and school improvement, which were used to examine the relationship between schooling inputs and learning outcomes

Previous studies revealed mixed results with regard to the gender gap in science achievement. In some instances, females perform equal to male peers in terms of the quality of coursework completed (Ingels & Dalton, 2008). However, statistics from the National Assessment of Educational Progress (NAEP) revealed that male students still outperform female students on the assessment at middle school and high school (Campbell, Hombo, & Mazzeo, 2001).

Additionally, the role of family socio-economic status (SES) in determining students' learning outcomes has always been an area of considerable attention in educational studies. A great number of studies have established an empirical relationship between students' family SES and their learning outcomes, even though the strength of the relationship varies to a great extent. Family socioeconomic status (SES) has been examined to influence academic achievement (Mau, 1997). Specifically, family SES not only provides home resources directly, but also determines the location of children's neighborhood and school. These benefits are able to build supportive relationships among schools and individuals (i.e., parent-school collaborations) that promote the sharing of societal norms and values, which are necessary to success in school (Dika & Singh, 2002).

The effects of time spent in learning on learning outcomes have also been embedded in previous studies which also have mixed findings. Dewey, Husted, and Kenny (2000) found that a longer school year in days (controlling for minutes in a day)

can lead to higher scores in verbal assessment, but has no impact on math performance. Konstantopoulos (2006) found that length of school year will not exert a statistically significant influence standardized test scores. Regarding the time spent in after-school programming, Dynarski, James-Burdumy, Moore, Rosenberg, Deke, and Mansfield (2004) found little effect of the afterschool program on students' learning outcomes.

Due to the increasing number of migrant workers, their children who are labeled as left-behind children have been a new special social group in China. Based upon this condition, one variable that portrays children's family separation is selected in this study. It identifies children who are left in hometown with caregivers other than parents who work in a different place. Among the previous studies on left-behind children's academic attainment, Chen, Huang, Rozelle, Shi, and Zhang (2009) found that there is no significant negative effect of migration on school performance, and educational performance improves in migrant households in which the father out-migrates.

Variables that describe schooling processes have been mentioned in the Chapter 1. Towards the current study, school variables are classified into two sets. One set, including school (enrollment) size, school mean father and mother SES, teacher education (level), and teacher (teaching) experience, describes the context of a school; the other set of variables, consisting of classroom practice, principal leadership, and professional development, depicts the climate of the school. According to Ma et al (2008), both of these two sets of variable are associated with schooling that affect learning outcomes either directly or indirectly.

Instruments

Based on the current core content curricula and adopting the conceptual ideas from PISA, the SAAE achievement tests emphasize survival abilities in core content areas that students would need in their future to meet real-life challenges. Test content is categorized into knowledge recall, knowledge application, and problem solving. Knowledge recall questions generally require students to be familiar with facts and procedures. Application questions focus on the use of procedural and conceptual understanding to solve real-world problems. To test for problem solving, non-routine problems are presented to students that require them to extend their existing procedural and conceptual knowledge to new situations.

The SAAE science achievement test for eighth grade students includes biology, physics, and earth science. Apart from these specific content areas, there is a general category referred to as scientific inquiry that serves as an overarching assessment strand across (overlapping) various domains in content and cognition. There are three test brochures for science, and each student is administered one randomly (see Zeng, Luo, Zhao, & Xin, 2012). Item response theory (IRT) procedures are used to estimate scores for each student in science inquiry skills, biology, earth science, and physics. The performance of students is established on a common scale across content areas. Values in scales stand for potential scores for all students in the population with similar characteristics and identical patterns of item responses (see SAAE Research Group, 2009).

Three questionnaires are designed in the SAAE to collect background information from students, teachers, and principals (see SAAE Research Group, 2009). The student

questionnaire is administered to students to collect information about their home and school environment (e.g., home learning conditions, peer relationship, teacher-student relationship) as well as their learning experiences (e.g., academic workload, learning methods, attitudes toward learning). The teacher questionnaire includes information about teacher background (e.g., educational experience, professional position, teaching experience), classroom practice (e.g., teaching methods), and perception on critical educational issues (e.g., school curriculum, school administration). The principal questionnaire consists of information about school resources, administrative approaches, and perception on critical educational issues.

Variables and Measures

The dependent variables in the present study were science performance scores of eighth grade students in science inquiry skills biology, physics, and earth science. Again, they are equated IRT scores on a common measurement scale. The independent variables in the present study included student-level variables and school-level variables. Many variables at these levels were index variables created from a number of items in student, teacher, and principal questionnaires.

Gender, father socioeconomic status (SES), mother SES, and time spent in learning were selected as student-level variables. Another (unique) variable at the student level portrays children's family separation which identifies children who are left in hometown with caregivers other than parents who work in a different place (dummy coded as yes = 1 and no = 0). Father and mother SES were created based on occupation prestige using Duncan International Socioeconomic Index as standardized variables with a higher value indicating a higher SES. Time spent in learning was a continuous variable.

There were two groups of variables at the school level. The first group of variables depicted the context of a school including school (enrollment) size, school mean father and mother SES, teacher education (level), and teacher (teaching) experience. The other group of variables described the climate of a school including classroom practice, principal leadership, and professional development. Appendix A describes these variables in greater detail. Most school-level variables were index (continuous) variables derived from multiple items on SAAE teacher and principal questionnaires (see Appendix A). School mean father and mother SES were aggregated from SES at the student level. Descriptive statistics of dependent variables as well as student-level and school-level independent variables are presented in Table 6.

Analysis

As early as 1983, Barr and Dreeben viewed the schooling system as a set of nested layers so as to identify events that happen at each level and determine how events at one level influence those taking place at another level. The hierarchy (i.e., layers) in educational data (e.g., students nested within schools) creates grouping effects (i.e., interactions among students make those in the same group more alike than those in different groups). Consequently, the observation of students within a group can no longer be considered statistically independent. Traditional statistical approaches such as ANOVA, when applied to analyze data within a data hierarchy result in flawed estimates (e.g., Goldstein, 1995; Raudenbush & Bryk, 2002). To correctly analyze data with hierarchy, statisticians have developed what is referred to as hierarchical linear models (HLM) or multilevel models (e.g., Aitkin & Longford, 1986; Goldstein, 1987; Raudenbush & Bryk, 1986). Webster, Mendro, Orsak, and Weerasinghe (1998) have

identified HLM as efficient models that are extremely promising research tools in the area of school effectiveness. The research premise of the present study was based on Ma et al. (2008) who have provided detailed guidance on the application of HLM to examine school effects from both conceptual and statistical perspectives.

Specifically, the analytic approach in the present study was both multivariate and multilevel. The multivariate nature pertained to the fact that performance in science content areas are often highly correlated, and the multilevel nature pertained to the fact that the SAAE data were hierarchical with students nested within schools. Therefore, a multivariate multilevel model was developed with three levels. The first level can be referred to as the within-student model with four dichotomous variables denoting the four subject areas (*INQ* for inquiry skills, *BIO* for biology, *PHY* for physics, and *EARTH* for earth science):

$$SCORE_{ijk} = \pi_{1jk}*(INQ_{ijk}) + \pi_{2jk}*(BIO_{ijk}) + \pi_{3jk}*(EARTH_{ijk}) + \pi_{4jk}*(PHY_{ijk}) + e_{ijk}.$$

(1)

$SCORE_{ijk}$ is the outcome score in science subject area *i* for student *j* in school *k*. Without an error component, this within-student model is not a statistical model, but a mathematical "device" to make the univariate HLM a multivariate model (see Ma, 2001; Raudenbush, Rowan, & Kang, 1991).

The second level can be referred to as the between-student model (or within-school model) where each coefficient from the within-student model is modeled in terms of students' background characteristics. In this case, student-level variables included gender (*MALE*), father SES (*FSES*), mother SES (*MSES*), time spent in learning (*TIME*),

and family separation (*CHILD*). For example, the coefficient (π_{1jk}) for biology (*BIO*) is modeled as:

$$\pi_{1jk} = \beta_{10k} + \beta_{11k}*(MALE_{jk}) + \beta_{12k}*(FSES_{jk}) + \beta_{13k}*(MSES_{jk}) + \beta_{14k}*(TIME_{jk}) +$$

$$\beta_{15k}*(CHILD_{jk}) + r_{1jk}. \qquad (2)$$

In equation (2), the intercept (β_{10k}) is a measure of average performance for school *k* in, for example, biology (*BIO*) adjusted for student-level variables. Each β_{1pk} ($p = 1, 2, \ldots 6$) represents the slope between, for example, gender and biology achievement after adjusting for other study variables. Finally, r_{1jk} is a random error term unique to each student. Other coefficients (π_{2jk} and π_{3jk}) from the within-student model associated with earth science (*EARTH*) and physics (*PHY*) can be modeled in the same manner (with β_{20k} and β_{30k} as the corresponding intercepts).

The third level can be referred to as the between-school model where the intercepts ($\beta_{10k}, \beta_{20k}, \beta_{30k}$) from the between-student models are modeled in terms of school background characteristics. In this case, school-level variables include school (enrollment) size (*SCHSIZE*), school mean father SES (*MFSES*), School mean mother SES (*MMSES*), teacher education (*TEAEDU*), teacher experience (*TEAEXP*), classroom practice (*CP*), principal leadership (*PL*), and professional development (*PD*). For example, the intercept (β_{10k}) for biology (*BIO*) is modeled as

$$\beta_{10k} = \gamma_{100} + \gamma_{101}(SCHSIZE_k) + \gamma_{102}(MFSES_k) + \gamma_{103}(MMSES_k) + \gamma_{104}(TEAEDU_k) +$$

$$\gamma_{105}(TEAEXP_k) + \gamma_{106}(CP_k) + \gamma_{107}(PL_k) + \gamma_{108}(PD_k) + u_{10k}. \qquad (3)$$

The intercept (γ_{100}) in equation (3) is the grand mean of biology achievement adjusted for school-level variables, and each γ_{10q} ($q = 1, 2, \ldots 9$) represents the slope between, for example, school size and (school average) biology achievement. Finally, u_{10k} is an error

term unique to each school. Other coefficients (β_{20k} and β_{30k}) from the between-student model associated with earth science (*EARTH*) and physics (*PHY*) can be modeled in the same manner (with γ_{200} and γ_{300} as the corresponding grand means).

The above multivariate multilevel model was fitted first with what is often referred to as the "null" or "unconditional" model because it does not include any explanatory variables at the second (student) and third (school) levels. This model produced estimates of variances and co-variances among the four areas without any adjustment for student and school characteristics. Student-level variables were then introduced to this model without any variables at the school level. This model produced estimates of variances and co-variances among the four areas adjusted for student characteristics. Finally, what is often referred to as the "full" model was created with all variables at the student and school levels. This model produced estimates of variances and co-variances among the four areas adjusted for both student and school characteristics.

To measure consistency in performance across the four areas, correlation coefficient is employed (see Ma, 2001). Specifically, Goldstein (1987) used the following formula to calculate correlation coefficient. For example, correlation between biology (*BIO*) and physics (*PHY*) at the school level is calculated as:

$$Corr(BIO, PHY) = \sqrt{\frac{\tau^2_{BIO,PHY}}{\tau_{BIO}\tau_{PHY}}} \tag{4}$$

where τ_{BIO} and τ_{PHY} are variances of schools in biology and physics, and $\tau_{BIO,PHY}$ is the covariance between the two science subject areas. Correlation at the student level can be calculated in the same manner (with τ replaced with σ). In addition, both variances and

co-variances can be adjusted for student-level and school-level variables with the

calculation formula remaining the same.

Chapter 4 Results

Characteristics of Students and Schools

Table 6 contains means and standard deviations (SD) of outcome measures, as well as, variables at the student and school levels. Obviously, the means and SDs of the four outcome measures (i.e., scientific inquiry skills, as well as, achievement in biology, earth science, and physics) were similar. Approximately 52% of students were male. Father SES and mother SES were standardized indices calculated based on the entire sample. For those students involved in this analysis, father SES and mother SES shared similar means and SDs. Students, on average, spent approximately 2 units of additional time (equivalent to approximately 20 hours each week) studying beyond time spent on formal instruction. Approximately 18% of students lived with caregivers in their hometown while parents worked in a different place.

As to schools that these students attended, enrollment on average was approximately 12 units of students (equivalent to approximately 1200 students). School means and SDs for father SES and mother SES were similar. Teacher education is the sum of percentages of teachers who have bachelor, masters, or doctoral degrees. Approximately 92% of teachers had at least a bachelor's degree. Teacher experience is the sum of percentages of teachers with A Level or Advanced Level titles. Approximately 67% of teachers had at least A Level titles. Classroom practice, principal leadership, and professional development were composite variables with a measurement scale of 1 to 5. Schools on average scored close to 4 on the scale of 1 to 5 in classroom practice, principal leadership, and professional development. According to SDs, school scores were most variable in principal leadership and least variable in classroom practice.

Consistency of Performance across Science Subject Areas

Results from the multivariate multilevel model integrating academic performance from the four science subject areas for the examination of consistency of performance are presented in Table 7. This table has three vertical blocks. They contain correlation coefficients as a measure of consistency (a) unadjusted, (b) adjusted for student characteristics, and (c) adjusted for student and school characteristics. This table can also be seen from the two horizontal blocks that report correlation coefficients among students (within schools) and among schools (between schools) respectively.

A null or unadjusted multivariate multilevel model was the starting point to examine the issue of performance consistency. This unadjusted model contained neither student-level nor school-level variables; therefore, the results of this model were unadjusted for student and school characteristics (see the left block in Table 7). Without any adjustments for student and school characteristics, performance was highly correlated between the four science subject areas among students. The highest correlation was between biology and earth science (0.967) while the lowest correlation was between inquiry skills and physics (0.887). These extremely strong correlations indicated that Chinese eighth-grade students who performed well in one science subject area also performed well in other science subject areas. Furthermore, school average performance was even more highly correlated between the four science subject areas among schools. The highest correlation was between biology and earth science (0.997) and the lowest correlation was between inquiry skills and biology (0.984). These extremely strong correlations indicated that Chinese schools that performed well in one science subject area also performed well in other science subject areas. Overall, at both student and

school levels, there was extremely strong consistency or stability among Chinese students and schools in performance across the four science subject areas.

Student-level variables were then introduced into the unadjusted model thereby adjusting the model results for student characteristics (see the middle block in Table 7). The addition of student characteristics changed performance correlation coefficients very little across the four science subject areas both among students and among schools. For example, the highest correlation (between biology and earth science) among students changed from 0.967 to 0.966 and the highest correlation (between biology and earth science) among schools did not change at all (0.997). Therefore, student characteristics did not have any effects on the consistency or stability among Chinese students and schools in performance across the four science subject areas (i.e., adjustments over student characteristics did not change the consistency or stability among Chinese students and schools in performance across the four science subject areas).

Finally, both student-level and school-level variables were introduced into the unadjusted model, thereby adjusting the model results for both student and school characteristics (see the right block in Table 7). After adjustments to both student and school characteristics, performance correlation coefficients across the four science subject areas changed very little both among students and among schools. For example, the highest correlation (between biology and earth science) among students changed from 0.967 to 0.966 and the highest correlation (between biology and earth science) among schools changed from 0.997 to 0.996. Therefore, characteristics of students and schools did not have any effects on the consistency or stability among Chinese students and schools in performance across the four science subject areas (i.e., adjustments to student

and school characteristics did not change the consistency or stability among Chinese students and schools in performance across the four science subject areas).

Effects of Student and School Characteristics on Science Performance

Table 8 presents the results of the multivariate multilevel model estimating the effects of student and school characteristics on performance across the four science subject areas. This model has a unique capacity to identify statistically significant student-level and school-level variables that are important to performance across all science subject areas. At the student level, gender, father SES, mother SES, time spent learning, and family separation all indicated statistically significant effects on performance across all science subject areas. Statistically speaking, the effects of each independent variable are relative because of control over other independent variables in the model. The effects were translated into an effect size measure that used the percentage of a SD to indicate the strength of the effects.

Effect size of gender differences in favor of male students was approximately 8%, 21%, 20%, and 18% of a SD respectively across the four science subject areas (inquiry skills, biology, earth science, and physics). For one SD increase in father SES, the positive effects of father SES were approximately 2% of a SD across all science subject areas. Similarly, the positive effects of mother SES were approximately 1% of a SD across all science subject areas. With one unit (10 hours) increase in time spent in learning, approximately, the effects of time spent in learning were 14% of a SD in inquiry skills and 13% of a SD across biology, earth science, and physics respectively. Interestingly, students who stayed with caregivers (at hometown) while parents worked in a different place performed better across all science subject areas. Effect size was approximately 9%, 7%, 8%, and 7% of a SD respectively across the four science subject

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areas. All these effects, nevertheless, can be considered small (see Rosenthal & Rosnow, 1984).

At the school level, none of the variables selected for this analysis could demonstrate statistically significant effects on school average performance in any of the four science subject areas. In comparison, student-level variables appeared to be far more important to performance in science than school-level variables among Chinese eighth-grade students.

Aptness of Multivariate Multilevel Model

Table 9 presents the proportion of variance in each science subject area explained by the multivariate multilevel model as a measure of model-data-fit. In terms of inquiry skills, approximately 3% of the variance among students and 43% of the variance among schools were explained by the model. Overall, the model accounted for approximately 10% of the total variance in inquiry skills. In terms of biology achievement, approximately 3% of the variance among students and 42% of the variance among schools was explained by the model. Overall, the model accounted for approximately 11% of the total variance in biology achievement. In terms of achievement in earth science, approximately 3% of the variance among students and 45% of the variance among schools was explained by the model. Overall, the model accounted for approximately 11% of the total variance in achievement in earth science. In terms of physics achievement, approximately 3% of the variance among students and 43% of the variance among schools was explained by the model. Overall, the model accounted for approximately 11% of the total variance in physics achievement. Obviously, the model shared the same degree of model-data-fit across the four science subject areas. This is largely because variables that demonstrated statistically significant effects (otherwise lack of statistically

significant effects) on performance were the same at both student and school levels across the four science subject areas. The overall percentages (either 10% or 11%) are acceptable in social sciences (see Gaur & Gaur, 2006).

Chapter 5 Discussion

Summary of Principal Findings

The three-level HLM model developed in this study created a multivariate multilevel environment to examine (a) the effects of student-level and school-level variables on science achievement in four subject areas (science inquiry, biology, earth science, and physics) and (b) the consistency or stability of academic achievement across the four subject areas among students and among schools.

First of all, this study found that student characteristics, including gender, parental SES, time spent in learning, and the type of family separation, were directly correlated to high academic achievement in each of the four science subject areas. Specifically, male students' scores in the four subject areas were higher than scores of female students. Students from higher SES families showed better achievement in the four subject areas. Students who spent more time in learning had better performance in the four subject areas. Lastly, students who stayed with both parents in their hometown had lower scores in the four subject areas than students who did not stay with either parent in their hometown. In addition, no school characteristics were found to be significant factors of impact on students' academic performance in each of the four science subject areas.

Moreover, the results indicated that both schools and students with high academic achievement in one subject area also showed high academic achievement in other subject areas; and that the stability of science performance over the four subject areas did not depend on the inclusion of those student characteristics and school characteristics.

Contributions to the Literature

As mentioned earlier, unlike previous studies that examined the stability or consistency of academic performance across school subjects (e.g., mathematics, science,

reading, and writing), this study attempted to examine the stability or consistency of academic performance within one of the core content areas (i.e., school science). This type of research is not common in existing research literature. The current study found that if schools did well in one science subject area, then they did well in other science subject areas as well. Correlations ranging from 0.60 to 0.70 among schools are considered to be differentially effective (Sammons, West, & Hind, 1997). All of the correlations among schools in the present study are above this range, indicating that schools were equally successful in different science subject areas. Moreover, this study found that performance consistency of schools in different science subject areas is largely independent of student and school characteristics. Specifically, correlations of academic performance among schools responded little to the adjustment for both student and school characteristics. Therefore, the consistency or stability of school academic performance depended little on school differences.

In addition, gender, parental SES, time spent in learning, and the existence, or lack there-of, of family separation were found to be significant predictors of academic performance in the four science subject areas. Specifically, on average, male students' scores in the four subject areas were higher than those of female students; students from higher SES families had better achievement in the four science subject areas; and students who spent more time in learning had better achievement in the four science subject areas. These findings are consistent with previous studies on the factors impacting science achievement (e.g., Campbell et al., 2001; Mau, 1997; Kenny, 2000).

However, results indicating children who stayed with both parents in their hometown had lower scores in the four science subject areas than children who did not

stay with either parent in their hometown are, to some extent, inconsistent with studies on

the academic performance of left-behind children in China. Previous studies failed to

find any significant differences in the academic achievement between left-behind

children and their peers (e.g., Chen et al., 2009). Moreover, as no school characteristic in

this study is related to high academic achievement in each of four science subject areas,

effective schools in China might be different than those described in the school

effectiveness literature in western countries (e.g., Reynolds & Teddlie, 2000).

Overall, this study is one of the few studies on Chinese school effectiveness

research, and this study has revealed interesting findings on both school effectiveness and

stability or consistency of academic achievement in science subject areas. This study is

part of a continuing effort to produce more sophisticated and comprehensive school

effectiveness studies, and can also be used for reference in similar studies in China.

Policy Implications

This study would help science educators, administrators, and policymakers to

understand what predictors have a positive impact on science achievement of Chinese

middle school students. Gender and socioeconomic differences in academic achievement

in science subject areas were found in this study. Therefore, it is recommended that

Chinese policymakers pay more attention to programs that aim to narrow the gender gap.

Schools should make more effort in informing female students' parents about the

significance of scientific studies, and encourage them to influence their children's

preferences and academic choices. Meanwhile, the Chinese government needs to

increase its investment in education to narrow the socioeconomic gaps in academic

achievement created through differences in family background.

In this study, school size, school mean father SES, and school mean mother SES represented school context, while teacher education, teacher experience, classroom practice, principal leadership, and professional leadership represented school climate. It appears that the achievement of students in the four science subject areas is largely independent of school context and school climate, which is different from what has been mentioned in the school effectiveness literature in western countries. This difference might be due to the different schooling processes between China and western countries. Therefore, when Chinese policymakers plan to adopt another country's educational model, it should consider whether there is a good model with demonstrated results across countries. They should also ensure that the model takes into account different schooling processes, educational systems, and cultures.

Limitations and Further Research

The sample of this study was derived from provinces in southeastern China, which are the wealthiest and most developed regions in China. These findings may not be generalizable to other regions with different student demographics. The future studies on school effectiveness in China should sample both developed provinces, as well as, underdeveloped provinces to see which effectiveness factors are common across various areas and which are not. Further studies may look for opportunities to examine education in underdeveloped provinces in China.

Future studies on Chinese school effectiveness may seek more comprehensive information about demographics of students and, particularly, schools. They may also consider adding new variables which are different from those described in the school effectiveness literature in western countries. Variables such as: the role of Banzhuren (Class Advisor), the relationship between students and teachers, the importance of

students' test scores in teacher evaluation, and parents' concern about the clarity and fairness of the school's payment policy. These variables depict the unique schooling processes in China and can therefore be added to future school effectiveness research about Chinese education.

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Appendices

Table 1

Numbers of Students Enrolled in Each Level of Educational Institutions in 2010

Level of Education	Graduates	Entrants	Total Enrollments
Higher Education	6,137,845	7,155,728	33,518,142
Doctorate	48,987	63,762	258,950
Masters	334,613	474,415	1,279,466
Undergraduate	2,590,535	3,512,563	22,317,929
Professional (2 and 3 years)	3,163,710	3,104,988	9,661,797
Secondary Education	30,378,512	31,470,355	93,072,951
Senior High School	7,944,335	8,362,359	24,273,351
Vocational School	2,302,029	2,786,747	7,263,332
Professional School	2,646,434	3,166,319	8,777,141
Junior High School	17,485,714	17,154,930	52,759,127
Primary Education	17,396,364	16,917,007	99,407,043
Preschool Education	10,575,502	17,003,851	29,766,695

Note. Students in adult educational institutions are not included.

Source: Ministry of Education of the People's Republic of China (2012)

Table 2

Student-Teacher Ratio in China from 2001 to 2010

Year	Primary School	Junior High School	Senior High School	Higher Education
2010	17.70	14.98	15.99	17.33
2009	17.88	15.47	16.30	17.27
2008	18.38	16.06	16.78	17.23
2007	18.82	16.52	17.48	17.28
2006	19.17	17.15	18.13	17.93
2005	19.43	17.80	18.54	16.85
2004	19.98	18.65	18.65	16.22
2003	20.50	19.13	18.35	17.00
2002	21.04	19.25	17.80	19.00
2001	21.64	19.24	16.73	18.22

Source: Ministry of Education of the People's Republic of China (2012)

Table 3

Chinese Students' Academic Performance in International Mathematics Olympiads

(2003-2012)

Year	Number of Countries (Regions)	Number of Gold Medals	Ranking of China (Mainland)
2012	100	5	2
2011	101	6	1
2010	97	6	1
2009	104	6	1
2008	97	5	1
2007	93	4	2
2006	90	6	1
2005	91	5	1
2004	85	6	1
2003	82	5	2

Note. Each country (region) sends a team of six members.

Source: International Mathematical Olympiad (2013)

Table 4

Ranks and Mean Scores in Mathematics and Science in PISA 2009

Mathematics				Science			
	Rank	Mean	SE		Rank	Mean	SE
1.	China	600.1	2.82	1.	China	574.6	2.30
2.	Singapore	562.0	1.44	2.	Finland	554.1	2.34
3.	Hong Kong	554.5	2.73	3.	Hong Kong	549.0	2.75
4.	Korea	546.2	4.02	4.	Singapore	541.7	1.36
5.	Chinese Taipei	543.2	3.40	5.	Japan	539.4	3.41
6.	Finland	540.5	2.17	6.	Korea	538.0	3.44
7.	Liechtenstein	536.0	4.06	7.	New Zealand	532.0	2.58
8.	Switzerland	534.0	3.30	8.	Canada	528.7	1.62
9.	Japan	529.0	3.33	9.	Estonia	527.8	2.67
10.	Canada	526.8	1.61	10.	Australia	527.3	2.53

Source: Organization for Economic Cooperation and Development (2010)

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Table 5

Net Enrolment Ratio of School-Aged Children in Various Regions

Year	School-Aged Students	Students Enrolled	Net Enrollment Ratio (%)
2010	9,501.5	9,473.3	99.7
2009	9,606.6	9,548.6	99.4
2008	9,772.0	9,297.1	99.5
2007	9,947.9	9,896.8	99.5
2006	10,075.5	10,001.5	99.3
2005	10,207.0	10,120.3	99.2
2004	10,548.1	10,437.1	98.9
2003	10,909.3	10,761.6	98.7
2002	11,310.4	11,150.0	98.6
2001	11,766.4	11,561.2	99.1
2000	12,445.3	12,333.9	99.1
1999	12,991.4	12,872.8	99.1
1990	9,740.7	9,529.7	97.8

Note: Numbers are units with one unit = 10 thousand.

Source: Ministry of Education of the People's Republic of China (2012a)

Table 6

Descriptive Statistics of Outcome, Student-Level, and School-Level Variables

Variables	M	SD
Outcome variables		
Scientific inquiry skills (IRT score)	1.492	.914
Biology achievement (IRT score)	1.110	.781
Earth science achievement (IRT score)	1.559	1.117
Physics achievement (IRT score)	1.694	.857
Student-level variables		
Gender (male = 1, female = 0)	.519	.500
Father socioeconomic status (SES) (standardized index)	-.053	1.750
Mother SES (standardized index)	-.071	1.729
Time spent in learning (see Note)	2.062	.979
Family separation (see Note)	.175	.380
School-level variables		
School (enrollment) size (see Note)	12.007	8.732
School mean father SES (aggregated within school)	.011	.827
School mean mother SES (aggregated within school)	.090	.695
Teacher education (see Note)	.919	.127
Teacher experience (see Note)	.674	.162
Classroom practice (composite score)	4.112	.182
Principal leadership (composite score)	3.592	.413
Professional development (composite score)	3.700	.263

Note. Time spent in learning measures the total hours of practice in school, practice out of school, and extra class in school, in terms of the number of units with one unit as 10 hours. Family separation is a dichotomous variable with children who stay with both parents in hometown as the reference against which children who do not stay either with both parents or in hometown are compared. School (enrollment) size is measured in terms of the number of units with one unit as 100 students. Teacher education is the sum of percentages of teachers who have bachelor, masters, or doctoral degrees. Teacher experience is the sum of percentages of teachers with A Level or Advanced Level titles.

Table 7

Correlates of Science Achievement Scores among Students and Schools

	Unadjusted				Adjusted for Student Characteristics				Adjusted for Student and School Characteristics			
	I	B	E	P	I	B	E	P	I	B	E	P
Among students												
Inquiry skills (I)	1.000	.906	.908	.887	1.000	.907	.908	.886	1.000	.907	.908	.886
Biology (B)		1.000	.967	.945		1.000	.966	.943		1.000	.966	.943
Earth science (E)			1.000	.966			1.000	.965			1.000	.965
Physics (P)				1.000				1.000				1.000
Among schools												
Inquiry skills (I)	1.000	.984	.986	.985	1.000	.982	.984	.982	1.000	.975	.979	.976
Biology (B)		1.000	.997	.989		1.000	.997	.987		1.000	.996	.985
Earth science (E)			1.000	.994			1.000	.993			1.000	.992
Physics (P)				1.000				1.000				1.000

Table 8

Results of Multivariate HLM Model Estimating Effects of Student and School Characteristics on Science Achievement

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	Inquiry Skills		Biology		Earth Science		Physics	
	Effect	SE	Effect	SE	Effect	SE	Effect	SE
Student characteristics								
Gender	.070*	.011	.161*	.010	.225*	.014	.158*	.011
Father socioeconomic status (SES)	.022*	.002	.019*	.002	.025*	.003	.019*	.002
Mother SES	.011*	.002	.008*	.002	.012*	.003	.010*	.005
Time spend in learning	.132*	.016	.100*	.014	.140*	.020	.110*	.015
Family separation	.080*	.026	.057*	.023	.090*	.033	.063*	.025
School characteristics								
School (enrollment) size	.001	.029	-.001	.026	-.008	1.271	-.005	.955
School mean father SES	-.062	6.116	-.017	5.581	-.002	7.787	-.019	5.849
School mean mother SES	.398	10.116	.315	9.482	.433	12.906	.365	9.695
Teacher education	.396	13.973	.340	12.794	.473	17.879	.383	13.450
Teacher experience	-.043	17.606	.027	16.152	.002	22.566	-.027	16.961
Classroom practice	-.027	17.154	-.065	15.721	-.081	21.966	-.047	16.510
Principal leadership	.181	5.787	.165	5.291	.228	7.388	.173	5.552
Professional development	-.446	10.960	-.425	10.022	-.578	14.000	-.400	10.519

* $p < .05$.

Table 9

Proportion of Variance in Science Achievement Explained by Multivariate HLM Model

	Inquiry Skills	Biology	Earth Science	Physics
Among students	.026	.030	.027	.029
Among schools	.430	.422	.450	.433
Overall	.096	.106	.106	.105

Figure 1: Current Organizational Structure of Chinese Education System

Year			
21	Doctoral Program		
20	Doctoral Program		
19	Doctoral Program		
18	Master's Program		
17	Master's Program		
16	Undergraduate (4 years)		
15	Undergraduate (4 years)	Professional Higher Education (3 years)	
14	Undergraduate (4 years)	Professional Higher Education (3 years)	Professional Higher Education (2 years)
13	Undergraduate (4 years)	Professional Higher Education (3 years)	Professional Higher Education (2 years)
12	Professional School	Vocational School	Senior High School
11	Professional School	Vocational School	Senior High School
10	Professional School	Vocational School	Senior High School
9	Junior High School (compulsory)		
8	Junior High School (compulsory)		
7	Junior High School (compulsory)		
6	Primary School (compulsory)		
5	Primary School (compulsory)		
4	Primary School (compulsory)		
3	Primary School (compulsory)		
2	Primary School (compulsory)		
1	Primary School (compulsory)		

Note. Numbers represent years of education (grade levels prior to postsecondary education).

Figure 2: Description of Items Used to Create Student-Level and School-Level Variables

Student-Level Variables	Description
Gender	Your gender. (Male, Female)
Father (mother) SES	What is the highest level of schooling that your father (mother) has completed? (No schooling, Primary school, Middle school, Senior (vocational) high school, Professional college (2 or 3 years), Undergraduate, Graduate)
	What is your father's (mother's) job? (Worker, Farmer, Self-employed, Service, Government employee, Military personnel, Education personnel, Medical personnel, Researcher, Management personnel, Migrant workers, Unemployed)
Ethnicity	Your ethnicity. (Han, Others)
Caregiver	Your current situation. (Father is working outside my hometown, and I am living with my mother; Mother is working outside my hometown, and I am living with my father; Parents are working outside my hometown, and I am living on my own (with relatives); Living with parents who are working outside my hometown; Parents are working in my hometown, and I am living with them.
Time spent in learning	Homework assigned by teachers at school. (None, Less than 1 hour, 1-2 hours, 2-3 hours, 3-5 hours)
	Homework assigned by teachers at cram school. (None, Less than 1 hour, 1-2 hours, 2-3 hours, 3-5 hours)
	How much time do you typically spend per week learning with a tutor? (None, Less than 3 hours, 3-6 hours, 6-8 hours, More than 8 hours)

School-Level Variables	Description
School (enrollment) size	The total number of students in your school.
Teacher (workforce) size	The total number of teachers in your school.
Teacher Education	The percentage of teachers at each education level. (Senior high school, Vocational high school, Professional college (2 or 3 years), Undergraduate, Graduate)
Teacher experience	The percentage of teachers in each title. (Level 1, Level 2, Level 3, Advanced Level)
Classroom practice	How often do you carry out the following teaching activities? Adjust teaching method based on students' tests and assignments, Compile exercises based on teaching goals and students' learning problems,

	Discover students' learning problems and offer guidance to resolve them, Handle disciplinary incidents properly during teaching process, Motivate students to use various learning methods, Discover students' academic strengths and weaknesses, Offer different advices on learning to students, Assign different learning tasks for students of different abilities, Monitor students' progress in learning, Guide students to discuss a particular question, Motivate students to think independently and ask questions in or after class, Organize students for group activities, Make class instruction vivid and interesting, Communicate with students on classnotes, Connect class instruction with real life, Motivate students to conject and prove questions, Use examples to help students better understand content, Motivate students to draw inferences about other cases from one instance, Guide students to propose their own ideas, Motivate students to solve problems with various approaches, Propose a question that makes student think independently. (Never, Seldom, Sometimes, Often, Usually)
Principal leadership	How often does your principal work on the following tasks? Offer opportunities for teachers to express their opinions and suggessions, Treat each teacher fairly, Offer teachers many opportunities on decision making, Ask for advices from teachers on problems in school management, Advocate democratic management, Make school affairs transparent, Reward teachers based on students' performance, Motivate teachers to apply new teaching methods and accept new teaching ideas, Promote teachers' sense of responsibility and lead teachers to appreciate common goals, Respect and support teachers' innovation on teaching, Encourage teachers to obtain and communicate new knowledge, Create spaces for teachers to organize research group in different subjects, Offer many opportunities for professional development, Provide sufficient teaching materials for teachers, Provide sufficient information on professional development, Deliver different incentives based on the needs of teachers, Help teachers with their professional development based on their career plans, Provide teachers with professional guidance and assistance. (Never, Seldom, Sometimes, Often, Usually)
Professional development	How often do you participate in the following activities? Degree-seeking or non-degree-seeking programs, Lectures by experts, Subject-related studyies, Research activities, Audit other teachers' classes and discuss with them after class, Share experiences and discuss problems with colleagues, Self-evaluation of my teaching. (Never, Seldom, Sometimes, Often, Usually)

Note. School mean father (mother) SES (not listed) comes from aggregation of father (mother) SES at the student level.

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