Fachbereich Erziehungswissenschaft und Psychologie der Freien Universität Berlin

Pre-Service Science Teacher Education in China:

The Views of Students and the Views of Their Teachers

A Study of the Conditions and Effects of Science Teacher Training at Six Chinese Universities

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Erklärung

Hiermit erkläre ich, dass ich die vorliegende Arbeit selbständig verfasst und keine anderen als die angegebenen Quellen und Hilfsmittel benutzt habe.

Datum und Unterschrift

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Zusammenfassung

Diese Studie will anhand von quantitativen und qualitativen Ansätzen die Strukturen und die Qualität der universitären Lehrerbildung für den naturwissenschaftlichen Unterricht an sechs chinesischen Universitäten darstellen und untersuchen. *Fachwissen* (englisch: Content Knowledge), *Pädagogische Praktiken* (Pedagogical Practices), *Fachdidaktisches Wissen* (Pedagogical Content Knowledge), *Überzeugungen von Lehrkräften* (Teachers' Beliefs) und *Entdeckendes Lernen* (Inquiry-Based Learning), welche mit der Ausbildung von Lehrkräften für den naturwissenschaftlichen Unterricht eng verbunden sind, werden analysiert und als theoretischer Rahmen für diese Studie herangezogen. Die universitäre Lehrerbildung wird in China heutzutage durch Politik, Wirtschaft, Gesellschaft und Kultur stark beeinflusst. Daher werden einige wichtige Reformen und Dokumente zur Lehrerbildung für den naturwissenschaftlichen Unterricht in dieser Studie überprüft. Abschließend erfolgt eine Untersuchung des Curriculums und der Programmtypen für die universitäre Lehrerbildung in China.

Das chinesische Bildungsministerium hat 2001 eine achte Curriculumreform durchgeführt und das folgende Dokument *The Outlines for Curriculum Reform in Elementary and Secondary Education*, (Trial Version) veröffentlicht. Die Hochschulbildung wurde ebenfalls nach der Implementierung dieser Reform verändert: Als Folge dieser neuen Reform wurde das Fach *Naturwissenschaften*, welches zuvor als *Natur* bezeichnet worden ist, als förmliches Studienfach in die Lehrerbildung für die Lehrämter an Grund- und Sekundarschulen in China eingeführt. Seit 2001 haben schätzungsweise 66 Universitäten Naturwissenschaften als Hauptfach in China eingeführt, um mehr professionelle NaWi-Lehrkräfte ausbilden zu können.

Diese Studie basiert auf Daten aus sechs chinesischen Universitäten: Chongqing Normal University, Sichuan Normal University, Taiyuan Normal University, Changchun Normal University, Shanghai Normal University und Zhejiang Normal University. Diese befinden sich in vier Regionen: im Südosten, Nordosten, Nordchina und Ostchina. Mit dieser Studie soll eine breite Perspektive über die Organisation der universitären Lehrerbildung in China und deren Ausbildungsprogramme erschlossen werden. Diese Studie wird auch die Korrelationen und Interaktionen zwischen den fünf Elementen *Fachwissen* (englisch CK), *Pädagogische Praktiken* (PP), *Fachdidaktisches Wissen* (PCK), *Lehrerüberzeugungen* (TB) und *Entdeckendes Lernen* (IBL) analysieren. Zum Schluss werden Vorschläge für eine Verbesserung der Qualität und der Weiterentwicklung der universitären Lehrerbildung geäußert.

Schlüsselwörter: Lehrerbildung; Naturwissenschaften; NaWi; China

Abstract

This study illustrates the status and the quality of education for science teachers at six Chinese universities by using qualitative and quantitative approaches. Aspects of Content Knowledge (CK), Pedagogical Practices (PP), Pedagogical Content Knowledge (PCK), Teachers' Beliefs (TB) and Inquiry-Based Learning (IBL), all of which are closely linked to the education of science teachers, will be examined as the five elementary applications that make up the theoretical framework of this study. Education for pre-service science teachers in China is deeply influenced by Chinese politics, economy, society and culture. Some important reforms and documents related to such education will therefore be reviewed in this study. Finally, the curriculum and types of educational programs for pre-service science teachers in China will be examined.

In 2001, the Ministry of Education (MOE) carried out its eighth curriculum reformation and issued the document: *The Outlines for Curriculum Reform in Elementary and Secondary Education (Trial Version)*. Due to this new reform, *Science Education*, which until then used to be named *Nature*, was set up as an official course in Primary and Secondary Schools in China. Higher education also underwent rapid changes following the implementation of this reform. Since 2001, around 66 universities offered *Science Education* as an undergraduate major in China, aiming at preparing more professional science teachers.

This study is based on data collected from six Chinese universities: Chongqing Normal University, Sichuan Normal University, Taiyuan Normal University, Changchun Normal University, Shanghai Normal University and Zhejiang Normal University. They are located in four regions: "The Southwest", "The Northeast", "Northern China" and "Eastern China". The output of this study will provide a broad picture of how education for pre-service science teacher is organized in China, and elucidate the ways in which CK, PP, PCK, TB and IBL are reflected in training programs for pre-service science teacher. This study will also examine the correlations and interactions between these five domains. Lastly, some recommendations for the improvement of the quality of education for pre-service science teacher and the promotion of the development of such educational programs will be provided.

Key words: pre-service education; science teacher education; China

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Abbreviations

The following abbreviations are used in this study:

CCCPC	Central Committee of the Communist Party of China
CK	Content Knowledge
DEEWR	Department of Education, Employment and Workplace Relations
HDI	Human Development Index
IBL	Inquiry-Based Learning
MOE	Ministry of Education
NRC	National Research Council
NPC	National' s People Congress
OECD	Organization for Economic Co-operation and Development
PCK	Pedagogical Content Knowledge
PISA	Programme for International Student Assessment
PP	Pedagogical Practices
SCSJSE	Science Curriculum Standards for Junior Secondary Education
SCSPE	Science Curriculum Standards for Primary Education
TB	Teachers' Beliefs
UNDP	United Nations Development Programme

Chapter 1 Introduction

1.1 Study Background

The People's Republic of China (PRC) was established in 1949. While initially founded as a socialist state with a centrally-planned economy, it now has a mixed economy that is described by its government as "Socialism with Chinese characteristics". With a population of 1.39 billion, PRC is the world's most populous country and it is still expanding currently. In fact, the rate of the Chinese annual population growth was 0.6% in 2014 and 0.59% in 2016. In comparison with the Human Development Index (HDI) of 0.501 in 1990, China has made great progress over the past few decades. The HDI of China was 0.727 in 2014, which is within the range of high human development now (Human Development Report, 2015).

In 1978, China carried out a great national reform and issued *The Reform and Opening up* policy, which was implemented as the basic state policy in China. Since then, China has opened its gate to the world and communicated more openly with the rest of the world on all levels. Since the 1980s, drastic changes have occurred in both the Chinese economy and society. Among these changes, the progress in education is one of the fastest and most obvious. The Chinese government has taken numerous measures to promote the development of education. A well-known example for this progress was the implementation of the *Illiteracy Elimination Movement*, which was put in place to lower the illiteracy rate. Additionally, the Chinese government enacted the *Law on Compulsory Education* in 1986 to protect the educational rights of every child, especially for girls and children in rural regions who were, prior to enforcement of this act, offered little to no education at all. Together with this law, nine-years of compulsory education was implemented on a nationwide level. Consequently, the rate of adult literacy increased from 77.8% in 1990 to 95.1% in 2010 and is still on the rise (Human Development Report, 2015).

Now that an increasing number of people have access to education, more and more citizens have come to expect not just education but *good* quality education. Many Chinese, therefore, begin to pay more attention to the quality of education. The teacher, as the person educating the student, is key to the deliverance of good quality education. As such, teachers should be carefully and properly trained to ensure the quality of their teaching skills. The ratio of teachers to students is also imperative in ensuring maximum absorption of the knowledge that is imparted. Problems such as classroom discipline could arise if the number of teachers managing the class is not reasonable, i.e. one teacher in charge of ninety students. In other words, the quantity of teachers and the quality of their teaching exert a direct influence on the quality of education.

China has the biggest population in the world. In 2015, there were about 140 million students and 9.16 million full-time teachers in a total of 242.900 schools, who were involved in the scheme for compulsory education (grades 1-9) (Ministry of Education, 2015). There was an imbalance in the number of students and teachers involved in senior secondary education (grade 10-12) and higher education. In fact, there were approximately 2.54 million full-time teachers teaching 40 million students between grades 10-12 in 24.900 schools, and more or less 2.37 million full-time teachers who were teaching 36 million higher education students in 2852 colleges and universities. This meant that the ratio of teachers to students was grossly out of proportion.

According to this data, it appears that the Chinese education system has been suffering from a serious shortage of teachers for quite some time. Thus, training more teachers who are qualified to teach has become a pressing issue for the nation. The Chinese language and mathematics are traditionally considered as two of the most important subjects in Chinese education. However, with China's new reform and openness policies, English has gradually gained more attention. This creates a new problem for the education sector as there is now a demand for English teachers that is unfulfilled due to the lack of qualified English teachers. However, this is not the most urgent issue yet as this lack can be temporarily filled by introducing foreign English teachers into the system.

On the other hand, education in natural sciences, which is still developing slowly in China, is now the biggest problem. Despite the obvious fact that technology and sciences play very important roles in our daily economic and social lives, China has not placed sufficient emphasis on science education until recent years. As such, there is a void in the education system that is unfilled and unable to be filled due to the lack of quality professional training for science teachers. In order to meet the needs of societal and economic development in China, training more qualified teachers in the area of natural sciences has become one of the most urgent current matter. This is why the government stepped in and began to promote the value in science education.

The development of science education has so far experienced three different periods (Liang, Liu & Fulmer, p.7, 2017). Since the end of the *Cultural Revolution* in 1976, the fields of politics, economy and culture have changed in every aspect in China. The "recovery period" in science education extended from 1977 until 1985. The Central Committee of the Communist Party of China (CCCPC) issued an important document in 1985: *The Decision for Educational Infrastructure Reform* (CCCPC, 1985). This document initiated the reformation of the Chinese educational infrastructure, thus pushing education in China into a new era. The "transformation period" in Chinese education began in 1985 and lasted until 2001. In 2001, the Ministry of Education (MOE) carried out its eighth curriculum reformation and issued the document: *The Outlines for Curriculum Reform in Elementary and Secondary Education (Trial Version)* (MOE, 2001a). Since this reformation, *Science*, which used to be called *Nature*, was set up as a subject in grades 3-6 of the primary education, as well as in grades 7-9 in the secondary education. Since 2001, science education has rapidly developed and improved itself. The latest standard of science curriculum, which was issued in 2016, introduced science into the syllabus of the grade 1 students instead of the grade 3. This means that primary students who started their education post-2016 begin to study sciences three years before their pre-2016 counterparts. This is a clear sign that science has become more valued as a subject than before.

In comparison to other countries, especially the Western countries, science education was introduced quite late in China. Many measures have been undertaken since 1977 to promote the development of science education. Science is a comprehensive and integrated subject which not only encompasses natural sciences, but also social sciences, history and technology. According to the report published by PISA in 2015, science literacy was defined as "the ability to engage with science-related issues, and with the ideas of science, as a relative citizen" (PISA 2015 Results Volume I, p.50, 2016). This definition emphasizes on the fact that students should not only be equipped with the knowledge of science, but also have the ability to apply such scientific knowledge in their daily lives, in order to be considered literate in science.

The curricular reformation in 2001 saw a remarkable improvement in science education, not only in aspects of quality, teaching and learning, but also in the demand for better qualified science teachers. In order to prepare more professional and qualified science teachers to take up teaching posts in schools, many higher education institutions began to take serious measures in the development of education for science teachers. Chongqing Normal University was the first university in China to introduce Science Education as a new undergraduate degree in 2001, with the aim of nurturing professional science teachers. Since then, there have been around 66 universities that offer Science Education as one of their majors (see details from Figure 1.1). From 2001 until now, a large number of professional science teachers have graduated. The education programs for science teachers are designed to fulfil the requirements of the curriculum reformation and to facilitate the development of scientific education, as well as to meet the demands for more qualified science teachers as the Chinese society develops.

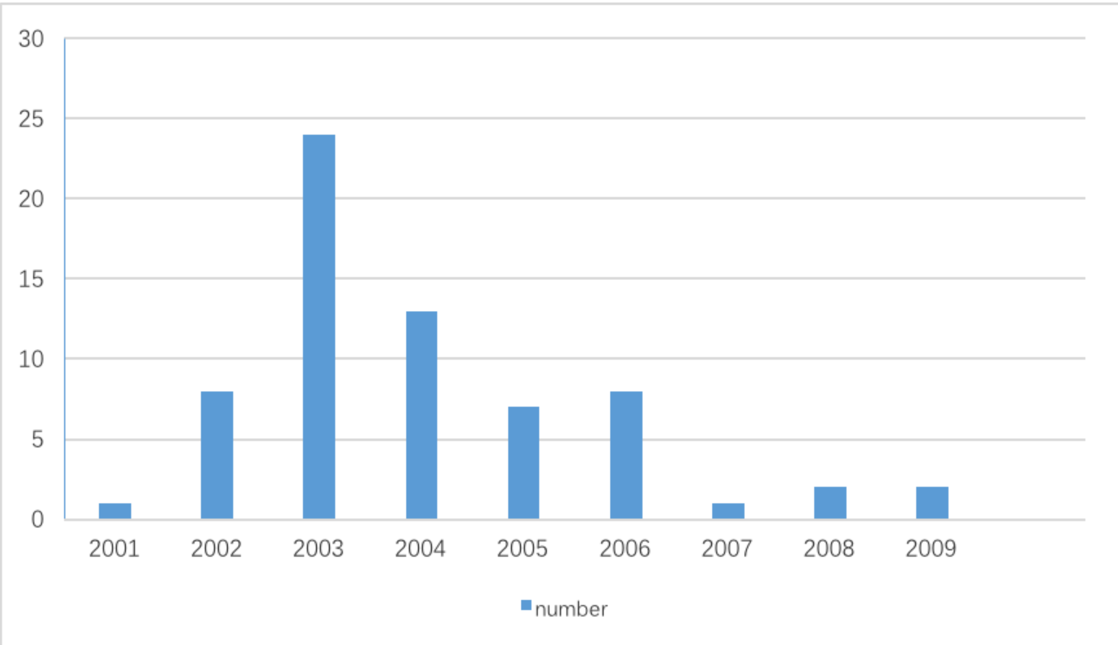

Figure 1.1: Number of Universities Introducing Science Education Since 2001

Data source: Liao, Boqin (2013). *Science Education*. Beijing: Science Press.

Figure 1.1 shows that the popularity of Science Education has experienced an obvious fluctuation from 2001 until now, going from a rapid rise to a dramatic declination. In 2001, there was only one university that introduced Science Education as a new undergraduate major. From 2002 to 2003, the number of universities offering Science

Education increased dramatically from just 8 to 24. However, this number dropped gradually from 13 in 2004 to only 2 in 2009. There was only one new university offering Science Education as an undergraduate major in 2007. What appears to be even worse is the fact that no other university introduced Science Education as a subject major from 2010 onwards. Looking at Liao's study of Science Education (2013), it appears that several universities even stopped matriculating undergraduates in Science Education. These figures indicate that education for pre-service science teachers is met with huge challenges.

1.2 Objectives of the Study

The main objective of this study is to explore education for pre-service science teachers in China and its educational organization. Further related questions will be answered in this study:

(a) Do education programs for pre-service science teacher in China reflect the importance of Content Knowledge (CK), Pedagogical Practices (PP) and Pedagogical Content Knowledge (PCK)? If so, in which ways?
(b) Does education for pre-service science teachers in China illustrate the Teachers' Beliefs? If so, in which aspects?
(c) Do science students experience Inquiry-Based Learning during their pre-service science teacher training? How?
(d) How do CK, PP, and PCK interact with Teachers' Beliefs, in conjunction with education for Chinese pre-service science teachers?
(e) What are the correlations between CK, PP, PCK and Inquiry-Based Learning?

(f) How do Teachers' Beliefs correlate and collaborate with Inquiry-Based Learning?

Based on the objectives listed above, the hypotheses for this study are:

H1: Education programs for pre-service science teachers in China reflect CK, PP and PCK.

H2: Education for pre-service science teachers in China reflects the Teachers' Beliefs.

H3: Science students experience Inquiry-Based Learning in the education programs for pre-service teachers.

H4: Teachers' Beliefs correlate in varying degrees with CK, PP and PCK, in accordance with education for pre-service science teachers in China.

H5: Inquiry-Based Learning correlates in certain aspects to CK, PP and PCK.

H6: Teachers' Beliefs correlate to some extent with Inquiry-Based Learning.

1.3 The Significance of the Study

As mentioned above, science literacy not only insists of acquiring the scientific knowledge in explaining some scientific phenomena, but also emphasizes on how to incorporate what students have learnt into their daily life and how to apply these scientific concepts to resolve problems. According to PISA in 2015, there are three forms of knowledge present in science: "Content Knowledge, Knowledge of the standard methodological procedures used in science, and knowledge of the reasons and ideas used by scientists to justify their claims" (PISA 2015 Results Volume I, 2016, p. 50). "Content Knowledge" refers to theories and facts of the subject matter while "knowledge of the standard methodological procedures used in science" refers to the scientific techniques commonly used in science experiments. On the other hand, "knowledge of the reasons and ideas used by scientists to justify their claims" refers to conceptual and theoretical knowledge that is derived out of the work of other scientists to prove or evidenced scientific laws and regulations.

A large number of studies have demonstrated that the quality of teachers plays an essential role in students' scientific achievements. Ware (1992) pointed out that these factors are necessary and important in igniting students' interests in science and nurturing their scientific abilities: "the appropriateness and currency of the curriculum; the availability and quality of textbooks; the appropriateness of the assessment system; the availability of laboratories and scientific equipment; the school environment in which learning takes place; and the quality of the science teacher" (p. 1). In other words, an unreasonably planned curriculum, a lack in literary resources, an inappropriateness in the assessment system, a lack in scientific facilities, a poor or non-conducive environment for learning, or an unqualified teacher, could either or all be obstacles in the path of learning science.

As the direct providers of scientific knowledge that is prerequisite in the students' learning syllabus, the teachers play crucial roles in education. The teachers' pedagogy strategies for teaching science, as well as their attitudes toward science, will exert a huge influence on the students' achievements. Studying the education for pre-service science teachers is therefore extremely necessary and meaningful, because the findings from such research can offer valuable suggestions on how these educational programs can be customized in ways that serve to better-prepare professional science teachers, who can eventually add value to the students' scientific achievements. In other words, conducting proper education for pre-service science teachers can ensure the quality of science teachers to a rather large extent.

Although Science Education was introduced in China only recently, the last couple of years have seen more and more Chinese scholars beginning to pay close attention to the value that this major inevitably yields (when structured with quality content that produces better teachers and students) and the ways in which this field can be better developed so as to better educate potential science teachers. However, the studies of these scholars were far less accomplished than similar studies carried out by their Western counterparts. The main reason for this is that science is still not considered as a main subject in China. In comparison to Chinese, Mathematics and English, which are seen as the most important subjects in primary and secondary education, science education receives little to negligible attention. As such, educating future science teachers is not seen as a priority in China. In fact, there is to-date only a small number of studies on education for pre-service science teachers in China, out of which many focused more on the theoretical, rather than empirical, studies. Thus, this study approaches and analyses the education system of pre-service science teachers in an empirical and conceptual manner, paying close attention to the aspects of Content Knowledge, Pedagogical Practices, Pedagogical Content Knowledge, Teachers' Beliefs and Inquiry-Based Learning.

1.4 Structure of the Study

The study consists of seven chapters arranged as follows:

Chapter 1 provides an introduction to the study. It first provides the background for the study, and then outlines the objectives, significance, organization and limitations of this thesis.

Chapter 2 discusses the theoretical frameworks of this study.

Chapter 3 presents an overview of Science Education and education for pre-service science teachers in China.

Chapter 4 describes and explains the methodology of the study, including the collection of samples, designs, and data, followed by an analysis of the information.

Chapter 5 presents the overall analysis and findings of the questionnaires.

Chapter 6 displays the overall analysis and findings of the interviews.

Chapter 7 provides the conclusions and implications of this study.

1.5 Delimitations

The present study has been carefully delimited in its approaches, areas of investigation, samples and models of analysis. For instance, the data for this study had been collected from six universities located over four regions in China: (a) The Southwest, (b) The Northeast, (c) Northern China, (d) Eastern China. Although these universities are regionally spread across China, they are not indicative of the education for pre-service science teachers in China as a whole. In fact, they cannot even represent the education for pre-service science teachers in their respective region. As such, the data collected must be assumed to be random and individualistic.

Besides, since the data for this study was collected between the months of October and November in 2014, some figures referred to in this study may not reflect the latest updates on the subject.

Also, the participants of questionnaire were only science student-teachers, without science teacher educators. This was due to the number of collected questionnaires from science teacher educators was so small that it made no sense to analyse the data of them. Thus, their data were missing in the study.

Furthermore, this study was designed to collect data from undergraduate student-teachers who were in their second, third, and fourth year of study at the time of the data collection. This is due to an assumption that higher grades students are more experienced in terms of scientific education (because they have completed a certain amount of training in a given duration) than students who are in their first year. This assumption is logically premised on the notion that the more advanced a student is in his educational training, the more knowledge he would have accumulated. It follows, then, that data for the study would be more accurate when obtained from such a sample space. However, due to the different curriculums and study arrangements of the six universities, not all the students in year four could take part in the study. In China, students in their fourth year normally do internships outside of the universities. As such, many of the final year students were absent and unable to take part in the study. The total number of participants is thus limited.

As a result, there were only four universities that satisfied the criteria for students between second to fourth year. In order to have enough participants, this study had to collect data from students between first and third year of their studies, in two other universities. In this case, a comparison of the results across all levels in these six universities might not be very accurate. There is, therefore, an error tolerance that may influence the results of this comparative study. However, the researcher tried to negotiate this error by extracting data from a common sample (students in their second and third year) for the analysis. Additionally, the data analysis was performed using information extracted from participating universities which had the same sample groups. It was discovered that all the results were substantially the same, which further confirmed that the results across all grades are stable and reliable enough to be used in the study.

Finally, there might be a translation problem in this study: doing a research in another language. The author works in a German surrounding in English language on a Chinese reality, which brought some special problems.

Chapter 2 Theoretical Framework of the Study

A good theoretical framework can provide many illuminating ideas and different or alternate perspectives to the research topic. As with any other study, a theoretical framework plays a crucial role in assisting the generation of appropriate questions for formulating hypotheses and offering new dimensions to the new research. Thus, a systematic and critical theoretical framework is necessary and important. Previous work and findings of other scholars provide immensely useful information in the construction of my theoretical framework.

For the purpose of this study, I have reviewed numerous works before selecting five fields of literature on which I premise my own work. These five aspects are: Content Knowledge, Pedagogical Practices, Pedagogical Content Knowledge, Teachers' Beliefs and Inquiry-Based Learning. All of them are relevant to scientific education and are integral to the planning of education for science teachers. The following are the five components of my theoretical framework for this study:

2.1 Content Knowledge

Before the 1980s, less attention was given to content-based knowledge as compared to the actual teaching of subjects. This is especially true in the field of educating future science teachers for Chinese schools. This lack of attention is now recognized to be problematic in both aspects of teaching and learning science. In Shulman's (1986) words, there is a "missing paradigm" between content and pedagogy in which "the missing paradigm refers to a blind spot with respect to the content that now characterizes most research on teaching and, as a consequence, most of our state-level programs of teacher evaluation and teacher certification" (Shulman, 1986, pp. 7-8). The development of Content Knowledge is slow and ineffective and is very much a gaping hole in China's education for pre-service science teachers.

Schulman's words had an immediate effect on all those in the education sector, especially sparking the interest of educational researchers, educators and policy makers of Content Knowledge and Pedagogical Content Knowledge. He claims that "Content Knowledge refers to the amount and organization of knowledge per se in the mind of the teacher…the teacher need not only understand that something is so, the teacher must further understand why it is so" (Shulman, 1986, p. 9). In other words, Schulman recognizes that the pursuit of knowledge is equally important as the acquisition and possession of knowledge.

Being in command of the subject content is imperative to what makes a good teacher. This is found to exert a positive effect on the decision-making that is related to changing pedagogical strategies in the creation of better learning opportunities. In addition, sound content knowledge seems to have a positive effect on the planning, assessment, implementation, and development of the curriculum. According to the study of Harlen and James (1997), teachers cannot assist their students in understanding the subject content if they themselves are not familiar with, or do not understand, the given concepts. The studies of Corcoran and Goertz (1995) and Gess-Newsome (1999) also provide the amply illustrated evidences that the teachers with enough content knowledge related to the subjects they taught, could provide more appropriate and reasonable assistance to guide their students to learn, thus, exerting a positive impact on the performance and achievements of students.

In order to become a professional teacher, what kinds of knowledge should a teacher acquire? Schulman (1987) pointed out that the teacher should at least be well-versed in:

"- Content Knowledge;
- general pedagogical knowledge, with special reference to those broad principles and strategies of classroom management and organization that appear to transcend subject matter;
- curriculum knowledge, with particular grasp of the materials and programs that serve as "tools of the trade" for teachers;
- pedagogical Content Knowledge, that special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding;
- knowledge of learners and their characteristics;
- knowledge of educational contexts, ranging from workings of the group or classroom, the governance and financing of school districts, to the character of communities and cultures;

- knowledge of educational ends, purposes, and values, and their philosophical and historical grounds" (Shulman, 1987, p. 8).

This group of knowledge sets out a higher requirement for teachers and emphasizes on the important role of Content Knowledge in the area of professional teaching. Teachers should be well-trained in the subject that they are teaching, and ought to be well-equipped with content-specific teaching strategies. In addition, teachers should have a sufficiently deep and complex understanding of the science concepts that they are teaching, must be able to make connections among science concepts or topics, and should be able to apply scientific concepts in explaining natural phenomena or real-world situations (Lee et al., 2007).

According to the National Research Council (NRC) (2000), science teachers should also be able to engage in inquiries that are related to the practice of science. This is because in their daily job, they generate questions, design and carry out investigations, analyse and draw conclusions, as well as communicate findings through the use of multiple formats. Furthermore, science teachers should also be able to develop arguments that justify their hypotheses or derive solutions based on experiential evidence (Lemke, 1990). Only with sufficient scientific Content Knowledge can teachers employ appropriate Pedagogical Practices that can guide the students towards an understanding and an inquiry of the subject. What students learn is greatly influenced by the way the knowledge is imparted (NRC, 1996). In other words, teachers, as the providers of knowledge, exercise a large degree of control over their students' learning abilities and by extension, scientific achievements. Thus, the teachers' knowledge of scientific content is related to Pedagogical Practices, which, in turn, impact the students' learning abilities (NRC, 2000).

2.2 Pedagogical Practices

What is pedagogy? What do Pedagogical Practices indicate? There are numerous studies related to the definitions of pedagogy and how a teacher should engage in Pedagogical Practices.

According to the Oxford English Dictionary, pedagogy is "the method and practice of teaching, especially as an academic subject or theoretical concept." The Department of Education, Employment and Workplace Relations (DEEWR) (2009a) described pedagogy as "the function or work of teaching: the art or science of teaching, education instructional methods" (DEEWR, 2009a, p. 42). Alexander (2004) defined pedagogy as "the act of teaching and its attendant discourse and postulates three domains of ideas, values and evidence" (Alexander, 2004, p. 7). In the words of James and Pollard: "pedagogy expresses the contingent relationship between teaching and learning... and does not treat teaching as something that can be considered separately from an understanding of how learners learn" (James & Pollard, 2011, p. 280).

In other words, pedagogy is very much about the process of learning, as well as teaching. In fact, pedagogy attempts to reveal the complex and interdependent relationship between teaching and learning, implying that styles of teaching function as intermediaries between the learners and the knowledge that they seek to acquire, which is also the same knowledge that the teachers seek to impart.

Many studies find that pedagogy correlates closely with the extent of engagement in which students and teachers exchange knowledge and beliefs. The knowledge in the teachers' possession directly influences the types of knowledge that they pass on to the students, as well as the ways in which this knowledge is passed on. Teachers' Beliefs pedagogically affect this relationship between teachers and students. Besides, the students' participation in the learning process, and to some extent, the teaching process, are also variables that influence, and are influenced by, practices of pedagogy. According to Niemi, Heikkinen and Kannas, "involving students... in educational decision-making, and listening seriously to their stories of experiences as learners are essential first steps in developing education" (Niemi, Heikkinen & Kannas, 2010, p. 139). This is helpful towards increasing the teachers' understanding of their students and may, as a result, influence the ways in which they teach (Robinson & Taylor, 2007).

Interestingly, this also means that there is no one rigid set of pedagogical practices that applies across the board and encompasses all subjects and levels or types of students. The development of pedagogy depends largely on a particular group of students whom the teacher must get to know and understand their learning habits, knowledge demands, and speed of absorption. In other words, good pedagogical practices refer to a demonstration of ability in adjusting the activities, approaches or strategies when teaching different groups of students. Alexander (2000) stated that teaching practices comprise of:

> “(a) teacher spoken discourse (including instruction, explanation, metaphor, questioning, responding, elaboration and management talk);
> (b) visual representation (using a chalkboard, writing, diagrams, pictures, textbook, learning aids such as stones, experiments, drama) to understand or construct the new knowledge being presented or indicated to the learners;
> (c) the act of setting or providing tasks for learners to cognitively engage with new content or develop physical skills, such as experimentation, reading, writing, drawing, mapping, rehearsing, problem solving, practicing;
> (d) a variety of social interactions, in which language is central between learners or learners and teacher such as pairs, groups, individually or whole-class;
> (e) teachers’ monitoring, use of feedback, intervention, remediation and formative and summative assessment of the students or assessment by the students themselves” (Alexander, 2000, p. 66)

To sum it up, Pedagogical Practices play an important role in ensuring the quality of teaching sciences. No matter what kinds of strategies, actions and approaches adopted by the teachers, their ultimate goal is to guide the students’ learning.

2.3 Pedagogical Content Knowledge

Pedagogical Content Knowledge consists of two important components, namely: content knowledge (CK) and pedagogical knowledge (PK) (Shulman 1987, Barrett & Green 2002). Good PK functions as a support that enhances the teachers’ skills in the design, application, and assessment of the learning process. Meanwhile, CK supports the ability of teachers in imparting knowledge on a suitable level so that the students can grasp the concepts. CK also supports the effectiveness of the learning strategy of a certain type of learning material.

However, a similar German term, “Fachdidaktik”, had already been hypothesized much earlier than Shulman’s Pedagogical Content Knowledge. The German mathematician, Walther Lietzmann, has already used it in 1919 (Lietzmann, 1919).

References to Pedagogical Content Knowledge (PCK) in literatures that pertain to Science Education has attracted considerable attention ever since Shulman (1986, 1987) introduced the term. Shulman (1986) proposed Pedagogical Content Knowledge (PCK) as a specialized knowledge that connects Content Knowledge with the practice of teaching. He defined Pedagogical Content Knowledge (PCK) as:

"The most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations – in a word, the most useful ways of representing and formulating the subject that make it comprehensible to others… Pedagogical Content Knowledge also includes an understanding of what makes the learning of specific topics easy or difficult: the conceptions and preconceptions that students of different ages and backgrounds bring with them to the learning of those most frequently taught topics and lessons" (Schulman, 1986, p. 9).

In other words, PCK has become a way of understanding the complex relationship between pedagogy and content through an integrated process rooted in classroom practices (Van Driel et al., 1998). As a concept, Pedagogical Content Knowledge focuses on representations and conceptions or misconceptions. Grossman (1990) pointed out that

> […] Teachers must draw upon both their knowledge of subject matter to select appropriate topics and their knowledge of students' prior knowledge and conceptions to formulate appropriate and provocative representations of the content to be learned (p. 8).

Along the same vein of thought, Shulman (1987) writes that "Pedagogical Content Knowledge is the category most likely to distinguish the understanding of the content specialist from the pedagogue" (p. 8). From these words, it is clear that Pedagogical Content Knowledge is not only the combined knowledge of content and pedagogy, but also a kind of amalgam of knowledge of content and pedagogy, which is central to the knowledge needed for teaching (Ball, D. L., Thames, M. H., & Phelps, G., 2008, p. 392).

According to the study of Abell (2008), Pedagogical Content Knowledge is not just the simple combination of Content Knowledge and Pedagogical Knowledge. It is a complicated combined knowledge with knowledge about instructional strategies, knowledge about understanding students, knowledge about assessing students and knowledge about objective of the topic in the curriculum (Henze, van Driel & Verloop, 2008). In this way, the development of PCK is a complex process that is determined by the content to be taught, the context in which the content is taught and the ways in which the teachers combine their understanding of their current students with their previous teaching experiences to come up with a suitable teaching style for them.

Thus, the pre-service teacher training programs need to provide sufficient conditions for the teacher educators to combine the content-related knowledge and pedagogical knowledge through their experience of planning, conducting and reflecting the class. Only the teachers who have first experienced the learning environments themselves expected, they could implement in their real classroom (Magnusson et al., 1999). After all, imagined scenarios and expectations are always different from the actual reality. It is necessary to realize that education for teachers is a process that not only encourages possibility but also needs realization, whose goal is to prepare future professional teachers and promote students' achievements.

2.4 Teachers' Beliefs

Many studies have investigated the importance of Teachers' Beliefs (TB) in the experience of teaching. Generally, there are two broad categories of Teachers' Beliefs (TB) recognized in such literature. For instance, Woolley et al. (2004) drew a distinction between 'traditional teaching' beliefs, which refers to teacher-centered approaches to teaching and learning, and 'constructivist teaching' beliefs, which encompass student-centered approaches. 'Traditional teaching' beliefs are also known as 'teacher-centered' (Bramald, Hardman, & Leat, 1995) or 'transmissive' beliefs (see Sang et al., 2009), and they are adopted by those teachers who concentrate on knowledge transmission, devise well-organized teaching plans, and embrace step-by-step teaching methods. Meanwhile, 'constructivist beliefs' are also known as 'progressive beliefs' or 'student-centered approaches' (Bramald et al., 1995) and are often regarded as beliefs that 'support student learning' (Samuelowicz & Bain, 1992). Those teachers who focus on constructive and progressive teaching, as well as encourage independent learning processes, adopt constructivist beliefs.

Different persons will have different beliefs. Considering the teachers, the pre-service teachers, novice and experienced teachers will present the different beliefs of learning and teaching. There are many existing studies attempting to identify the differences of their beliefs and examine in which ways they are different and why these differences happen. As a result, how these different beliefs will have an effect on their learning and teaching process. By that, I refer to the ways in which teachers learn how to teach. Teacher Beliefs are central to recent theories about the identities of teachers and the roles which they believe they play within the classroom. Recent reformation in Science Education focuses on Teachers' Beliefs. The term "beliefs'' has been defined in the literature in a variety of ways.

Beijaard et al. (2004) stated that beliefs are considered as the significant elements to form the professional identities of teachers. Beliefs are reflections of how the teachers view themselves in relation to the students, inside the classroom, and as educators and knowledge transmitters. This implies that beliefs are crucial in the training process of teachers. In spite of the fact that there are many researchers studying the concepts of beliefs, the definitions of beliefs are multiple and still rather unclear. In other words, different researchers have different opinions regarding beliefs.

Speer (2005) and Thompson (1984) found that Teachers' Beliefs directly correlate to Pedagogical Practices. In this case, more and more researchers are interested in the relationships between Teachers' Beliefs and their Pedagogical Practices because beliefs are crucial elements that influence Pedagogical Practices (Speer, 2005, 2008; Pajares, 1992). Besides, many studies have illustrated the relationship between people's beliefs and behaviours. Pajares (1992) asserts that beliefs are ''the best indicators of the decisions that individuals make throughout their lives'' (p. 307). Thus, Teachers' Beliefs play a major role in the decision-making that teachers do in terms of curriculum and instructional tasks (Nespor, 1987).

2.5 Inquiry-Based Learning

Inquiry-Based Learning (IBL) is seen as a worldwide preferred way of teaching sciences. In fact, the current trend is to employ Inquiry-Based Learning as the key to solving problems in scientific education. Inquiry-Based Learning is greatly influenced by the American educator and philosopher John Dewey (1859-1952), who made an effort to promote 'learning by doing' (Dewey, 1933). Influenced by Dewey's idea of 'learning by doing', Inquiry-Based Learning appeared in America in 1970s and was adopted by teachers as an effective teaching strategy. However, Inquiry-Based Learning in China, there is a severe misunderstanding about Inquiry-Based Learning and also a grave misconception about how to apply such learning techniques that often makes Inquiry-Based Learning an ineffective teaching method in the classroom.

Generally, inquiry is often described as any hands-on, problem-based, project-based, student-centred, inductive and dialogic approaches (Anderson, 2002; Hayes, 2002). It is a meaningful pedagogical method that makes students to create knowledge by themselves so that they can experience this creation processes. It is a kind of student-centred approaches and self-regulated learning. Students are initiative, but not passive to learn the knowledge. Spronken-Smith et al., (2007) pointed out that "the core ingredients of an Inquiry-Based Learning approach that most researchers are in agreement with are:

- learning stimulated by inquiry, i.e. driven by questions or problems;
- learning based on a process of seeking knowledge and new understanding;
- a learning-centred approach to teaching in which the role of the teacher is to act as a facilitator;
- a move to self-directed learning with students taking increasing responsibility for their learning and the development of skills in self-reflection;
- an active approach to learning." (Spronken-Smith et al., 2007, p. 2-3)

Based on these components of Inquiry-Based Learning, it is obvious that IBL is beneficial for students in the development of their learning skills and the preparation for life-long learning. Thus, scientific inquiry often refers to activities like free discussions (whereby students are allowed to pose questions freely), data collection and analysis, and the construction of evidence-based arguments. Linn, Davis, & Bell (2004) state that

> "We describe inquiry instruction as engaging students in the intentional process of diagnosing problems, critiquing experiments, distinguishing alternatives, planning investigations, researching conjectures, searching for information from experts, and forming coherent arguments." (Linn, Davis, & Bell, 2004, p. xvi)

Along the same vein of thoughts, Anderson (2002) claims that "Inquiry science is a hands-on constructivist approach to science education. Students address teachers' and students' questions about natural phenomena or events by conducting scientific investigations in which they collaboratively develop plans, collect and explain evidence, connect the explanations to existing scientific knowledge, and communicate and justify the explanations" (Anderson, 2002, p. 9). In other words, the emphasis on "inquiry" invites the student to be as much a participant as the teacher in the acquisition and exchange of knowledge. This makes students and teachers collaborators in the processes of teaching and learning.

In general, Inquiry-Based Learning makes the procedure of knowledge acquisition potentially more appealing to the students by permitting the students to pose any questions as long as they are relevant to the scientific topic in discussion. With this, the students could have a deep understanding of the discussed topics and finally acquire the scientific knowledge. In effect, the students develop very good critical thinking and media research skills, which then help them to become highly knowledgeable about a particular topic. Logically, it follows that as the level of engagement increases, the extent of academic achievement becomes broader, and the scope of learning outcomes become more optimistic. All of these intersect with one another to influence the consequence of science education.

Chapter 3 Science Education and Education for Pre-Service Science Teachers in China

3.1 Introduction

Education in China has always been extensively influenced by Chinese culture and is always considered as immensely important in the eyes of the Chinese, who view academic achievements as a tool that awards a freedom in mobility among different social classes. Alexander (2000) wrote: “Life in schools and classroom is an aspect of our wider society, not separate from it: a culture does not stop at the school gates” (p. 29). From Alexander’s words, it would be incorrect to omit Confucianism from our discussion on education. Confucianism is the cornerstone of Chinese society and the hallmark of Chinese culture. Because of this, it is undeniable that Confucianism and its emphasis on the value of the teacher has shaped the way the Chinese view education and organize educational systems.

Across all age groups in China, the teacher has always held a respected position and enjoyed a high status within Chinese society. They are sometimes referred to as the “gardeners” in charge of nurturing the people and imparting knowledge to the next generation. In fact, a good analogy would be to think of the classroom as a garden, the students as seeds, and the teachers as gardeners. Whether the garden yields good trees and flowers depend on how the gardener fertilizes and waters the seedlings. In this case, sufficient space for growth becomes the analogy for freedom in knowledge acquisition, fertilizer becomes the teaching methods employed by the teacher, water becomes the content knowledge in question, while sunlight refers analogically to the variable that is each student’s learning ability and potential. With the exception of sunlight, the gardener is in charge of basically every factor that accounts for the healthy growth of each plant. This is identical to how the teacher’s ability to teach, extent of knowledge in possession, and application of pedagogical tactics directly correlate to the students’ ability to learn. This is the reason why it is so imperative for education programs to train teachers professionally.

Approaching from the view of a prospective teacher in China, the profession means that one has a stable occupation. Teachers are treated as civil servants and are thus entitled to the government’s welfare and salary schemes. The teaching profession offers tremendous job security, which is why the Chinese often refer to the occupation of teacher as an “iron bowl”. Metaphorically, the “iron bowl” refers to an unbreakable rice bowl that is a literal figurative for an endless supply of rice. Rice is the staple for Chinese and so, this metaphor simply means that a teacher will never face hunger.

The average salary for teachers in China has drastically increased over the last couple of years, leading to a sudden increase in the number of students who now decide to enter the teaching profession upon graduation. This is especially true of female students, who are particularly attracted to the stability, the competitive salary, and the long periods of paid holidays that come with the position of a teacher. Hence, it is unsurprising that the number of female teachers is clearly higher than that of the male teachers; and this is even more apparent in pre-schools and primary schools, in which the roles of teachers take on an even more nurturing nature than as compared with higher educational institutions.

In China, the teacher is traditionally seen as the authoritative figure in the classroom while the students take on the role of passive listeners who follow and execute what their teachers tell them to do. This conventional method of teaching has often been the subject of criticism in other countries. Such a traditional teaching method has its advantages and its drawbacks. On the one hand, the authority conferred onto teachers means that it is more convenient for them to organize their classes and manage their classrooms so as to maximise the learning experiences of these students. On the other hand, this teacher-centred way of teaching does not promote the student’s creativity, nor does it spark any interest in them to learn new things. This is because there is always a diversity present in a class and it is difficult for the teacher to know each student well enough to customize the lessons. Or rather, it is difficult for the teacher to cater to each individual student as the learning habits of all the students in the class can be too diverse. Fortunately, recent Chinese scholars have realized that such a conventional way of teaching needs to be shifted from a teacher-centred method into student-centred teaching approach and some importance measures have been taken into.

3.2 Important Documents on Education, Teacher and Science Education in China

3.2.1 Education Act

In 1995, the National People's Congress enacted *The Education Act*, which formed the foundation of education in China. This act focused on every aspect of the Chinese educational system. It focused on schools, teachers, and students at all levels, as well as the relationship between education and society, education investment and insurance, and the international exchange of education. For the very first time, *The Education Act* required the government to implement a certification system for all qualified teachers and develop a professional system for the assessment and the recruitment of teachers. This act also demanded that the government improve the working conditions and salaries for teachers, as well as raise the social status of teachers through the implementation of education programs to train qualified teachers.

3.2.2 The Compulsory Education Act

The Compulsory Education Act was issued by the National People's Congress in 1986. It required that all schools in China implement nine years of compulsory (primary and secondary) education and all children to participate in it. The local governments were responsible for supporting the compulsory education. One of the main reasons why this act was carried out was because before the 1980s, many children between 6-15 were unable to receive education due to certain familial conditions or cultural bias. This was especially true in the rural areas of China.

For instance, many secondary students from the countryside dropped out of school to seek employment due to financial problems. At the same time, there was also a gender inequality that was keeping female children out of schools and this gender bias lasted for a very long time in China. The dropout rate of girls was much higher than boys because girls were seen as an inferior investment with little or no pay-out. Most of the parents from rural areas were under the impression that it was useless for girls to receive formal education. For a very long time, the role of women went uncontested and the consensus was that women should just get married to have babies. Therefore, the parents were not willing to spend money on educating their girls. These two realities contributed to a continuing increase in the illiteracy and semi-illiteracy rates in China.

Additionally, another reason why the illiteracy and semi-illiteracy rates increased was that a lot of teachers had not received any formal training and were unqualified to teach before the 1980s. As such, even children who attended formal lessons in schools were not getting properly trained in academic subjects. Due to these reasons, China urgently needed to regulate and develop some semblance of basic educational system.

The Compulsory Education Act stated clearly that in order to promote the development of education on the whole, education for teachers must first and foremost be developed. The goals stated in the Act thus claimed that teachers at the primary level should be trained for a minimum of two years in normal schools, while teachers at the secondary levels should undergo training for three years in professional teacher colleges. The Act also focused on in-service training for current teachers and required that teachers must provide a higher standard of nurturing that encompasses the caring for their students, an engagement in teaching and lifelong learning, as well as a constant improvement of their teaching competence. Additionally, the Act required the government to set up a teacher evaluation system to issue certification to all qualified teachers. Finally, the Act required the government to improve the social status and living conditions of teachers, as well as reward teachers who demonstrate excellence.

3.2.3 Teacher's Law

The Teacher's Law was issued in 1993. This law is the beginning of the establishment of the certification system for qualified teachers. All Chinese citizens who are keen on being part of the education system, who pass the national teachers' qualification examinations, and who demonstrate strong educational and teaching abilities, can obtain teaching certification upon being examined.

The standards for the teachers' qualification examinations for certificate have been designed in accordance with this law (MOE, 2011a, 2011b). Valid educational experience with a specialization in a discipline and a certificate for pedagogical training are two prerequisites for the application of the teaching certificate. These standards are essential in the designing of the K-12 pre-service science teachers' training programs, which develop the candidates' understanding of both content and pedagogical knowledge.

This Act has further explained the requirements for teachers at different levels of education. For example, to become a kindergarten teacher, one must graduate from an early-childhood normal school or higher. To qualify as a teacher in a primary school (grades 1–6), one must be a graduate from a secondary normal school or higher. To become a teacher in a junior secondary school (grades 7–9), one must graduate from a specialized higher normal school or college or university with at least 2 years of training. To qualify as a teacher in a senior secondary school (grades 10–12), one must be a graduate from a normal college or a college or university with at least four years of training. To become a teacher in a university, one must obtain a minimum of Master's degree. In fact, most universities currently require a doctor's degree.

3.2.4 Promoting and Guiding the Reformation of Science Education in Primary Schools

In the 1980s, the new reform and China's opening to the world brought about considerable economic and societal changes. These changes meant that more qualified manpower is needed in China. Education suddenly had to improve to meet the needs of the new reformative era in Chinese history. Science also developed itself significantly during this period, as a series of educational reforms came into effect. In 2001, the Ministry of Education carried out a new round of curriculum reformation. This reformation officially introduced *Science* as a subject in primary and junior secondary schools.

In 2006, the State of Council of China issued the document *National Scientific Literacy Action Plan*, which aimed at improving the scientific literacy of Chinese citizens. In 2008, the document *Promoting and Guiding the Reform of Science Education in Primary School* was published. This document created awareness in the importance of science education amongst people across all social classes in society. The objective is to improve the scientific literacy of the Chinese. The main updates carried over from the previous reforms are as followed:

(a) Highlight the importance of science education and make it a subject major, just like Chinese and mathematics, in primary schools.

(b) Improve the education programs for pre-service and in-service teachers, enhance the scientific literacy and teaching skills of teachers, and reinforce the existing teams of science teachers.

(c) Start science education in grade 1 at the primary level.

(d) Set up special funds in the Natural Science Foundation to support research in scientific education.

(e) Arouse the power of every field in our society, especially in the field of technology, in order to promote the sustainability and rapid development of science education.

3.3 Educational System in China

The Chinese educational system is a 6-3-3 format based on the American system: it starts with six years of primary education (grade 1-6), three years in junior secondary school (grade 7-9) and three years in senior secondary or secondary vocational school (grade 10-12). With the introduction of *Law of Compulsory Education* in 1986, primary and junior secondary education (a total of nine years) have become compulsory in China, i.e. all children starting from six years old (in some rural area, the age can be extended to 7) must be enrolled in a primary school. The junior secondary, senior secondary and secondary vocational schools are attended by respective students from the ages of 12 to 14 years old and 15 to 17 years old. Higher education is normally organized into three stages: Bachelor’s programme (four years) or vocational college (three years), Master’s programme (two to three years) and Doctoral programme (three to four years). Table 3.1 shows the overall structure of the educational system in China.

As explained earlier, primary and junior secondary education, i.e. nine years, is compulsory in China. Before the 1990s, students could enter junior secondary schools upon a successful entrance examination. Schools enrolled students according to their examination scores. The result is that some students could not attend junior secondary schools after failing their entrance examination. This misfortune went against the principles of the law of compulsory education. In order to offer everyone a fair opportunity to receive nine years of compulsory education, the government abolished the system of entrance examination, replacing it with the students’ residence status instead (OECD, p. 10, 2016). This means that schools can now recruit their students based on where they live rather than how well they fare in their entrance examinations. This way, every student has a chance to receive at least nine years of education, which is a monumental effort in achieving educational equality.

After finishing nine years of compulsory education, students need to take part in a public examination called *Zhongkao* in order to enter the senior secondary schools. Based on their scores, students can choose which schools they wish to attend. There are two main types of senior secondary schools: general senior secondary schools and secondary vocational schools. General senior secondary schools are mostly attended by students hoping to progress onto tertiary education while secondary vocational schools refer to technical or specialized secondary schools, adult secondary, vocational secondary and crafts schools (OECD, p.10, 2016). Students who make it into general senior secondary schools will have to sit for an examination at the end of the three years to fight for a chance to advance onto varsity education. On the other hand, students who graduate from these secondary vocational schools will not advance to university. Instead, they will train in a specific set of practical skills that allows them to seek employment upon graduation.

Table 3.1: China's Educational System

Age			Schooling	Level
28	**PhD Programme (Doctor's degree) 3-4 Years**		11	**Higher Education**
27			10	
26			9	
25			8	
24	**Master's Programme (Master's degree) 2-3 Years**		7	
23			6	
22			5	
21	**University (Bachelor's degree) 4 Years**		4	
20		**Vocational College 3 Years**	3	
19			2	
18			1	
17	**General Senior Secondary School 3 Years**	**Secondary Vocational Schools 3 Years**	12th	**Secondary Education**
16			11th	
15			10th	
14	**Junior Secondary School 3 Years**		9th	
13			8th	
12			7th	
11	**Primary School 6 Years**		6th	**Primary Education**
10			5th	
9			4th	
8			3rd	
7			2nd	
6			1st	
5	**Kindergarten 3 Years**		K	**Pre-school Education**
4			K	
3			K	

Data Source: OECD (2015), *OECD Economic Surveys: China*, OECD Publishing, Paris. Retrieved from: http://dx.doi.org/10.1787/eco_surveys-chn-2015-en.

After studying for three years in senior secondary schools, students who wish to enter into university will have to take part in a national examination called *Gaokao*, otherwise known as the university entrance examination. Admissions into universities or colleges are based on the scores of this examination. Students with higher scores can enter the best-ranked universities or colleges.

3.4 Science Education

In China, there are two types of courses offered in Science Education at schools. One of which includes departmental subjects of natural sciences, such as physics, chemistry, biology, and earth science. The other one is known as the integrated science course, which mixes knowledge in various subjects of natural sciences together. Content of the latter sort is not restricted to the natural sciences, but rather, includes knowledge in scientific technology and social sciences. The structure of science courses logically has an effect on the development of science education. In foreign countries, integrated sciences are often part of the curriculum in primary and junior secondary education. Additionally, departmental sciences are also part of the curriculum in junior secondary education. Based on the new round of curricular reformation and curricular standards for sciences in 2016, China also adopts a similar structure in scientific education in schools. Lessons on integrated sciences are taught from grade one to six in primary schools while lessons on integrated sciences and departmental sciences are taught in conjunction as part of the scientific education at the junior secondary level. This means that classes on both integrated and departmental sciences can be conducted in junior secondary schools. Based on the needs of students, local schools can decide to which to implement. Figure 3.1 shows the structure of Science Education in China.

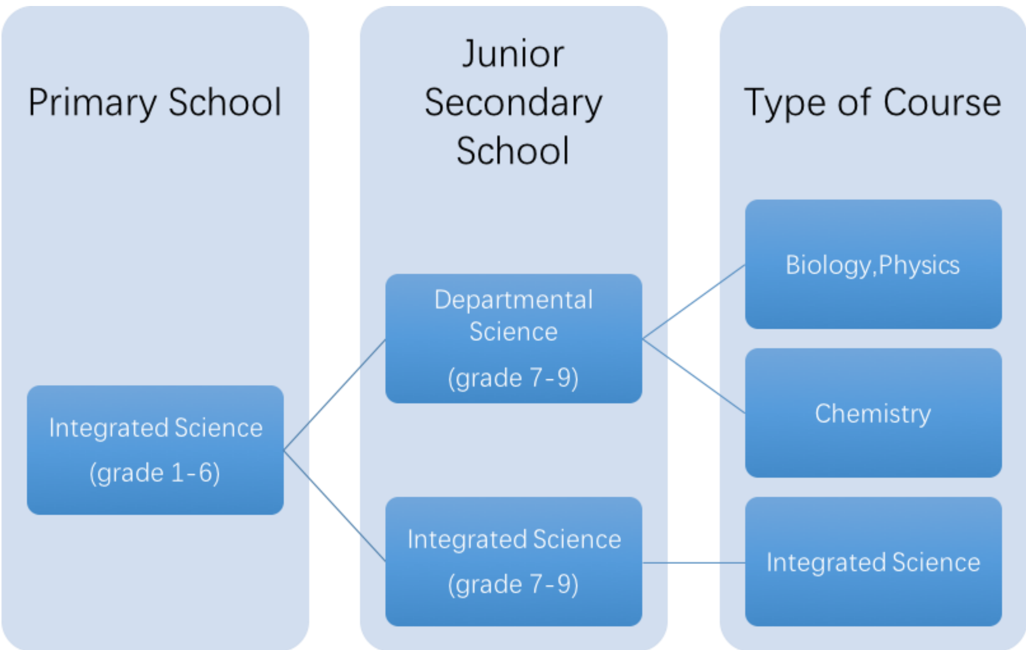

Figure 3.1: The Structure of Science Education in China

This structure illustrates the way in which science education is organized in Chinese schools. Regarding science education at the primary level, all the primary schools in China offer integrated science courses as stipulated by the government policy. However, in regard to science education at the secondary level, there are two ways of implementation. The first way is to offer departmental sciences as traditional school subjects, i.e. to conduct science lessons inside the classroom. The other way is to facilitate scientific learning through the reform-oriented method, which is to teach through the engagement in learning activities. As of today, many cities in China still adopt the traditional way of conducting science lessons in junior secondary and senior secondary schools. Only a few junior secondary schools in economically advanced cities, such as Shanghai, Zhejiang and Shenzhen, opt for the implementation of the reform-oriented way.

One reason why there are two patterns of science education in junior secondary school is because the Chinese education system is still very much exam-oriented. To advance from junior secondary school to senior secondary school, the students must participate in an important entrance examination (*Zhongkao*). Most of the students, parents and teachers are still stereotypical in that they think integrated sciences are not very helpful to students in their preparation for the *Zhongkao*. This mentality extends to the opinion that there will be opportunities for such innovative scientific learning during senior secondary education. Comparatively, the people in advanced cities are more willing to accept new thoughts and ideas. Therefore, they do not mind trying out new types of science education.

As this study focuses on education for pre-service science teachers, with an objective of preparing professional science teachers for schools (especially at the primary level), "science" in this thesis refers to integrated sciences, which contain not only subjects of natural sciences, but also technology and social sciences.

3.5 Science Contents Standards for Primary Education

The Science Curriculum Standards for Primary Education (SCSPE) (2016) stated that science courses at the primary educational level should be integrated and practical (Science Curriculum Standards for Primary Education, p.2). The objectives are to promote knowledge and understanding in, and the application of, sciences in the daily lives of primary students. In order to achieve these purposes, it is imperative to find a way to bridge theory and practical knowledge. This is so that students are able to witness how science can be applied through actual activities and then, infer from the given examples other ways in which the same concepts can be applied in other similar situations. This is the reason why there is an emphasis on teaching and learning science in an inquiry-based way.

Teachers should motivate their students' interests to learn by creating lessons that are student-centered. This means that there is a sudden demand for the acquisition of knowledge in Pedagogical Practices, Inquiry-Based Learning, Content Knowledge, and Teacher's Beliefs. Teachers must learn how to teach practical skills in addition to theories. As the teaching of such practical skills encompass more than just classroom teaching, the teachers must also improve their knowledge in science, as well as learn how to effectively impart knowledge that they know to their students. The focus on these aspects indicated a great improvement in science education in China as the education programs are now more comprehensive and intensive because they include knowledge in both scientific content and teaching strategies.

This part will outline the scientific content knowledge that students in primary schools must learn. According to SCSPE (2016), there are four categories of scientific content, namely: physics, life sciences, earth and space sciences, and technology and engineering (p. 16). 18 topics have been selected to make up the science syllabus for primary students. There are 6 topics on physics, 6 topics on life sciences, 3 topics on earth and space sciences, and 3 topics on technology and engineering.

The contents for physics, life sciences, and earth and space sciences aim to help students acquire scientific facts, concepts, principles, theories and models in each respective discipline. These contents are basic but important in building a solid foundation in sciences. Meanwhile, the contents covered in technology and engineering aim to help integrate students' knowledge with application in real-life situations. This helps to relate sciences with our daily lives.

In order to discuss each category of content in a lucid manner, one example from each category will be presented in the following as case studies.

3.5.1 Physics

As mentioned above, there are 6 selected topics on physics that are included in the science syllabus. These are related to the nature of material, such as the nature of water, the nature of air, the movement of objects, the function of power and energy (such as sound energy, luminous energy, heat energy, electric energy, magnetic energy and mechanical energy). Refer to the example shown in Table 3.2.

Table 3.2: Air is a Common and Important Mixed Object

Physics			
Study Content	Study Objectives		
	Grade 1-2	Grade 3-4	Grade 5-6
Air has mass and takes up space. Its shape changes according to the shape of the container. Air has no fixed volume.	Observe and describe the characteristics of air, such as color, state and smell.	Know that air has mass and takes up space. Air fills every part around us.	
Air is a mixture of nitrogen, oxygen, carbon dioxide and so on.		Know that oxygen and carbon dioxide are significant to living-things.	Know that air is a mixture. Nitrogen and oxygen are the main components of air.
Wind is produced by the movement of air.		(a) Describe the phenomenon: hot air rises, cold air sinks. (b) Know that wind is produced by the movement of air. (c) List some common reactions that give out air in our daily lives.	

3.5.2 Life Sciences

There are 6 topics on life sciences. They are related to living-things on earth, such as the features of plants and animals, the body systems, the reproduction of plants and animals, and ecology (the relationship among plants, animals and the environment). Table 3.3 shows an example of this syllabus.

Table 3.3: Animals Adapting to the Environment and Sustaining Their Lives by Absorbing Nutrients of Plants and Other Animals

Life Sciences			
Study Content	**Study Objectives**		
	Grade 1-2	**Grade 3-4**	**Grade 5-6**
Animals interact with and respond to the environment using different organs.	Give some examples to prove that animals interact with and respond to the environment using their eyes, noses, ears and so on.	Give some examples to illustrate the ways in which animals can interact with the environment using skin, wings, branchia and so on.	
Animals can adapt to the changes in seasons.		(a) List the methods which animals use in adapting to the changes in seasons. (b) Explain how these changes help animals to sustain their lives.	
Animals' behaviors can adapt to the changes in environment.		.	Give some examples to show how animals' behaviors change along with environmental changes in climate, food, air, water and so on.

3.5.3 Earth and Space Sciences

As mentioned above, 3 topics on earth and space sciences have been included in the primary science syllabus. They are related to the movement of earth and moon, the components and the role of earth. Refer to Table 3.4.

Table 3.4: Earth is the Homeland of Human Beings

Earth and Space Sciences			
Study Content	Study Objectives		
	Grade 1-2	Grade 3-4	Grade 5-6
Earth provides all kinds of natural resources for human beings to exist.	(a) Give some examples that human beings cannot exist without plants and animals. (b) Know the importance of protecting natural resources of plants and animals.	(a) Give some examples that human beings cannot exist without fresh water. (b) Realize the importance of water-conservation. (c) Give some examples on how human conduct agricultural production by making use of soil. (d) Realize the importance of protecting the fertility of soil.	(a) Know that the sea provides numerous resources, such as marine life, energy and mineral resources for the sustenance of human beings. (b) Know that some natural resources are renewable while others are not. (c) List which resources or products are recyclable. (d) Realize the importance of protecting resources.
Human beings need various types of resources to exist.			(a) Explain why human beings cannot exist without energy. (b) Know that solar power is a recyclable and clean energy. (c) Realize the importance of conserving energy.
(a) Human beings need to withstand all kinds of disaster in order to exist. (b) Human activities will influence natural environment.		Know the impacts of meteorological disaster on human beings, such as typhoon, flood, drought and so on.	(a) Know some basic knowledge of how to protect themselves in the face of natural disasters. (b) Point out the results of unreasonable human activities that impact the environment. (c) List the possible measures to protect environment.

3.5.4 Technology and Engineering

There are 3 topics in the category of technology and engineering that are associated with the manmade world. These include essential knowledge of technology and engineering. See Table 3.5.

Table 3.5: The Manmade World Makes Our Lives More Convenient and Comfortable

Technology and Engineering			
Study Content	Study Objectives		
	Grade 1-2	Grade 3-4	Grade 5-6
The natural world is different from the manmade world.	(a) Know that the natural world consists of plants, animals, rivers, mountains, seas and so on. (b) The manmade world is organized with architectural structures, vehicles, household appliances, communication tools and so on. (c) Know that the manmade world is created by human beings.	Know how to distinguish between natural materials and artificial materials in our daily lives.	
Engineering and technical products change the lives of human beings, as well as their ways to produce things.	Experience how scientific products make people's life more convenient and comfortable.	(a) List some products that are created and produced by human.	(a) Know that great inventions can deeply influence the development of society. (b) Know that some technical products will have negative effects on the lives of human beings and the environment.

3.6 Science Contents Standards for Junior Secondary Education

As discussed before, there are two patterns of science education within the junior secondary education curriculum. However, my work will only cover the reform-oriented way, which conducts classes on integrated sciences in junior secondary schools in grades 7-9.

As several detailed examples on the four categories of the primary science syllabus have already been provided in the previous section, this section will not give detailed examples about them anymore. Instead, this part describes the scientific contents that are excluded from the primary science education and discusses the pros and cons of such omission.

Based on the Science Curriculum Standards for Junior Secondary Education (SCSJSE) (2011), there are five content categories in sciences at this level. They are: scientific inquiry; life sciences; physics; earth and space sciences; sciences, technology, society and environment (p.13).

The biggest difference in scientific content between the primary level and the junior secondary level lies in the aspect of scientific inquiry. SCJSE pointed out that science as an inquiry is a basic strategy conducted in science education. It provides students with opportunities to make inquiries and develop critical thinking skills, thereby reacting based on inquiry. Potential reactions include generating further questions of relevance, designing and conducting scientific investigations, thinking critically and understanding hypotheses about scientific inquiries. This ensures that the knowledge acquired by students is comprehensive and useful. Table 3.6 shows an example topic on how to conduct scientific inquiry.

Table 3.6: The Way to Conduct a Scientific Inquiry

Scientific Inquiry			
Study Content	**Study Objectives**		
	Grade 7	**Grade 8**	**Grade 9**
Generate Questions	(a) Asking questions based on previous knowledge. (b) Know that scientific inquiry originates from questions.		
Formulate Hypotheses	Hypothesize and justify these hypotheses.		
Design Investigation		(a) Design experiments to conduct investigations based on the research questions. (b) Choose a suitable methodology to aid inquiry, such as observation, experiment, field work and so on.	
Collect data and evidence		Collect data and any evidences that support the investigation.	
Analyze and Examine Data			Develop the ability to analysis and assess the reliability of data.
Explain Questions			Connect findings with scientific knowledge to answer questions.
Present the Findings and Communicate Opinions with Others			(a)Use media tools to present the findings. (b)Draft research report. (c)Exchange ideas with others and respect their comments on the research.

3.7 Education for Teachers in China

Education for teachers in China generally refers to pre-service education and in-service education for students who are preparing to become teachers. As this study concerns itself with education for pre-service teachers, education for in-service teachers will not be discussed.

There are three types of education programs for pre-service teachers that train potential teachers in China. The first type takes place in Secondary Teacher School. Students in these schools are trained to become teachers at the kindergarten level. The second type takes place in Normal College, which trains teachers to teach in primary schools. The third type of teacher education program is offered by Normal University. Students normally take four years to obtain a Bachelor's degree in education, which allows them to teach in both primary and secondary schools. However, with the continuous expansion of enrolment in Chinese universities, competition in the job market has become fiercer. Some students who obtained a Bachelor's degree can no longer find a suitable position in secondary schools. Instead, they teach in primary schools, as do some of the Master's program graduates. Several comprehensive universities and colleges have also begun to offer majors that train teachers. However, the three types of education programs for training teachers remain the most popular in China, with the third type being the most popular.

Most teachers in China are trained at Normal University. The English word "Normal" is translated into "shi fan" in Chinese, which means "teacher training". However, this does not mean that all graduates of Normal University will go on to become teachers later on in life. Besides, teachers in China are not only trained at Normal University, they can also study in other comprehensive universities or technology universities, which award them the teacher certificates with a specialization in one or several subjects, after some examinations about education and psychology, as well as the subjects they are going to teach.

China has the largest population in the world, and surely also the biggest number of students. Sadly, the ratio of students to teachers is still very uneven. The shortage of teachers is even more serious in rural parts of China. The number of science teachers is very low when compared with the number of teachers in other subjects. This is mainly due to the less important status of science as a study subject (such mentality persisted for a long time in China) as opposed to other subjects such as Chinese, English and Mathematics. Before 2001, there was no science taught at schools. Instead, a subject called *Nature* was taught. In the past, *nature* courses were normally taught by teachers of other subjects and not by science teachers. Starting from 2001, however, the government began to emphasize on the importance of science education.

Schools thereby started teaching science in a proper manner while universities created an undergraduate major – Science Education – to train professional science teachers to take up positions in the classroom. This measure caused a drastic transformation in the role of Science Education in China.

Science Education is now an official undergraduate major at Normal universities under the departments of chemistry, physics and biology. Science Education is taught in these departments rather than in the educational departments because most of the courses in this major are related to natural sciences, which means that the teachers teaching these subjects need to be properly trained in the respective sciences before they can enter the classroom to impart knowledge. In addition, science courses generally require students to conduct experiments in labs, as well as take part in field work. Since the educational departments typically do not have these infrastructures, it is not well-equipped to train teachers with the contents of science, such as chemistry, physics, biology and earth science.

The following section will introduce some national laws and policies on the qualifications and employment of teachers, and the typical training program for pre-service science teachers at “normal” institutions, with a focus on the Bachelor’s program. Some examples will be provided to illustrate how the education programs for pre-service science teachers are organized. By that, I refer to the admission requirements and course curriculum of institutions that train prospective teachers.

3.8 Education for Pre-service Science Teachers in China

There are different ways to train teachers in China. Nevertheless, this study will only focus on the education programs for teachers at Normal universities. This is because the other education institutions for teachers do not offer programs as good as the ones offered by Normal universities. Also, students at Normal universities achieved higher scores and perform better overall in the university entrance examinations when compared with other education institutions for teachers. To some extent, students at Normal universities are more qualified than those studying in other education institutions for teachers. Furthermore, Normal universities are recognized as the typical training institutions for teachers and can better reflect the broad situation of education programs for teachers in China.

As direct facilitators of the science courses in schools, science teachers exert a big influence on the quality of science education. Universities in China did not introduce Science Education as an undergraduate major until 2001, which meant that there were no qualified science teachers in schools prior to that. With the implementation of the Eighth Basic Education Curriculum Reform in 2001, many educators in China called for the introduction of Science Education at universities to complement the educational structure of training programs for teachers. This is also to train more qualified science teachers, and to develop better science education. Consequently, 66 universities introduced Science Education as a major after the 2001 reformation, so as to train professional science teachers to take up teaching positions in primary and junior secondary schools (Liao, 2013).

Science education for teachers, as a relatively new subject major in China, is still faced with many problems, such as disparities in the infrastructure and curriculum of different universities, the inefficiency of the curriculum's organization and the lack of professional educators who are qualified to train science teachers (Liao, 2013). It is thus necessary for the government, the academic communities and the universities to join forces and come up with legal regulation, expert guidance and innovation in management to resolve these problems.

3.8.1 Admission into Education Programs for Pre-service Science Teachers

Admission into an education program for pre-service science teachers is determined mainly by the scores that students obtain in their national university entrance examinations (*Gaokao* in Chinese). Students submit applications to the respective universities of their choice based on the scores that they received.

Since 2007, there was another way for students to enter Normal universities. The Chinese government carried out a "Free Normal Education Program" for students who wish to become teachers in the future. This program is sponsored by the central government and it collaborates with six excellent Normal universities that are under the direct governance of the Ministry of Education. Students participating in this program must obtain stellar scores in their university entrance examinations as they are recruited based on abilities. Thanks to this program, students, especially those from rural areas, can be enrolled for free in training programs for pre-service teachers at Normal universities. They also receive stipends from the government that pay for their daily living expenses. Upon graduation, the government will arrange for them to teach at schools. Of course, there are some requirements for students who enjoy such free education. For instance, they are required to return to their homelands to teach for 10 years at either the primary or the secondary level. This program has trained many qualified teachers, including science teachers, and it encourages more students to take up teaching as a profession.

3.8.2 Bachelor's Degree in Education Programs for Pre-Service Science Teachers

A Bachelor's program normally takes four years of study in China. The Bachelor's degree in education for pre-service science teachers at a Normal university also takes four years to obtain. The education programs for science teachers are designed for students to gain both theoretical and practical knowledge that is related to science and teaching. In the first year, students will take several general courses that set the foundation for the remainder of their studies. In the second and third years, students will systematically accumulate scientific content knowledge. At the same time, they will go to a primary or secondary school for actual class observation, under the guidance of their teachers. These visits last around one to two weeks and are called "educational probation". During this period, students do not participate in the teaching. Instead, they observe the classes and listen to the lessons. This experience is to help them learn how to teach and manage the class.

In the fourth year, the students will do an internship that is eight weeks long at a school. This time, they will participate in teaching activities to gain some actual experience. After this internship, they need to write their theses. Once they have acquired enough credits in subjects that are related to science and education, they can graduate. One of the differences between students in normal universities and students in other universities or educational institutions is that students in normal universities don't need to take extra examinations to obtain a teacher certificate once they graduate whereas students in other universities or educational institutions have to take extra examinations if they wish to become teachers.

3.8.3 Case Study: Shanghai Normal University

Shanghai Normal University was founded in 1954 and it is a key university in Shanghai. It is a comprehensive local university with special features in training teachers. There are now more than 21,000 undergraduates and 7,000 postgraduates at Shanghai Normal University. The institution boasts a highly qualified staff of 2,915 teachers and researchers, including 1,831 full-time teachers, among which there are about 300 professors and 667 associate professors. Among the faculty members, 1,596 (86.1%) are master's or doctoral degree holders, out of which 948 are doctoral degree holders. In addition, the university has about 500 part-time teachers.

Although education programs for pre-service science teachers vary at different universities in terms of objectives, courses and credit requirements, they share curricular structures that are more or less the same. These structures are organized mainly into three aspects: general courses, major courses, teacher education courses. The curricular structure of science education can, to some extent, represent the structure of its education programs for teachers. In order to inspect the ways in which education programs for pre-service science teachers are organized in China, this section will take Shanghai Normal University as a case study. Its curriculum of the Bachelor's degree in Science Education will be introduced in the following.

Science Education at Shanghai Normal University is offered in the department of biology, where the students are required to take three types of courses: general foundation courses (which trains students in basic theories and technical abilities), professional major courses (of related subjects) and teacher education courses (e.g. practices of pedagogy). There is a total of 2790 study periods. 160 credits (including 42 credits in specialized courses) are the prerequisite for graduation. Tables 3.7, 3.8, 3.9 and 3.10 will present the curriculum of each academic year respectively.

Table 3.7: Curriculum for Science Education in the First Academic Year

Semester	Series	Course Code	Course	Period	Credit	Assess Manner
Semester I	Common required Courses	0000020	Cultivation of Mentality, Morality and Legislation	2	2	Check
		0000032	Outline of the China's modern history	2	2	Check
		0000014	*College English	5	4	Test
		0000013	P.E.	2	1	Check
		0000005	Military Affairs	2	2	Check
		0000004	*Computer	4	3	Check
	Speciality Required Courses	1410801	*General Chemistry I	4	4	Test
		1410801	*General Chemistry Lab	2	2	Test
		1410096	*General Biology	5	5	Test
		1410951	Advanced Mathematics	3	3	Test
	Total			31	28	
Semester II	Common Required Courses	0000031	Principles of Marxism	2	2	Check
		0000014	*College English	5	4	Check
		0000013	P.E.	2	1	Check
		0000004	*Computer	4	3	Check
	Speciality Required Courses	1410802	*General Chemistry II	4	4	Test
		1410802	*General Chemistry Lab II	3	3	Test
		1410096	*General Biology	3	3	Test
		1410951	Advanced Mathematics	3	3	Test
	Total			24	21	

Note: “*” refers to the compulsory courses that student must take in order to obtain the credits required for the Bachelor’s degree.

As we can see from Table 3.7, in the first academic year, the courses focus on general knowledge such as history, politics and English. This basic knowledge is useful towards opening the minds of students so that they are able to develop critical thinking skills for themselves. With regard to the courses related to sciences, there are six professional majors, but these only include chemistry and biology.

Table 3.8: Curriculum for Science Education in the Second Academic Year

Semester	Series	Course Code	Course	Period	Credit	Assess Manner
Semester I	Common Required Courses	0000033	*Mao Zedong' s Thoughts, Deng Xiaoping's Theory and Jiang Zemin’s Theory	4	4	Test
		0000014	*College English	5	4	Test
		0000013	P.E.	2	1	Check
	Speciality Required Courses	1410041	*General Physics	4	4	Test
		1410719	*Earth and Space Sciences	4	4	Test
	Restricted Elective curricula		Integrated Ability Oriented Course	2	2	Check
	Restricted Elective curricula		Speciality Required Courses	6	6	Test
	Random Elective		Random Elective	2	2	Check
	Practice		Teaching work Observation	1 Week		Check
	Total			29	27	
Semester II	Common Required Courses	0000014	*College English	5	4	Check
		0000013	P.E.	2	1	Check
	Speciality Required Courses	1410041	*General Physics	4	4	Test
	Restricted Elective curricula		Integrated Ability Oriented Course	2	2	Check

	Restricted Elective curricula		Speciality Required Courses	6	6	Test
	Random Elective		Random Elective	2	2	Check
	Practice		Teaching work Observation	1Week		Check
	Total			25	23	

Note: "*" refers to compulsory courses that student must attend in order to obtain the credits for the Bachelor's degree.

Table 3.8 shows the shift from general courses to professional foundational courses in the second academic year. This is to develop basic technical potential of the students into abilities. At the same time, students begin to attend classes on how to teach, such as Work Observation. This practical course, which lasts one week per semester, allows students to acquire practical knowledge that is related to teaching. As for professional courses related to science, three courses on physics and earth sciences are introduced into the curriculum.

Table 3.9: Curriculum for Science Education in the Third Academic Year

Semester	**Series**	**Course Code**	**Course**	**Period**	**Credit**	**Assess Manner**
Semester I	Common Required Courses	0000028	College Oral English	2	1	Test
	Speciality Required Courses		*Education Course I	3	3	Test
			*Education Course II	1	1	Test
		1410971	*Science	3	3	Test
		1410724	*Applied chemistry	2	2	Test
	Restricted Elective curricula		Speciality Required Courses	9	9	Test

	Elective curricula		Elective curricula	4	4	Check
	Practice		*Teaching work Observation	1Week		Check
	Total			20	19	
Semester II	Common Required Courses	0000028	College Oral English	2	1	Test
	Speciality Required Courses		*Education Course II	5	5	Test
		1410975	*Study of Middle School Integrated Science Lab	6	6	Test
		1410725	*Pedagogy of Science	3	3	Test
	Restricted Elective curricula		Speciality Required Courses	6	6	Test
	Elective curricula		Elective curricula	2	2	Check
	Practice		Teaching work Observation	1Week	2	Check
	Total			23	24	

Note: "*" refers to compulsory courses that student must attend in order to obtain the credits for the Bachelor's degree.

Table 3.9 shows the curriculum o the third academic year. These courses focus on knowledge in science, such as sciences, the pedagogy of science and scientific experiments. At the same time, this is the year when students begin to attend theoretical courses on education and continue to attend classes on how to teach (as customary, lasting for two weeks per year).

Table 3.10: Curriculum for Science Education in the Fourth Academic Year

Semester	Series	Course Code	Course	Period	Credit	Assess Manner
Semester I	Speciality Required Courses	1410976	*Science, Technology and Society	3	3	Test
	Practice		*Educational Practice	8 Week	6	Check
	Total			3	9	
Semester II	Practice		*Pre-graduation work practice	1 Week	1	Check
			*Thesis	8 Week	6	
	Total			0	7	

Note: "*" refers to compulsory courses that student must attend in order to obtain the credits for the Bachelor's degree .

From Table 3.10, we can see that the fourth year offers only one course that is related to science. The curriculum for the fourth year emphasizes more on the educational practice in schools. After students have completed their internships at the school, they begin to write their thesis for graduation.

It is clear from the curricula listed above that the professional knowledge of scientific content is acquired mostly in the first three years. The science courses at Shanghai Normal University are split into five categories: chemistry, biology, physics, earth science and sciences. This fully covers the science curriculum requirements of both primary and secondary schools, which demonstrating clearly that the university aims at providing scholastic science education. The educational courses at Shanghai Normal University cover both theoretical and methodological aspects, otherwise known as the general education courses and teaching observation. However, it seems that education courses specially for teachers are still inadequate.

Chapter 4 Methodology of the Study

4.1 Introduction

In order to meet the objectives and prove the hypotheses mentioned in the first chapter, this study employs both quantitative and qualitative approaches to collect data. This provides evidence that helps to answer the research questions and hypotheses. This study is considered to be a case study because it performs investigation based on data that is collected from six sample universities in China. These universities were selected from the Eastern and Western regions in China, from the north to the south, in order to best represent the overall situation of education for pre-service science teachers in China. The similarities and differences between them will also be tackled. This chapter will cover the sampling design, the participants, as well as the methods, used in this study. It will also describe the research instruments, the process of the data collection and the procedure of data analysis.

4.2 The Sample

This study was designed on the premise of Chinese education. Samples for the study were taken from six universities, each offering Science Education as an undergraduate major. These six case studies are selected out of about 66 Chinese universities that offer Science Education as a major. These 66 universities are located across seven regions (see Table 4.1).

Table 4.1: Distribution of University Introducing Science Education

Region	Number
Northern China	6
The Northeast	8
Eastern China	16
Central China	10
South China	4
The Southwest	14
The Northwest	8
Total	**66**

Data source: Liao, Boqin (2013). *Science Education*, p.241, Beijing: Science Press.

Due to time constraint, my study will only look at six universities across these four regions: "**The Southwest**", "**The Northeast**", "**Northern China**" and "**Eastern China**" (see Table 4.2). During the selection of the sample universities, two factors were considered: (1) whether the chosen universities would be an appropriate representation of different regions of Chinese universities (The Southwest, Northern China, Eastern China and The Northeast) and (2) the academic ranking of these universities and the current state of its education program for science teachers (such as training goals, curriculum and teaching methods).

The six sample universities are Chongqing Normal University, Sichuan Normal University, Taiyuan Normal University, Changchun Normal University, Shanghai Normal University and Zhejiang Normal University. These are public universities supported by the Chinese government.

Table 4.2: Sample Universities

Region	Sample Universities	Number
The Southwest	Sichuan Normal University	2
	Chongqing Normal University	
Northern China	Taiyuan Normal University	1
The Northeast	Changchun Normal University	1
Eastern China	Shanghai Normal University	2
	Zhejiang Normal University	
Total		**6**

4.3 Participants of the Study

4.3.1 Selection of the Participants

Participants of the study are educators of future science teachers and these potential science teachers (student-teachers) themselves. Each participant had been carefully selected to minimise inaccuracies in the data collected for the study. The educators were selected according to the length of time in which they have been in service, their educational background and the subjects which they teach. The people in charge of planning the academic curriculum for the training of science teachers were our target participants. Meanwhile, student-teachers were selected according to their performance and results in these courses. Chinese students typically need four years to complete their undergraduate study and courses are typically structured such that the foundational subjects are covered in the first year while the advanced subjects are taught in the remaining years. As such, this work targets student-teachers in the middle and advanced stages of their study to ensure that the data was collected from those who have completed modules in both science and teaching.

4.3.2 Procedures for the Recruitment of Participants.

After having selected the sample universities and decided on the criteria of the study, the next step was to recruit the participants for this study. It is far easier to conduct field research in China than in other countries because all one has to do is to obtain permission from the deans of the respective universities. Thus, I contacted the respective deans responsible for the education programs for science teachers to seek for permission and help. I contacted the deans via the e-mail addresses listed on the homepages of the universities and briefly introduced myself and my project. Then, I extended an invitation to their teachers and students for participation in the study and explained that all collected data is for research purposes only and would be remain private and confidential. Based on the criteria I listed, the deans contacted potential candidates on my behalf. Thankfully, the response rate was 100%; all of the invitees were willing to participate in my project.

4.4 Description of Survey Tools

The study used two types of survey methods to obtain the data: questionnaires and semi-structured interviews. Questionnaires with research questions and hypotheses were handed out to the educators and the student-teachers. Following, semi-structured interviews were carried out with the educators to gain deeper insights into the thought processes behind the planning of curriculums in different universities and to learn about the factors which must be taken into consideration during the designing of these education programs. On the other hand, interviews were conducted with the student-teachers to obtain feedback about these courses from their perspectives. By feedback, I mean the usefulness of the compulsory modules, the levels of intensity of the curriculum, the methods in which each subject is taught, and the scope of comprehensiveness of the course.

The instruments used in this study include two sets of questionnaires and four sets of semi-structured interview guidelines. The names of these surveys are as follow:

(1) Questionnaire for Pre-Service Science Teacher Educators
(2) Questionnaire for Pre-Service Science Student-Teachers
(3) Semi-Structured Interview Guidelines for Educators of Pre-Service Science Teachers
(4) Semi-Structured Interview Guidelines for Pre-Service Science Student-Teachers
(5) Semi-Structured Interview Guidelines of PCK for Educators of Pre-Service Science Teachers
(6) Semi-Structured Interview Guidelines of PCK for Pre-Service Science Student-Teachers

The objectives of these questionnaires are to test for the categories of Pedagogical Practices, Teachers' Beliefs, Inquiry-Based Learning and Content Knowledge. The items on the questionnaires were all from previous studies, which would be explained in more details in Chapter five. However, some minor changes have been made to the question items so that they fit the objectives of this study. The general interview guidelines for students and teachers were designed by the researcher, based on related studies about science education. The interview guidelines for PCK referred to the study of Henze, van Driel and Verloop (2008), see details in Appendix 6.

The questionnaires and the interview guidelines were designed in English, then translated into Chinese. A copy of each survey, in both English and Chinese versions, is provided in Appendix 1-12. Below is a brief description of each instrument.

4.4.1 Questionnaire for Educators of Pre-Service Science Teachers

Educators from each sample university were asked to complete this questionnaire, which includes questions on Pedagogical Practices, Teachers' Beliefs, Inquiry-Based Learning and Content Knowledge. The questionnaire took approx. 25-30 minutes to complete.

4.4.2 Questionnaire for Pre-Service Science Student-Teachers

Student-teachers of each sample university were required to answer this questionnaire. The questionnaire also inquired about Pedagogical Practices, Teachers' Beliefs, Inquiry-Based Learning and Content Knowledge, but this time from the perspective of students. This study can thus observe similarities and differences between the ways teachers and students approach the courses. The questionnaire was designed to be completed with 25-30 minutes.

4.4.3 Semi-Structured Interview Guidelines for Educators of Pre-Service Science Teachers

This survey form for educators of science teachers was used to collect basic information about the participants, such as their educational backgrounds and teaching years. The questions were formulated in a way that allows them to express their opinions on the study curriculum, teaching approaches, teacher's role, instructional materials, and the extent of professional preparation. Additionally, participants were asked for suggestions on how to improve these education programs. The interview took 30-60 minutes to complete.

4.4.4 Semi-Structured Interview Guidelines for Pre-Service Science Student-Teachers

This survey form for science student-teachers collects basic information about the participants, such as their educational backgrounds and their motivation for choosing Science Education as their undergraduate major. It was also designed to collect data about their views of the science curriculum, their learning experience, the kinds of attitudes they acquire towards science during and after the course, student's role, and educational support for learning. Participants were also asked for suggestions on ways to improve the education program. The interview was designed to be completed in 30 to 60 minutes.

4.4.5 Semi-Structured Interview Guidelines of PCK for Educators of Pre-Service Science Teachers

The purpose of this survey was to learn about the PCK of the educators. Four elements are examined about the PCK of these participants: (a) Knowledge about instructional strategies; (b) Knowledge about the students' understanding; (c) Knowledge about ways to assess the students' understanding; (d) Knowledge about goals and objectives. It was designed to be completed in 30 to 60 minutes.

4.4.6 Semi-Structured Interview Guidelines of PCK for Pre-Service Science Student-Teachers

This survey was used to discover the PCK of the science student-teachers. The same four elements as 4.4.5 are examined in order to understand the PCK from the perspective of students. The survey was designed to be completed within 30-60 minutes. The results are then used in a comparative study with that of the educators.

4.5 Data Collection

Data collection was conducted in Chinese via questionnaires and semi-structured interviews. Both the questionnaires and semi-structured interviews were carried out at the six sample universities between October and November 2014. It took 2 days to complete the survey in each university. Due to the amount of work, one assistant was employed to collect the data. This field assistant holds a bachelor's degree in education and had experience in carrying out field work.

The objectives of the questionnaires and interviews in this study is to, on the one hand, reflect both the students and the teachers' views on Pedagogical Practices, Teachers' Beliefs, Inquiry-Based Learning and Content Knowledge in pre-service science teacher education; and on the other hand, to identify the problems and challenges that China faces in the way the country educates, or fails to properly educate, pre-service science teachers.

4.5.1 Pre-testing and Finalization of the Questionnaires and Interview Guidelines

Before the final data collection was retrieved, a pre-testing of the interview guidelines was implemented in two universities in Southwestern and Southern China, from January to February 2014, while the pre-testing of the questionnaires was carried out via e-mail at two universities in Eastern China, from July to September 2014. The questionnaires and interview guidelines had been implemented prior to the actual testing for the following purposes:

(a) to verify that the participants could understand the questions;
(b) to determine the adequacy of the sampling;
(c) to determine the relevance of questions;
(d) to assess the amount of time required to answer the questions.

Based on the findings of the pre-test, the questionnaires and interview guidelines were modified where necessary. After that, I finalized the data collection instruments under the guidance of my supervisor.

4.5.2 Data Collected from Questionnaires

732 questionnaires were handed out to the student-teachers at their respective university and then collected upon completion of the survey. The response rate was 100% and 692 (95%) questionnaires were valid. The remaining 30 (5%) questionnaires were invalid because some questions were unanswered or some answers were similar to the responses given for different questions.

In comparison, 30 questionnaires were handed out for the science teacher educators and only 20 questionnaires were given back. Out of these 20 questionnaires, only 16 were valid. The remaining 4 questionnaires were invalid because of incomplete answers. The size of data collected from the educators' questionnaires is so small that it fails to represent the majority. As a result, it becomes meaningless to analyse the data that these educators provided in this study. Therefore, this thesis will only analyse the questionnaires of science student-teachers and attempt to answer the hypotheses put out earlier.

4.5.3 Data Collected from Interviews

The technique used for the interviews was a traditional face-to-face meeting with all the interview participants. The student-teachers were interviewed as a group, based on the current level of their study. On the other hand, the educators were interviewed individually. During the interview process, open-ended questions were asked and the interviewees were given free time to answer the questions. Before conducting individual interviews with potential participants, the author contacted each of the participants via e-mail and phone calls, informing each of them of the nature and purpose of this research, as well as inviting their voluntary participation in the interviews. Altogether, 24 student-teachers and 6 teacher educators, who expressed a willingness to participate in the study, were recruited.

To make sure that the participants felt at ease, the researcher obliged the participants' preferences for the locations of the interviews, such as coffee shop, classroom or office, so that they would feel more comfortable. The researcher started off with interview session by making small talk. This is to put the interviewee at easy and to help them relax sufficiently to response to the questions naturally. During the interviews, the researcher spoke in Mandarin (the participants' mother tongue) so that they could freely express their opinions and thoughts. With the consent of each of the participants, all the interviews were recorded with a digital recorder for transcription purposes.

The interview guidelines were prepared in advance. The interviewees can read them before the commencement of the official interview. The interview guidelines were general and flexible, thus not restricting the interviewer to a specific set of questions. The interviewer had the freedom to modify or choose questions that were not listed in the guidelines, depending on the direction that the session took.

4.6 Data Processing

In order to respect the validity and reliability of the collected data, a systematic processing procedure had to be applied.

4.6.1 Data Processing of the Questionnaires' Data

For the questionnaires, the data processing mainly consisted of checking, editing and encoding data, as well as data entry. For the checking, editing and encoding parts of the process, special attention must be paid to the following: (a) whether each questionnaire had been properly completed; (b) whether all the codes had been correctly entered; (c) whether the questions were consistent. The data entry was done using SPSS 20.0 for Windows. In order to check whether the data had been correctly entered, 5% of the questionnaires were manually rechecked by the researcher on a random basis. Data entry was carried out by the researcher as well as another colleague at the Centre for Research in Primary Education (ABP) at Freie Universität Berlin.

4.6.2 Processing of the Interviews' Data

For the interviews, data processing mainly consisted of transcribing, encoding, member-checking and peer review. All the relevant recorded interview data was transcribed verbatim. In accordance with the privacy principles, private information that could identify the participants was not recorded and kept confidential.

Since Bryman (1988) has claimed that "respondent validation" occurs when researchers consistently solicit feedback on the data and conclusions from their participants (cited in Maxwell, 2006, p. 111), I sent parts of the data and its analysis to the participants at the six sample universities for validation purposes. The participants were asked whether they thought the data and analysis were accurate. I also asked them to provide some suggestions about the data analysis that may be useful for future data analysis. I also shared some parts of data analysis with two of my colleagues who specialized in qualitative research and sought their opinion on my analysis methods. Their suggestions were beneficial in the reviewing and analysis of my data.

4.7 Data Analysis

In this study, both quantitative and qualitative data was collected. The gathered information retrieved from the numerous participants pertained to the different aspects of education for pre-service science teachers in China. The data analysis included descriptive and inferential statistics. Prior to the processing of the data, providing a framework for tabulation and analysis was necessary. The analysis of the questionnaires' data was done using the tools of descriptive statistics, such as averages, standard deviation, frequency distribution, etc. Cross tabulation of relevant data was also performed.

4.7.1 Data Analysis of Questionnaires

As described earlier, the data analysis was based on six sample universities. The data sources included 692 student-teachers' questionnaires. Two important factors were taken into account during the analysis: 1) the unit of university and 2) the level of the participant's study at the time of the interview. This is to explore whether, and to what extent, Pedagogical Practices, Teachers' Beliefs, Inquiry-Based Learning and Content Knowledge existed in the pre-service science teacher programs of these six universities, and how they varied from university and university, level by level. Besides, the correlation of Pedagogical Practices, Teachers' Beliefs, Inquiry-Based Learning and Content Knowledge will also be examined to investigate the ways in which they interact with one another.

4.7.2 Data Analysis of the Interviews

The interviews were recorded on a digital recorder to enable a systematic analysis. The transcripts of the interviews were recorded by the researcher and one student assistant. All the interview data has been transcribed and reviewed carefully by the researcher and the assistant to ensure its accuracy. The interview data was encoded line by line. Charmaz (2006) pointed out that a line-by-line encoding of the interview data is helpful so that the researcher "remain[s] open to the data and (to) see nuances in it" (p.50). Then, the code category will be generated.

At the beginning of the data analysis, the researcher first studied the raw data of each participant carefully and then encoded, extracted, recorded and categorized the themes that emerged from each set of data. In order to protect the privacy of every participant, all personal information that identify the participants would not be presented in the study. Instead, I replace each of them with a code. Following, the researcher recorded all the information into tables and the content was analysed to track the consistency of the common themes that emerged from the data. The researcher then categorized and summarized the common themes. After that, these common features of the interviews were encoded, cut out and placed in one or more categories, thus cross-checking and making it convenient to track them across categories. Finally, using the research questions as a guide, the researcher generated the final findings.

Chapter 5 Data Analysis and Findings of Questionnaires

5.1 Introduction

The data for this study draws on the quantitative survey of six Chinese universities. A few samples are selected across the board to increase the diversity in the study by taking into account the difference among the science education programs, teaching and learning strategies, and content knowledge, within these universities. The sample space was created based on the following criteria:

(a) each program is a four-year bachelor's degree program at a normal university or college; (b) each program currently offers Science Education as a major; (b) the programs vary with regard to objective and curriculum; (c) the programs vary in their administration, size and location;

Among these six sample universities, Chongqing Normal University was the first university in China to introduce Science Education as a major. It aims at preparing professional science teachers for their entrance into schools. This was the start of a meaningful new era in the development of education for science teachers in China. Sichuan Normal University was chosen for its active cooperation with local primary schools in the training of science student-teachers. Taiyuan Normal University was chosen for its teaching objectives, which aims at preparing science teachers at a secondary level. This institution has already offered Science Education as a major for over ten years. Interestingly, not a single graduate student there went on to teach integrated science after graduation. Instead, they teach mathematics, chemistry, Physics and Life Sciences. Changchun Normal University was chosen for its great emphasis on Science Education. This university constantly tries its best to develop this major so as to train better and more professional science teachers. Shanghai Normal University was chosen for its location as the most advanced and modern city in China. It is the leading city in science education and contributes the most to the development of education for science teachers. Zhejiang Normal University was chosen for the important role it holds in the area of science education. In fact, the whole Zhejiang province demonstrates a keenness on developing and improving the standards of education it offers for potential science teachers. Students majoring in

Science Education in Zhejiang can easily take up an occupation as science teachers at both primary and secondary schools.

In order to have a general picture of the education programs provided for pre-service science teachers, this study selected samples from the North to the South and the West to the East of China. The selected universities vary in their location, economic and cultural background.

5.2 Questionnaire Scales

The data collection was made via questionnaires. They were edited from previous studies on how to teach science (Santau, Secada, Cone, Maerten-Rivera & Lee, 2010) and theoretical beliefs about how to learn science (Rakoczy, Buff & Lipowsky, 2005), as well as the PISA testing items for science (PISA, 2006). The questionnaire used in this study includes four scales to measure the science student-teachers' Pedagogical Practices, Teachers' Beliefs, Inquiry-Based Learning and Content Knowledge. These four scales seek to explore the nature of education programs for pre-service science teacher in China.

Questionnaire. The questionnaire included the following four scales. Each scale has ten to sixteen questions (see Appendix 1-4):

(1) *Pedagogical Practices scale* measures the learning practices of student-teachers in regard to acquiring scientific knowledge. This scale was designed by the study of Santau, Secada, Cone, Maerten-Rivera & Lee (2010).

(2) *Teachers' Beliefs scale* measures the beliefs and attitudes that the student-teachers exhibit towards the nature of science, science curriculum, teaching science and learning strategies, and their roles in class. This scale was designed according to the study of Rakoczy, Buff & Lipowsky (2005).

(3) Inquiry-Based Learning scale measures the experience of the student-teachers' in terms of Inquiry-Based Learning to examine the effectiveness of engaging in scientific learning activities as a form of knowledge acquisition. This scale was also designed according to the study of Rakoczy, Buff & Lipowsky (2005).

(4) *Content Knowledge scale* measures the knowledge that student-teachers possess in terms of scientific content. It was designed not to judge the performance of individuals, but to examine the general standard of their scientific knowledge. This scale was adopted from the science related items in PISA (2006).

To measure how often student-teachers carry out their Pedagogical Practices, this scale uses a four-point rating system (1 = never or almost never; 2 = some lessons; 3 = most lessons; and 4 = every lesson). Similarly, to measure the extent to which student-teachers reported their Teachers' Beliefs and Inquiry-Based Learning, these two scales use a four-point rating system (1 = strongly disagree; 2 = disagree; 3 = agree; and 4 = strongly agree). Meanwhile, the scale used to measure the degree of Content Knowledge that the student-teachers possess makes use of a two-point rating system (1=false, 2=right).

5.3 The Participants

The participants who make up the sample space in this study are undergraduate students majoring in Science Education. They had all completed their secondary education before entering the education programs for science teachers. Participants were also selected randomly from the pool of student-teachers who fitted the profile created for this study. Priority was given to students in advanced years of their study since they would have had more scientific training as compared to their junior counterparts. In total, 732 questionnaires were handed out to the participants and all were collected upon completion. The response rate was 100% and 692 (95%) questionnaires were valid.

The data of the general participants are presented in Figures 5.1 and 5.2. Among the 692 valid participants, 16% were male and 84% were female. The grades of the participants ranged from one to four (grade one: 10%; grade two: 34%; grade three: 35%; grade four: 21%). Specific data of some participants was analysed by Crosstable (see details in Table 5.1).

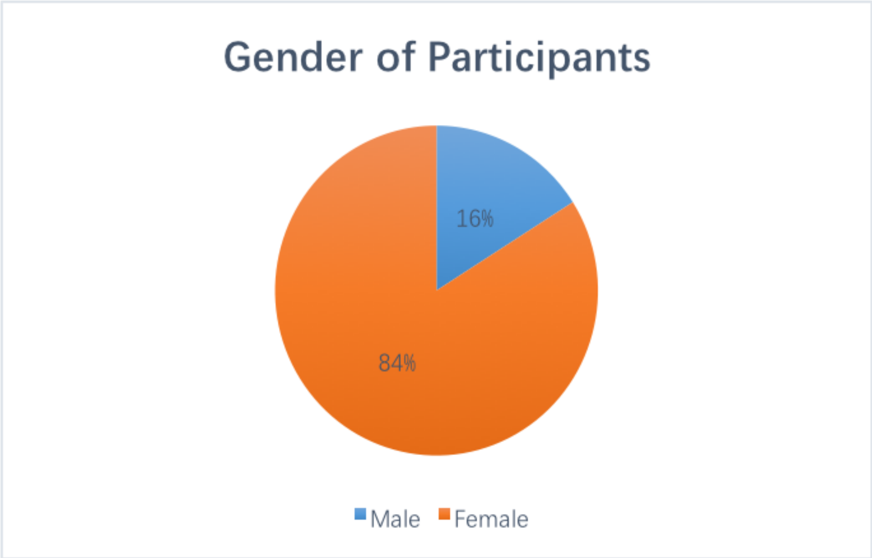

Figure 5.1: Gender of Participants

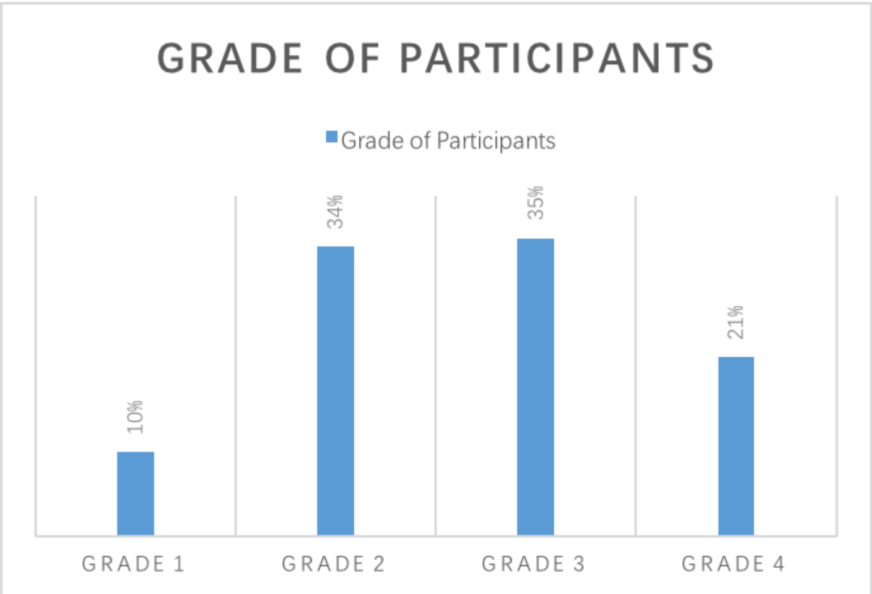

Figure 5.2: Grade of Participants

Table 5.1: Sample Participants Sorted According to University, Grade and Gender

University	Grade	Gender	
		Male	**Female**
Chongqing Normal University	Second year of study 42% (N=21)	0 .0%	21 100.0%
	Third year of study 38% (N=19)	1 5.3%	18 94.7%
	Fourth year of study 20% (N=10)	2 20.0%	8 80.0%
	Total	**3**	**47**
Sichuan Normal University	Second year of study 35.2% (N=38)	8 21.1%	30 78.9%
	Third year of study 44.4% (N=48)	2 4.2%	46 95.8%
	Fourth year of study 20.4% (N=22)	0 .0%	22 100.0%
	Total	**10**	**98**
Taiyuan Normal University	Second year of study 32.1% (N=45)	3 6.7%	42 93.3%
	Third year of study 32.9% (N=46)	1 2.2%	45 97.8%
	Fourth year of study 35% (N=49)	3 6.1%	46 93.9%
	Total	**7**	**133**

Zhejiang Normal University	Second year of study	17	45
	32.8% (N=62)	27.4%	72.6%
	Third year of study	11	48
	31.2% (N=59)	18.6%	81.4%
	Fourth year of study	15	53
	36% (N=68)	22.1%	77.9%
	Total	**43**	**146**
Changchun Normal University	First year of study	7	30
	34.3% (N=37)	18.9%	81.1%
	Second year of study	5	31
	33.3% (N=36)	13.9%	86.1%
	Third year of study	8	27
	32.4% (N=35)	22.9%	77.1%
	Total	**20**	**88**
Shanghai Normal University	First year of study	7	24
	32% (N=31)	22.6%	77.4%
	Second year of study	11	23
	35.1% (N=34)	32.4%	67.6%
	Third year of study	13	19
	33% (N=33)	40.6%	59.4%
	Total	**31**	**66**

5.4 Variables of the Questionnaires

The data used in my analysis was obtained from six Chinese universities, as described earlier. The data sources include a total of 692 questionnaires completed by the student-teachers. Since the questionnaire was created for the student-teachers, the data analysis was performed according to the university and grade of each individual to study their Pedagogical Practices, Teachers' Beliefs, Inquiry-Based Learning and Content Knowledge. Then, using the analysis results, an overall in-depth review of education programs for pre-service science teachers in China is done, which evaluates the correlation among each study item and the ways in which they influence and shape education for science teachers.

To examine the Pedagogical Practices, Teachers' Beliefs, Inquiry-Based Learning and Content Knowledge of the student-teachers, the mean values and standard deviations of the questionnaire responses were calculated, and the results were analyzed. To ensure the accuracy of the analysis, frequencies and percentages were calculated too. According to the analysis of factors, four questionnaire scales were arranged into groups to form nine new variables:

(1) Pedagogical Practices (PP): Theoretical knowledge
(2) Pedagogical Practices (PP): Methodological knowledge
(3) Teachers' Beliefs (TB): Teaching can be self-regulated by the students at school
(4) Teachers' Beliefs (TB): Teaching should be controlled by the teachers at school
(5) Inquiry-Based Learning (IBL): Learning is regulated by the students at university
(6) Inquiry-Based Learning (IBL): Learning is controlled by the teachers at university
(7) Content Knowledge (CK): Earth Sciences
(8) Content Knowledge (CK): Physics
(9) Content Knowledge (CK): Life Sciences

The reliability analysis was carried out using the variables PP, TB, IBL and CK. Internal consistency reliability estimates the scores of the scales using Cronbach's alpha (α) ranging from .623 to .741. All estimates were within an acceptable range, with the exception of the variable of TB (Teaching can be self-regulated by the students at school), which was slightly below the lower limit of the range. The reliability estimates for each scale and grade are displayed in Table 5.2.

Table 5.2: Reliability Estimates for Questionnaire Variables (Cronbach's α)

Variables	Number of Questions	Cronbach α Coefficient
PP: Theoretical knowledge	5	.741
PP: Methodological knowledge	5	.732
TB: Teaching can be self-regulated by the students at school	7	.623
TB: Teaching should be controlled by the teachers at school	9	.700
IBL: Learning is regulated by the students at university	5	.671
IBL: Learning is controlled by the teachers at university	8	.693
CK: Earth Sciences	5	.710
CK: Physics	4	.7.03
CK: Life Sciences	3	.678

5.5 Descriptive Data of the Questionnaire Variables

5.5.1 Pedagogical Practices

Since the rating system of the Pedagogical Practices was based on the answers: "never or almost never", "some lessons", "most lessons" and "every lesson", it was first necessary to describe the variables of the Pedagogical Practices in a modal manner to find out the distributions of the answers. The mean value of the scales for Pedagogical Practices are presented in Figures 5.3 and 5.4. All the results were based on the SPSS statistical analysis. See details below.

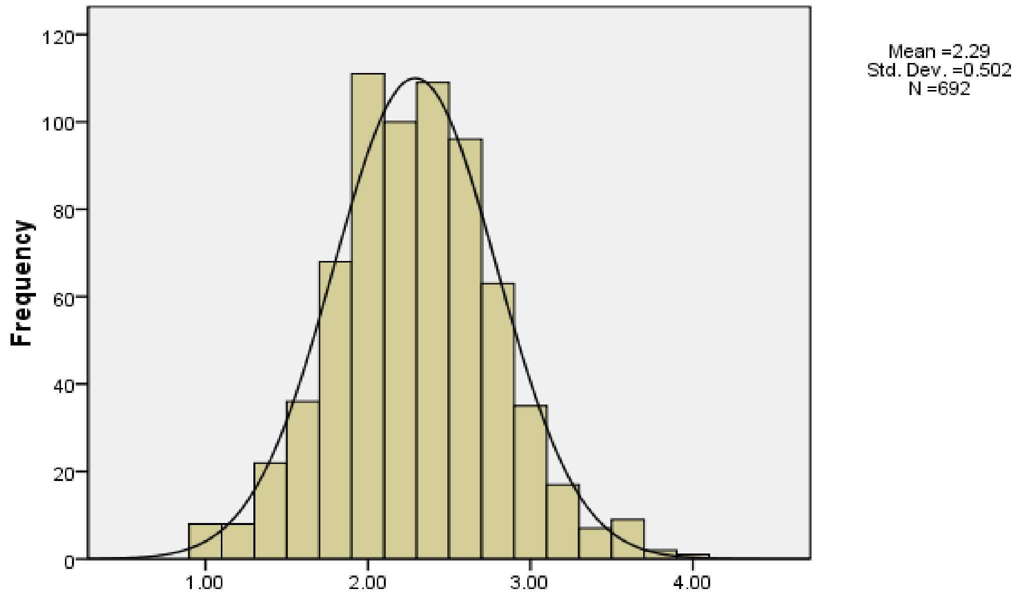

Figure 5.3: Frequency of Pedagogical Practices: Theoretical Knowledge

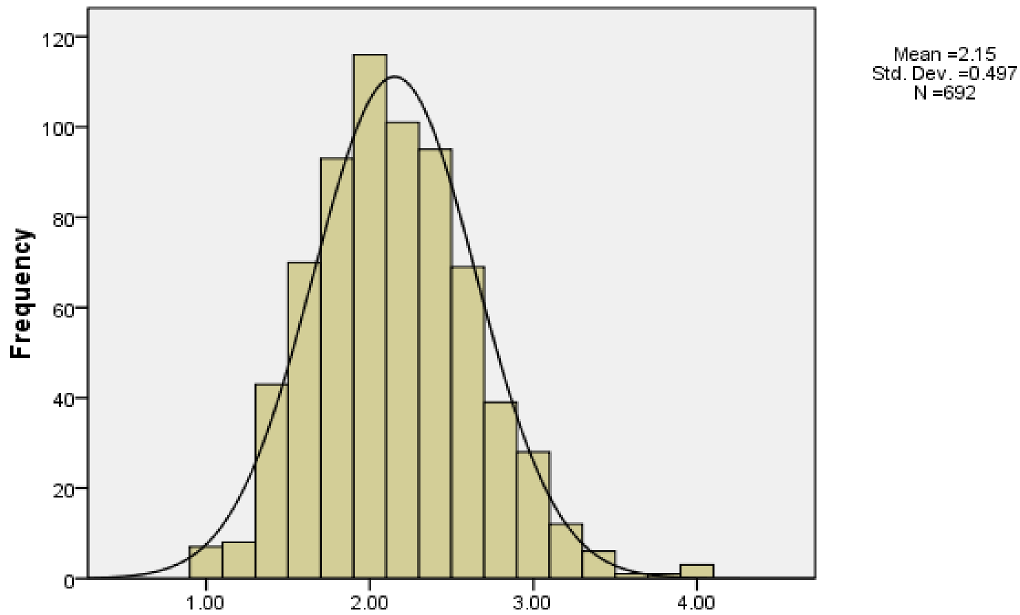

Figure 5.4: Frequency of Pedagogical Practices: Methodological Knowledge

Figures 5.3 and 5.4 show the analysis output of the variables of Pedagogical Practices. The scores of the Pedagogical Practices were based on a four-point rating system

(1=never or almost never; 2=some lessons; 3=most lessons; 4=every lesson). The mode of Pedagogical Practices is around 2. This indicates that many student-teachers acquire scientific skills through application. In other words, active participation in science experiments helps to promote scientific learning in "some lessons".

5.5.2 Teachers' Beliefs, Inquiry-Based Learning and Content Knowledge

The rating system of the Teachers' Beliefs and Inquiry-Based Learning is classified into: "strongly disagree", "disagree", "agree" and "strongly agree". It was necessary to describe these variables using the mean values so as to better understand the answers provided by the student-teachers. Content Knowledge was measured by a two-point rating system (1=false, 2=right), which tested for the extent of scientific knowledge possessed by these student-teachers. It was also necessary to describe the variables of Content Knowledge using the mean values to find out the basis of the participants' scientific knowledge. The descriptive data analysis on the Teachers' Beliefs, Inquiry-Based Learning and Content Knowledge are shown in Table 5.3.

Table 5.3: Questionnaire Variables: Means and Standard Deviations (SD)

Scale	Minimum	Maximum	Mean	SD
TB: Teaching can be self-regulated by the students at school	2.00	4.00	3.10	.346
TB: Teaching should be controlled by the teachers at school	1,89	4.00	3.01	.328
IBL: Learning is regulated by the students at university	1.20	4.00	2.91	.390
IBL: Learning is controlled by the teachers at university	1.75	4.00	2.88	.331
CK: Earth Sciences	1.00	2.00	1.59	.272
CK: Physics	1.00	2.00	1.70	.193
CK: Life Sciences	1.20	2.00	1.89	.136
Valid N=692 (listwise)				

Table 5.3 displays the analysis output of the variables for Teachers' Beliefs, Inquiry-Based Learning and Content Knowledge of the student-teachers. The scores of the Teachers' Beliefs and Inquiry-Based Learning were derived out of a four-point rating

system (1 = strongly disagree; 2 = disagree; 3 = agree; and 4 = strongly agree), while the scores of Content Knowledge were derived out of a two-point rating system (false=1, right=2). The mean values for Teachers' Beliefs were mostly around 3. This indicates that most of the student-teachers preferred to conduct their future science teaching in an inquiry-based method to discover problems and find different approaches to solve problems. The means values for Inquiry-Based Learning were mostly around the 3, which shows that most of the student-teachers have participated in activities involving inquiry when learning science at the university level. The mean values for Content Knowledge was generally around 2. This result suggests that most of the student-teachers master the knowledge of scientific content at their grade level well. Additionally, they performed exceptionally well in modules under Life Sciences.

5.6 Pedagogical Practices: Comparing Differences by University and Grade

The scale for Pedagogical Practices measures the practices of student-teachers in relation to learning science. This includes the practice of using appropriate tools to gather and analyse data, designing scientific experiments and conducting scientific investigation. This part analyses the differences in the Pedagogical Practices at each university and grade. The result shows that Pedagogical Practices vary across the different universities.

University: Setting the university as an independent variable, *theoretical knowledge* and *methodological knowledge* as dependent variables, to do One-Way Analysis of Variance (One-Way ANOVA), using Bonferroni as Post Hoc. See details in Table 5.4.

Table 5.4: Differences in Pedagogical Practices by University

Scale	University	Mean	SD	Post Hoc
PP: Theoretical knowledge (F=8.77*, df=5, Sig.=0.000)**	Chongqing Normal University	2.25	.510	n.s.
	Sichuan Normal University	2.23	.526	2<4
	Taiyuan Normal University	2.18	.429	3<4
	Zhejiang Normal University	2.47	.457	4>2,3,5,6
	Changchun Normal University	2.15	.533	5<4
	Shanghai Normal University	2.28	.521	6<4
PP: Methodological knowledge (F=2.30*, df=5, Sig.=0.043)	Chongqing Normal University	2.11	.465	n.s.
	Sichuan Normal University	2.20	.563	n.s.
	Taiyuan Normal University	2.03	.398	n.s.
	Zhejiang Normal University	2.19	.454	n.s.
	Changchun Normal University	2.17	.566	n.s.
	Shanghai Normal University	2.19	.541	n.s.

Note：$^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

Table 5.4 shows the comparison of Pedagogical Practices in the sample universities. ANOVA results indicate there are significant differences in the six universities for each of the two scales.

Except for Chongqing Normal University, post-hoc comparisons highlight the significant differences in the other five universities in the scale for *theoretical knowledge (p<.001)*. Taking these five universities into comparison, the mean values of Zhejiang Normal University (*M* =2.47) were higher than those of Chongqing Normal University, Taiyuan Normal University, Changchun Normal University and Shanghai Normal University.

Table 5.4 also shows the significant differences in the six universities in the scale for *methodological knowledge (p<.05)*. After making multiple comparisons post-hoc, I discovered that although there is no obvious difference among these six universities where methodological knowledge was concerned, there is, nevertheless, a tendency to differ in terms of characteristics. Taking all six universities into comparison, the mean value of Sichuan Normal University (M = 2.20) was found to be higher than those of the other five universities, with Taiyuan Normal University scoring the lowest (M =2.03).

Grade: Using grade as an independent variable, *theoretical knowledge* and *methodological knowledge* as dependent variables, I performed a One-Way Analysis of Variance (One-Way ANOVA), using Bonferroni, Post Hoc. See details in Table 5.5.

Table 5.5: Differences in Pedagogical Practices by Grade

Scale	Grade	Mean	SD	Post Hoc
PP: Theoretical knowledge (F=5.70, df=3, Sig.=0.001)**	First year of study	2.17	.519	1<4
	Second year of study	2.25	.503	2<4
	Third year of study	2.28	.480	3<4
	Fourth year of study	2.43	.502	4>1,2,3
PP: Methodological knowledge (F=3.04*, df=3, Sig.=0.029)	First year of study	2.09	.595	n.s.
	Second year of study	2.12	.493	2<4
	Third year of study	2.14	.486	n.s.
	Fourth year of study	2.26	.459	4>2

Note：$^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

Table 5.5 shows the comparisons of Pedagogical Practices by grades, across the six sample universities. The ANOVA results indicate that there were significant differences in the four grades for each of the two scales.

Post-hoc comparisons suggest that all four grades display significant differences in the measurement of *theoretical knowledge (p<.01)*. Taking all the grades into comparison, the mean values of grade four were found to be higher than those of the other three grades (M =2.43).

As for the differences in grades and the scale for *methodological knowledge*, post-hoc comparisons indicate that the measurement of grade four was found to be significantly different from that of grade two *($p<.05$)*. The mean values of grade four (M=2.26) are higher than those of grade two (M=2.12).

5.7 Teachers' Beliefs: Comparing Differences by University and Grade

The Teachers' Beliefs scale measures the attitudes of the student-teachers and their opinions on issues pertaining to the nature of science, their roles in the class, the curriculum of Science Education, as well as the teaching techniques and the learning strategies of science. This part analyses the differences between Teachers' Beliefs among different universities and grades. The output shows that Teachers' Beliefs vary from one university to another, as do the grading systems.

University**:** Setting the university as an independent variable, *Teaching should be controlled by the teachers at school* and *Teaching can be self-regulated by the students at school* as dependent variables, I perform a One-Way Analysis of Variance (One-Way ANOVA), using Bonferroni, Post Hoc. See details in Table 5.6.

Table 5.6: Differences in Teachers' Beliefs by University

Scale	University	Mean	SD	Post Hoc
TB: Teaching can be self-regulated by the students at school **(F=1.610, df=5, Sig.=1.55)**	Chongqing Normal University	3.00	.356	n.s.
	Sichuan Normal University	3.07	.339	n.s.
	Taiyuan Normal University	3.13	.343	n.s.
	Zhejiang Normal University	3.11	.334	n.s.
	Changchun Normal University	3.15	.342	n.s.
	Shanghai Normal University	3.10	.372	n.s.
TB: Teaching should be controlled by the teachers at school **(F=6.618***, df=5, Sig.=0.000)**	Chongqing Normal University	2.88	.278	1<5,6
	Sichuan Normal University	2.91	.326	2<4,5,6
	Taiyuan Normal University	3.02	.325	n.s.
	Zhejiang Normal University	3.02	.310	4>2
	Changchun Normal University	3.05	.337	5>1,2
	Shanghai Normal University	3.12	.334	6>1,2

Note： $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

Table 5.6 compares the Teachers' Beliefs among the six sample universities. The ANOVA results indicate that there were significant differences among them in the scale for *Teaching should be controlled by the teachers at school*, and that there was a statistically non-significant difference among the universities in the scale for *Teaching can be self-regulated by the students at school*.

Post-hoc comparisons revealed that except for Taiyuan Normal University, the other five universities exhibit significant differences in the scale for *Teaching should be controlled by the teachers at school (p<.001)*. Taking these five universities into comparison, the mean values of Chongqing Normal University (*M* =2.88) and Sichuan Normal University (*M* =2.91) were found to be lower than those of Changchun Normal University and Shanghai Normal University. Besides, the mean values of

Zhejiang Normal University (*M* =3.02) were higher than those of Sichuan Normal University.

Grade: Using grade as an independent variable, *Teaching should be controlled by the teachers at school* and *Teaching can be self-regulated by the students at school* as dependent variables, I perform a One-Way Analysis of Variance (One-Way ANOVA), using Bonferroni, Post Hoc. See details in Table 5.7.

Table 5.7: Differences in Teachers' Beliefs by Grade

Scale	Grade	Mean	Std. Deviation	Post Hoc
TB: Teaching can be self-regulated by the students at school (F=1.081, df=3, Sig.=0.356)	First year of study	3.16	.332	n.s.
	Second year of study	3.11	.321	n.s.
	Third year of study	3.08	.362	n.s.
	Fourth year of study	3.10	.364	n.s.
TB: Teaching should be controlled by the teachers at school (F=5.117, df=3, Sig.=0.002)**	First year of study	3.12	.338	1>3,4
	Second year of study	3.04	.316	n.s.
	Third year of study	2.97	.343	3<1
	Fourth year of study	2.97	.300	4<1

Note： $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

Table 5.7 presents the comparisons between Teachers' Beliefs by grades. The ANOVA results indicate that there were significant differences in the grades of the scale for *Teaching should be controlled by the teachers at school*; however, the differences in the grades for the scale of *Teaching can be self-regulated by the students at school* were non-significant.

Post-hoc comparisons brought to my attention that with the exception of grade two, the other grades (grade 1, 3 and 4) exhibited significant differences in the scale for *Teaching should be controlled by the teachers at school (p<.01)*. Taking these three grades into comparison, the mean value of grade one (*M* =3.12) was found to be higher than those of grades and grade four.

5.8 Inquiry-Based Learning: Comparing Differences by University and Grade

Inquiry-Based Learning measures the reported practices of student-teachers in learning sciences through the system of inquiry by identifying scientific questions, thinking critically and logically and considering alternative explanations. This part analyses the differences in Inquiry-Based Learning according to university and grade. The result suggests that Inquiry-Based Learning varies in the different universities and grades.

University**:** Using university as an independent variable, *Learning is regulated by the students at university* and *Learning is controlled and guided by the teachers at university* as dependent variables, I perform a One-Way Analysis of Variance (One-Way ANOVA), using Bonferroni, Post Hoc. See details in Table 5.8.

Table 5.8: Differences in Inquiry-Based Learning by University

Scale	University	Mean	SD	Post Hoc
IBL: Learning is regulated by the students at university (F=3.361, df=5, Sig.=0.005)**	Chongqing Normal University	3.04	.339	1>6
	Sichuan Normal University	2.92	.413	n.s.
	Taiyuan Normal University	2.90	.389	n.s.
	Zhejiang Normal University	2.88	.371	n.s.
	Changchun Normal University	3.00	.397	5>6
	Shanghai Normal University	2.84	.395	6<1,5
IBL: Learning is controlled by the teachers at university (F=2.415*, df=5, Sig.=0.035)	Chongqing Normal University	2.82	.287	n.s.
	Sichuan Normal University	2.84	.317	n.s.
	Taiyuan Normal University	2.89	.336	n.s.
	Zhejiang Normal University	2.86	.334	n.s.
	Changchun Normal University	2.94	.342	n.s.
	Shanghai Normal University	2.95	.330	n.s.

Note： $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

Table 5.8 shows the comparisons of Inquiry-Based Learning in the six sample universities. The ANOVA results show that there were significant differences among the universities in the two scales used for Inquiry-Based Learning.

Post-hoc comparisons indicated that there were significant differences in the scales of Chongqing Normal University, Changchun Normal University and Shanghai Normal University for *Learning is regulated by students at university (p<.01)*. Taking these three universities into comparison, the mean values of Shanghai Normal University (*M* =2.84) were found to be lower than those of Chongqing Normal University and Changchun Normal University.

Table 5.8 also shows that there were significant differences in the scales of the six sample universities for *Learning is controlled and guided by the teachers at university*. However, the post-hoc comparison results displayed differences that are non-significant among these six universities, indicating that although the tabulated comparisons demonstrated visible differences among them, these differences might be a mere manifested tendency that is contested in reality.

Grade: Setting grade to be an independent variable, *Learning is regulated by the students at university* and *Learning is controlled and guided by the teachers at university* as dependent variables, I perform a One-Way Analysis of Variance (One-Way ANOVA), using Bonferroni, Post Hoc. See details in Table 5.9.

Table 5.9: Differences in Inquiry-Based Learning by Grade

Scale	Grade	Mean	SD	Post Hoc
IBL: Learning is regulated by the students at university (F=4.014, df=3, Sig.=0.008)**	First year of study	3.05	.379	1>2
	Second year of study	2.87	.391	2<1
	Third year of study	2.92	.395	n.s.
	Fourth year of study	2.91	.373	n.s.
IBL: Learning is controlled by the teachers at university (F=4.048, df=3, Sig.=0.007)**	First year of study	2.99	.352	1>4
	Second year of study	2.90	.301	n.s.
	Third year of study	2.88	.333	n.s.
	Fourth year of study	2.83	.353	4<1

Note: $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

Table 5.9 displays the comparisons of Inquiry-Based Learning among different grades. The ANOVA results show that there were significant differences in grades of the two scales used for Inquiry-Based Learning.

Post-hoc comparisons indicate that only grades one and two displayed significant differences in the scale for *Learning is regulated by the students at university* ($p<.01$). The mean value of grade one (M=3.05) was found to be higher than that of grade two (M=2.87).

Also, post-hoc comparisons indicate significant differences between grades one and four in the scale for *Learning is controlled and guided by the teachers at university* ($p<.01$). The mean values for grade one (M=2.99) scored higher than those of grade four (M=2.83).

5.9 Content Knowledge: Comparing Differences by University and Grade

Content Knowledge measures the extent of scientific content knowledge possessed by the student-teachers. This part analyses the differences of Content Knowledge by university and grade. The main output shows that Content Knowledge varies in the different universities and grades.

***University*:** Using university as an independent variable, *Earth Sciences*, *Physics* and *Life Sciences* as dependent variables, I perform a One-Way Analysis of Variance (One-Way ANOVA), using Bonferroni, Post Hoc. See details in Table 5.10.

Table 5.10: Differences in Content Knowledge by University

Scale	University	Mean	SD	Post Hoc
CK: Earth Sciences (F=47.666*, df=5, Sig.=0.000)**	Chongqing Normal University	1.54	.275	1<4
	Sichuan Normal University	1.57	.262	2<4 2>3,5
	Taiyuan Normal University	1.44	.229	3<2,4,6

	Zhejiang Normal University	1.80	.196	4>1,2,3,5,6
	Changchun Normal University	1.47	.256	5<2,4,6
	Shanghai Normal University	1.59	.240	6<4 6>3,5
CK: Physics (F=10.733*, df=5, Sig.=0.000)**	Chongqing Normal University	1.59	.245	1<4
	Sichuan Normal University	1.62	.228	2<4
	Taiyuan Normal University	1.59	.234	3<4
	Zhejiang Normal University	1.71	.207	4>1,2,3,5,6
	Changchun Normal University	1.53	.242	5<4
	Shanghai Normal University	1.57	.221	6<1,4
CK: Life Sciences (F=6.529*, df=5, Sig.=0.000)**	Chongqing Normal University	1.81	.224	n.s.
	Sichuan Normal University	1.81	.225	2<4
	Taiyuan Normal University	1.78	.235	3<4
	Zhejiang Normal University	1.90	.162	4>2,3,5,6
	Changchun Normal University	1.78	.229	5<4
	Shanghai Normal University	1.81	.254	6<4

Note： $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

Table 5.10 displays the comparisons in Content Knowledge across the six sample universities. The ANOVA results show that there were significant differences in the three scales used for Content Knowledge.

Post-hoc comparisons indicate that all six universities exhibited significant differences in the scale for *Earth Sciences (p<.001)*. Taking all the universities into comparison, the mean values of Zhejiang Normal University scored the highest (*M* =1.80). Meanwhile, the mean values of Sichuan Normal University (*M* =1.57) and Shanghai Normal University (*M* =1.59) were found to be higher than those of Taiyuan Normal University and Changchun Normal University.

Post-hoc comparisons also suggest that the six universities all displayed significant differences in the scales for *Physics (p<.001)*. Compared with all the other universities, the mean values of Zhejiang Normal University scored the highest for Physics (*M* =1.71) while the mean values of Shanghai Normal University (*M* =1.57) were lower than those of Chongqing Normal University (*M* =1.59).

Post-hoc comparisons also indicate that except for Chongqing Normal University, the other five universities exhibited significant differences in the scales for *Life Sciences (p<.001)*. Taking all the universities into comparison, the mean values of Zhejiang Normal University was found to be the highest (*M* =1.90).

Grade: Setting grade as an independent variable, *Earth Sciences*, *Physics* and *Life Sciences* as dependent variables, I perform a One-Way Analysis of Variance (One-Way ANOVA), using Bonferroni, Post Hoc. See details in Table 5.11.

Table 5.11: Differences in Content Knowledge by Grade

Scale	Grade	Mean	SD	Post Hoc
CK: Earth Sciences (F=9.205*, df=3, Sig.=0.000)**	First year of study	1.47	.244	1<2,3,4
	Second year of study	1.59	.260	2<4
	Third year of study	1.57	.269	3<4
	Fourth year of study	1.67	.287	4>1,2,3
CK: Physics (F=5.501*, df=3, Sig.=0.001)**	First year of study	1.54	.248	1<3,4
	Second year of study	1.58	.214	2<3
	Third year of study	1.64	.228	3>1,2

	Fourth year of study	1.65	.256	4>1
CK: Life Sciences (F=2.712, df=3, Sig.=0.044)	First year of study	1.79	.250	n.s.
	Second year of study	1.80	.233	n.s.
	Third year of study	1.84	.213	n.s.
	Fourth year of study	1.85	.195	n.s.

Note: $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

Table 5.11 displays the comparisons in Content Knowledge according to grades. The ANOVA results show that there were significant differences by grades in the scales for *Earth Sciences* and *Physics*. On the other hand, it was found that the differences among the grades in the scale for *Life Sciences* is non-significant.

Post-hoc comparisons indicate that all the grades reflected significant differences in the scale for *Earth Sciences ($p<.001$)*. Taking all the grades into comparison, the mean values of grade four is the highest (*M* =1.67), while the mean values of grade one is the lowest (*M* =1.47).

Post-hoc comparisons show that all the grades exhibited significant differences in the scale for *Physics ($p<.001$)*. Taking all the grades into comparison, the mean values of grade three (*M* =1.64) was found to be higher than those of grades one and two. Besides, the mean values of grade four (*M* =1.65) scored higher than those of grade one (*M* =1.54).

5.10 Correlation of Pedagogical Practices, Teachers' Beliefs, Inquiry-Based Learning and Content Knowledge

This part analyses the correlations of Pedagogical Practices, Teachers' Beliefs, Inquiry-Based Learning and Content Knowledge, aiming to find out whether they have some kind of relationship with each other. If so, how so they correlated with each other, and in which ways. Table 5.12 reported the descriptive statistics and correlations for each scale.

Table 5.12: Correlation of Pedagogical Practices, Teachers' Beliefs, Inquiry-Based Learning and Content Knowledge

Scale	PP: Theoretical knowledge	PP: Methodological knowledge	TB: Teaching can be self-regulated by the students at school	TB: Teaching should be controlled by the teachers at school	IBL: Learning is regulated by the students at university	IBL: Learning is controlled by the teachers at university	CK: Earth Science	CK: Physics	CK: Life Science
PP: Theoretical knowledge	-*	.626**	.254**	.154**	.257**	.212**	.225**	.176**	.101**
PP: Methodological knowledge		-	.146**	.093*	.246**	.167**	.137**	.091*	.023
TB: Teaching can be self-regulated by the students at school	.	.	-	.214**	.301**	.209**	.036	.021	-.053
TB: Teaching should be controlled by the teachers at school				-	.154**	.507**	.025	.045	-.064
IBL: Learning is regulated by the students at university					-	.352**	-.070	-.002	-.012
IBL: Learning is controlled by the teachers at university						-	.020	.001	-.021
CK: Earth Sciences							-	.313**	.243**
CK: Physics								-	.184**
CK: Life Sciences									-

Note：$^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

5.10.1 Correlation of Pedagogical Practices and Teachers' Beliefs

As Table 5.12 showed, Pedagogical Practices positively associated with Teachers' Beliefs in the study. Firstly, there was a significant relationship between *Theoretical knowledge* and *Methodological knowledge*, r=.626, p <.01.

Secondly, in comparison to the correlation between *Theoretical knowledge* and *Teaching should be controlled by the teachers at school*, r=.154, *Theoretical knowledge* reflected a higher positive correlation with *Teaching can be self-regulated by the students themselves at school*, r=.254 (all *PS* <.01).

Thirdly, *Methodological knowledge* also showed a positive correlation with *Teaching can be self-regulated by the students themselves at school*, r=.146, p <.01 and *Teaching should be controlled by the teachers at school*, r=.093, p<.05.

Fourthly, the correlation between *Teaching can be self-regulated by the students themselves at school* and *Theoretical knowledge*, r=.254, p <.01 was positively higher than that between *Teaching can be self-regulated by the students themselves at school* and *Methodological knowledge* r=.146, p <.01. Additionally, the correlation between *Teaching should be controlled by the teachers at school* and *Theoretical knowledge*, r=.154, p <.01, was also positively higher than that between *Teaching should be controlled by the teachers at school* and *Methodological knowledge* r=.093, p <.05.

Moreover, *Theoretical knowledge* also displayed positive associations with *Earth Sciences*, r = .225, *Physics*, r =.176 and *Life Sciences*, r =.101 (all ps < .01).

5.10.2 Correlation of Pedagogical Practices and Inquiry-Based Learning

From Table 5.12, it can be seen that Pedagogical Practices positively correlated to Inquiry-Based Learning in the study. Firstly, *Theoretical knowledge* showed a higher positive relationship with *Learning is regulated by the students themselves at university*, r =.257 than with *Learning is controlled by the teachers at university*, r =.212 (all ps < .01).

Secondly, *Methodological knowledge* also displayed a higher positive relationship with *Learning is regulated by the students themselves at university*, r =.246 than with *Learning is controlled by the teachers at university*, r =.167 (all ps < .01).

Thirdly, *Learning is regulated by the students themselves at university* showed a positive relationship with both *Theoretical knowledge* and *Methodological knowledge*, although its relationship with *Methodological knowledge*, r =.246 was lower than that with *Theoretical knowledge*, r =.257 (all ps < .01).

Furthermore, *Learning is controlled by the teachers at university* also reflected associations with *Theoretical knowledge* and *Methodological knowledge.* Its association with *Methodological knowledge, r* =.167 was lower than that with *Theoretical knowledge, r* =.212 (all *p*s < .01).

5.10.3 Correlation between Pedagogical Practices and Content Knowledge

It was clearly seen from Table 5.12 that Pedagogical Practices positively correlated to Content Knowledge. Firstly, *Theoretical knowledge* showed a higher positive relationship with *Earth Sciences, r* =.225 than with *Physics, r* =.176 and *Life Sciences, r* =.101 (all *p*s < .01).

Secondly, *Methodological knowledge* also demonstrated a higher positive correlation with *Earth Sciences, r* =.137, *p* <.01 than with *Physics, r* =.091, *p* <.05.

Thirdly, *Earth Sciences* correlated positively to both *Theoretical knowledge* and *Methodological knowledge.* Its correlation with *Theoretical knowledge, r* =.225 was higher than with *Methodological knowledge, r* =.137 (all *p*s < .01).

Moreover, *Physics* demonstrated significant positive correlations with both *Theoretical knowledge* and *Methodological knowledge.* Its correlation with *Theoretical knowledge, r* =.176, *p*< .01 was higher than with *Methodological knowledge, r* =.091, *p*< .05.

5.10.4 Correlation between Teachers' Beliefs and Inquiry-Based Learning

Teachers' Beliefs reflected a significant positive correlation with Inquiry-Based Learning in this study. Firstly, there was a significant relationship between *Teaching can be self-regulated by the students themselves at school* and *Teaching should be controlled by the teachers at school, r*=.214, *p* <.01.

Secondly, *Teaching can be self-regulated by the students themselves at school* displayed a higher positive correlation with *Learning is regulated by the students themselves at university, r* =.301 than with *Learning is controlled by the teachers at university, r* =.209 (all *p*s < .01).

Thirdly, *Teaching should be controlled by the teachers at school* displayed a lower positive association with *Learning is regulated by the students themselves at university*, r =.154 than with *Learning is controlled by the teachers at university*, r =.507 (all ps < .01).

Fourthly, *Learning is regulated by the students themselves at university* also exhibited a higher positive relationship with *Teaching can be self-regulated by the students themselves at school*, r =.301 than with *Teaching should be controlled by the teachers at school*, r =.154 (all ps < .01).

Furthermore, *Learning is controlled by the teachers at university* displayed a lower positive correlation with *Teaching can be self-regulated by the students themselves at school*, r =.209 than with *Teaching should be controlled by the teachers at school*, r =.507 (all ps < .01).

5.10.5 Correlation between Teachers' Beliefs and Content Knowledge

Table 5.12 shows that there was no significant correlation between Teachers' Beliefs and Content Knowledge.

5.10.6 Correlation between Inquiry-Based Learning and Content Knowledge

From Table 5.12, we can see that *Learning is regulated by the students themselves at university* demonstrated a positive correlation with *Learning is controlled by the teachers at university*, r =.352, p <.01. Along the same vein, *Earth Sciences* demonstrated a higher positive association with *Physics*, r =.313 than with *Life Sciences*, r =.243. *Life Sciences* also showed a positive correlation with *Physics*, *although* its correlation with *Physics*, r =.184 was lower than that with *Earth Sciences*, r =.243 (all ps < .01). However, it was shown in the study that there was no significant correlation between Inquiry-Based Learning and Content Knowledge.

5.11 Correlation Among Pedagogical Practices, Grade and Gender

This part described the correlations among Pedagogical Practices, grade and gender, so as to find out whether they were related to one another or if they influenced one another in some way. If so, in which ways? Table 5.13 presented the descriptive statistics and correlations among all the measurements.

Table 5.13: Correlation Among Pedagogical Practices, Grade and Gender

Scale	PP: Theoretical knowledge	PP: Methodological knowledge	Grade	Gender
PP: Theoretical knowledge	-	.626**	.136**	-.029
PP: Methodological knowledge		-	.122**	-.025

Note：$^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

Firstly, Table 5.13 showed a significant positive correlation between *Theoretical knowledge* and *Methodological knowledge, r* = .626. These two were, on the other hand, found to be uncorrelated to the gender of the student-teachers. Secondly, the grade of student-teachers also positively correlated to *Theoretical knowledge, r* = .136, and *Methodological knowledge*, *r* = .122 (all *ps* < .01).

5.12 Correlation Among Teachers' Beliefs, Grade and Gender

This part described the correlations among Teachers' Beliefs, grade and gender, so as to find out whether they related to one another or if they influenced one another in some way. If so, in which ways? Table 5.14 showed the descriptive statistics and correlations among all the measurements.

Table 5.14: Correlation Among Teachers' Beliefs, Grade and Gender

Scale	TB: Teaching can be self-regulated by the students themselves at school	TB: Teaching should be controlled by the teachers at school	Grade	Gender
TB: Teaching can be self-regulated by the students at school	-	.214**	-.047	.126**
TB: Teaching should be controlled by the teachers at school		-	-.145**	.010

Note：$^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

Table 5.14 clearly showed that *Teaching can be self-regulated by the students themselves at school* was significantly correlated to *Teaching should be controlled by the teachers at school,* r = .214, and the gender of the student-teachers, r = .126. Furthermore, the grade of the student-teachers correlated negatively to *Teaching should be controlled by the teachers at school,* r = -.145 (all ps < .001).

5.13 Correlation Among Inquiry-Based Learning, Grade and Gender

This part presented the correlations among Inquiry-Based Learning, grade and gender, so as to find whether they had correlations with one another or if they affected one another in some way. If so, in which ways? Table 5.15 showed the descriptive statistics and correlations among all the measurements.

Table 5.15: Correlation Among Inquiry-Based Learning, Grade and Gender

Scale	IBL: Learning is regulated by the students themselves at university	IBL: Learning is controlled by the teachers at university	Grade	Gender
IBL: Learning is regulated by the students themselves at university	-*	.352**	-.034	.059
IBL: Learning is controlled by the teachers at university		-	-.124**	-.016

Note： $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

Table 5.15 showed that firstly, there was a significant positive relationship between *Learning is regulated by the students themselves at university* and *Learning is controlled by the teachers at university*, r = .352. These were found to be uncorrelated to the gender of the student-teachers. Secondly, the grade of the student-teachers was negatively related to *Learning is controlled by the teachers at university*, r = -.124 (all *ps* < .01).

5.14 Correlation Among Content Knowledge, Grade and Gender

This part stated the correlation among Content Knowledge, grade and gender, so as to find whether they correlated with one another or if they influenced one another in some way. If so, in which ways? Table 5.16 provided the descriptive statistics and correlations among all the measurements.

Table 5.16: Correlation Among Content Knowledge, Grade and Gender

Scale	CK: Earth Sciences	CK: Physics	CK: Life Sciences	Grade	Gender
CK: Earth Sciences	-	.313**	.243**	.160**	-.207**
CK: Physics		-	.184**	.149**	-.052
CK: Life Sciences			-	.102**	-.096*

Note：$^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

It was clear from Table 5.16 that *Earth Sciences* related positively to *Physics*, r = .313, *Life Sciences*, r = .243 and the grade of the student-teachers, r = .160. It was at the same time negatively correlated to the gender of the student-teachers, r = -.207 (all *ps* <.01). Secondly, *Physics* relates positively to *Life Sciences*, r = .184, and the grade of the student-teachers, r = .149 (all *p*s < .01). The gender of the student-teachers was found to be uncorrelated with *Physics.* Thirdly, *Life Sciences* correlated positively to the grade of the student-teachers, r = .102, p<.01 and negatively to the gender of the student-teachers, r = -.096, p< .05.

5.15 Summary

5.15.1 Findings from Comparing University and Grade

According to the data analysis of the questionnaires, we can see that education programs for pre-service science teachers in China depend largely on the Content Knowledge, Pedagogical Practices and Teachers' Beliefs. Different universities, as well as different grades, possess different levels of Content Knowledge, reflect different views towards teaching sciences, and making use of different ways to learn science. Besides, many student-teachers support the use of Inquiry-Based Learning in the education programs for pre-service science teachers.

With regard to Pedagogical Practices, on the basis of comparing each university and grade, we find that the students in Zhejiang Normal University preferred mostly to apply theoretical knowledge in their science lessons at university. As compared to students in other grades, the students in grade four applied most methodological knowledge in learning science.

Regarding Teachers' Beliefs, based on the comparison of each university and grade, the students in Sichuan Normal University believed firmly that teaching should be regulated by the students themselves when learning science at universities. Meanwhile, compared with students in higher grades, students in lower grades believed more strongly that teaching should be controlled by their teachers.

With respect to Inquiry-Based Learning, the students in Shanghai Normal University experienced less self-regulated learning as compared to students in other universities. The students in grade one experienced more self-regulated learning than those in grade two. Meanwhile, as compared to the students in grade one, the students in grade four experienced less teacher-controlled learning. This means that the students in grade four were much more subjective in their thoughts and learning process, as compared to students in other grades.

Concerning Content Knowledge, students in Zhejiang Normal University performed the best among all the six universities. The students in grades three and four performed better than those in grades one and two. This means that as compared to the students in lower grades, the students in higher grades are able to better understand and master scientific content knowledge.

5.15.2 Findings of the Correlations Among the Test Items

Pedagogical Practices demonstrated significant correlations with Teachers' Beliefs, Inquiry-Based Learning and Content Knowledge. While Teachers' Beliefs correlated to Inquiry-Based Learning closely and positively, Content Knowledge was found to be uncorrelated to Teachers' Beliefs and Inquiry-Based Learning.

With regard to Pedagogical Practices, students in the higher grades experience more pedagogical practices than those in the lower grades. With regard to Teachers' Beliefs, male student-teachers express a stronger belief than female student-teachers in the idea that teaching can be self-regulated by the students. This indicates that male student-teachers are more subjective than their female counterparts when it comes to learning. Besides, when compared with students in the higher grades, students in the lower grades have stronger beliefs that teaching should be controlled by the teachers. Pertaining to Inquiry-Based Learning, students in the lower grades experienced more teacher-controlled learning than students in the higher grades. With regard to Content Knowledge, findings showed that as student-teachers progress in their learning journey, they tended to perform better in the acquisition of content knowledge. Besides, female student-teachers performed better than their male counterparts in the acquisition of knowledge about life sciences. Meanwhile, male student-teachers performed better than the female student-teachers in acquiring knowledge about earth sciences.

Chapter 6 Data Analysis and Findings of Interviews

6.1 Introduction

In order to best answer the research questions, a combination of research methods was applied in this study. At stage one of the study, quantitative research was used while at stage two, it was followed by qualitative research. This chapter reports on the semi-structured qualitative study that was conducted at stage two. The participants were undergraduate students majoring in Science Education and were from six selected universities in China. The design for the interviews was most faithful to the research questions which were used to formulate the profile of the target participants. For example, would the research benefit from the participation of individuals of a particular profession or field? How can we select the participants in order to ensure a full representation of perspectives and experience as related to the research topic? With these considerations in mind, I selected a total of 24 science student-teachers (4 students from each university) and 6 educators of science teachers (1 teacher from each university) to take part in the interviews. Each interview lasted between 33 minutes to 2 hours. The total duration of all the interviews for student-teachers and educators took approx. 12 hours and 9 hours. See the participants' information in Tables 6.1 and 6.2.

Table 6.1: Semi-Structured Interviews of Student Participants

<table>
<tr><th rowspan="2">University</th><th rowspan="2">Student Code</th><th colspan="4">Information about Students</th></tr>
<tr><th>Gender</th><th>Grade</th><th>Department</th><th>Interview Duration</th></tr>
<tr><td rowspan="4">Chongqing Normal University</td><td>1</td><td>female</td><td>three</td><td rowspan="4">Chemistry</td><td rowspan="2">1h28m</td></tr>
<tr><td>2</td><td>female</td><td>three</td></tr>
<tr><td>3</td><td>female</td><td>four</td><td rowspan="2">1h26m</td></tr>
<tr><td>4</td><td>female</td><td>four</td></tr>
<tr><td rowspan="4">Sichuan Normal University</td><td>5</td><td>female</td><td>three</td><td rowspan="4">Chemistry and Material Science</td><td rowspan="2">1h33</td></tr>
<tr><td>6</td><td>female</td><td>three</td></tr>
<tr><td>7</td><td>female</td><td>four</td><td rowspan="2">1h35</td></tr>
<tr><td>8</td><td>female</td><td>four</td></tr>
<tr><td rowspan="4">Taiyuan Normal University</td><td>9</td><td>female</td><td>three</td><td rowspan="4">Physics</td><td rowspan="2">42m</td></tr>
<tr><td>10</td><td>female</td><td>three</td></tr>
<tr><td>11</td><td>female</td><td>four</td><td rowspan="2">1h15</td></tr>
<tr><td>12</td><td>female</td><td>four</td></tr>
<tr><td rowspan="4">Zhejiang Normal University</td><td>13</td><td>male</td><td>three</td><td rowspan="4">Chemistry and Life Sciences</td><td rowspan="2">43m</td></tr>
<tr><td>14</td><td>male</td><td>three</td></tr>
<tr><td>15</td><td>female</td><td>four</td><td rowspan="2">33m</td></tr>
<tr><td>16</td><td>female</td><td>four</td></tr>
<tr><td rowspan="4">Changchun Normal University</td><td>17</td><td>female</td><td>two</td><td rowspan="4">Physics</td><td rowspan="2">57m</td></tr>
<tr><td>18</td><td>female</td><td>two</td></tr>
<tr><td>19</td><td>female</td><td>three</td><td rowspan="2">58m</td></tr>
<tr><td>20</td><td>female</td><td>three</td></tr>
<tr><td rowspan="4">Shanghai Normal University</td><td>21</td><td>male</td><td>two</td><td rowspan="4">Life and Environmental Sciences</td><td rowspan="2">35m</td></tr>
<tr><td>22</td><td>female</td><td>two</td></tr>
<tr><td>23</td><td>female</td><td>three</td><td rowspan="2">40m</td></tr>
<tr><td>24</td><td>male</td><td>three</td></tr>
</table>

Table 6.2: Semi-Structured Interviews of Teacher Participants

University	Teacher Code	Information about teachers				
		Gender	Teaching Year	Department	Interview Duration
Chongqing Normal University	1	male	7 years	Chemistry	1h30m
Sichuan Normal University	2	female	10 years	Chemistry and Material Science	1h30m
Taiyuan Normal University	3	male	15 years	Physics	2h
Zhejiang Normal University	4	male	13 years	Chemistry and Life Sciences	1h45m
Changchun Normal University	5	male	10 years	Physics	1h
Shanghai Normal University	6	male	16 years	Life and Environmental Sciences	1h25

As can be seen from Tables 6.1 and 6.2, Science Education was offered in different departments in different universities. All of them are in the department of natural sciences instead of the department of education. There are two universities (Changchun and Shanghai Normal University) from which student participants were from grades 2 and 3. This is because the students in grade 4 from these two universities were not on campus during the period when we were collecting data. At that time, they were doing their internship at schools. As for the other four universities, the participants were all from grades 3 and 4, as planned when designing this study. In total, there were 4 students from grade 2, 12 students from grade 3, and 8 students from grade 4. Regarding gender, 20 of the participants were female while the remaining 4 were male. As for the participants who were educators, 1 of them was female while the remaining 5 were males. The lengths of time for which they had been teaching (up to the point of this study) ranged from 7 to 16 years.

6.2 Research Tools

To generate enough data for the research, the author adopted individual interviews as a research tool. This is because interviews, as one of the most important methods for data collection in the process of conducting qualitative study, can provide the researcher with abundant opportunities to understand the thinking process of the interviewees. In other words, interviews assist the researcher in probing into interviewees' inner thoughts so that a more comprehensive description of the useful and helpful information about education for science teachers can be obtained. Also, the researcher allows interviewees to freely voice their thoughts, views and experiences.

In the process of conducting interviews, a semi-structured interview guideline was implemented. This allows the interviewees more freedom to express their opinions while still providing some extent of limitation for the researcher to maintain control over the direction of the interviews. This is imperative in order for the interview sessions to be productive. To attain the research purpose (under the suggestion of author's supervisor), the author developed 2 semi-structured interview guidelines for both student-teachers and educators to collect their views about Pedagogical Practice, Teachers' Beliefs, Inquiry-Based Learning and Content Knowledge (see Appendix 5&9). Another 2 semi-structured interviews guidelines were also developed to examine their PCK. All the interview questions for the student-teachers and educators were identical, keeping the focus on the following four questions:

(1) In terms of content and methods, which options do you think are the most effective for the teaching and learning of sciences?
(2) What is the respective role of teachers and students in the class?
(3) Have you experience Inquiry-Based Learning before?
(4) How do you interpret Inquiry-Based Learning?

Other than the above, regarding the survey on PCK, the questions concentrated on the following issues (see Appendix 6&10):

(1) In which activities and sequence did your students participate in the context of this chapter? Please explain your answer.

(2) What was (were) your role(s) as a teacher, in the context of this chapter? Explain your answer.
(3) Did your students need any specific previous knowledge in the context of this chapter? Explain your answer.
(4) What was successful and difficult for your students? Explain your answer.
(5) On which basis did you assess your students in the context of this topic? Explain your answer.
(6) Did your students achieve the learning goals in this topic? How do you know? Explain your answer.
(7) What was (were) your main objective(s) in teaching the topic ‘Models of the Solar System and the Universe’? Explain your answer.
(8) Which competencies should the students gain from learning this topic?

The main objective of this study was to find out how education for pre-service science teachers is organized in China. Pedagogical Practice, Teachers’ Beliefs, Inquiry-Based Learning, Content Knowledge and Pedagogical Content Knowledge are closely linked to the research of education for teachers in general. This study hopes to find out whether they are reflected in the Chinese education programs for pre-service science teachers. It is not the intention of this study to describe in detail each individual participant’s view about Pedagogical Practice, Teachers’ Beliefs, Inquiry-Based Learning, Content Knowledge and Pedagogical Content Knowledge. Instead, the objective of this study is to identify possible similarities and differences in the students and teachers.

6.3 Data Coding

The author of this study did open coding line by line for the first round of encoding because open coding “aims at expressing data and phenomena in the form of concepts” (Flick, p. 307, 2009) and is often used at the beginning of analysis. Flick (2009) stated that open coding can be applied in various degrees of detail. A text can be coded line by line, sentence by sentence, or paragraph by paragraph, or a code can be linked to whole texts (a protocol, a case, etc.). Thus, this line by line coding made use of one word or phrases to summarize the primary topic of the excerpt, and not simply reduce it. Since this is the first round of encoding, the codes listed below are not specific types of codes. They are just the “first impression” phrases derived from the collected data. After completing the line-by-line encoding for the first round, this study explored some of the resulting codes more deeply. See examples in Table 6.3.

Table 6.3: Examples of Line-by-Line Coding

Interview Transcript	Initial Coding
Interviewer: What do you consider to be characteristic of good science teaching at university?	
Interviewee: I personally think that good science teaching[1] should be built on a good teacher-student relationship. Make your students like[2] you and they will be willing[3] to take part in your lesson. If they don't like you, they will not be interested in your lesson. Secondly, when you design the lesson, it is better to make it relatable to the students' daily life[4]. In this way, the students' interests in learning science can be motivated[5]. Thirdly, teachers should guide[6] their students to think creatively[7], encourage[8] them to ask questions[9], and help[10] them expand their thinking[11], not to limit it.	1.opinion for science teaching 2.be fond of 3.willingness to learn 4.be related to reality 5.motivate the students' interests 6. teachers' guidance 7. creative thinking 8.teachers' encouragement 9.putting questions forward 10. teachers' assistance 11. expand to think

Based on the first round of encoding, research questions and hypotheses, a second round of coding was processed. The initial codes were recoded and summarized by analysing and comparing the results to find a consistency in the common themes that emerged from the data. Five categories were hence generated. Each of them had two to four codes. The analysis of the interviews aimed at collaborating and comparing with the analysis of the questionnaires. The new categories, a few sampling codes and the rearranged sub-codes are shown in Table 6.4. The PCK codes were generated from the study of Henze, van Driel and Verloop (2008). The accuracy of the category system was verified by the author and one research assistant who is experienced in the field of qualitative study. We discussed the results and modified the categorization system.

Table 6.4: The Code Categories for the Study

Category	Code	Description
Pedagogical Practices	Theoretical Element	Code representing theoretical methods applied in the teaching and learning of sciences, such as scientific reasoning.
	Methodological Element	Code representing methodological methods applied in the teaching and learning of sciences, such as tools and experiments.
Teachers' Beliefs	Student's Role	Code representing the attitudes of the students towards the relationship with their teachers in the classroom
	Teacher's Role	Code representing the attitudes of the teachers towards the relationship with their students in the classroom
Inquiry-Based Learning	Student-Monitoring of the Learning Process	Code representing the ways in which the students learn science
	Teacher-Monitoring of the Teaching Process	Code representing the ways in which the teachers teach science
Pedagogical Content Knowledge	Knowledge in Instruction	Code representing the teachers' knowledge in the teaching of specific concepts in a certain topic, and recognizing the extent of the students' understanding of these concepts
	Knowledge about Students' Understanding	Code representing the teacher's knowledge of how much their students understand certain concepts
	Knowledge about Assessment	Code representing the methods that teachers use to assess their students, such as written or oral examination and presentation
	Knowledge about Goals and Objectives	Code representing the teachers' perspectives on learning goals, such as knowledge domain or ability domain
Content Knowledge	Declarative Knowledge	Code representing knowing that something is the case
	Procedural Knowledge	Code representing knowing how to do something.

After encoding, the next step was to analyse the data. Yin (1989) pointed out that qualitative data analysis consists of a number of stages, i.e. examining, categorizing and recombining the evidence. According to the research of Krueger & Casey (2000), it was believed that all analysis should be performed based on the objectives of the study. In other words, the researcher must return to the research questions to determine the analytical rationale.

There are a number of approaches to analyse qualitative data, i.e. ethnography, case study, content analysis, conversation analysis, discourse analysis, analytical induction and grounded theory (Flick, 2009). According to different research questions and hypotheses and to fulfil the research goals, different approaches were applied to in the analysis of data. This study adopted content analysis as an approach to data analysis. As Flick (2009) pointed out, content analysis is a very classic approach to analyse data that has been collected from interviews. He went on to point out that an important feature of content analysis was "the use of categories, which are often derived from theoretical models: categories are brought to the empirical material and not necessarily developed from it, although they are repeatedly assessed against it and modified if necessary" (p. 323).

6.4 Findings in Student-Teachers' Interviews

6.4.1 Pedagogical Practices

In order to investigate how student-teachers learned science in class, after comparing the answers and reactions of all 24 students, all of them indicated that they learned according to theory and practice. They said their courses offered many science-related subjects which trained them in doing science experiments and using various materials and tools to learn science.

> *I think our curriculum is reasonable enough as it contains three kinds of courses: general education courses, professional education courses and teacher education courses. Professional education courses are the most important because without enough Content Knowledge, you cannot become a teacher. With regard to professional courses, we will attend courses related to Chemistry, Physics, Life*

> *Sciences and scientific techniques. We also have some science-related courses focusing on experiments. (Student 3)*

> *When we attend a course on experiment, our teachers normally give us enough freedom to design the experiment and we are allowed to use different tools to solve problems. If we don't have enough materials or tools, we can seek help from the teacher (Student 4).*

However, they also indicated that compared with theoretical ways, practical methods in learning sciences were much fewer. *"Well, even we have various subjects related to science, I still think some of them are too difficult and useless. Science education needs hand-on activities, but for us, these kinds of courses are not enough"* (Student 21). Most of the students expressed a desire to put what they learnt into practice so as to understand the nature of science. Also, they hoped to learn science through collaborative learning practices or to teach their future students how to learn science using collaborative methods.

> *When I finish my four-years of study in Science Education, I hope to be able to apply what I learnt into practice, to combine theory with practice. This way I will know whether I have really understood the knowledge that I acquired in the past four years (Student 1).*

> *I would like to teach my future students how to learn science by using collaborative practices. This collaborative method can arouse the students' interest in learning science and taking part in scientific activities (Student 6).*

6.4.2 Teachers' Beliefs

With an objective to find out more about the student's role in class, I compared the answers and reactions of all 24 students. Consequently, all of the students indicated that they were still passive receivers when it comes to learning science in the class. Most of time they just recorded the teachers' notes, memorized the texts, followed the teachers' instructions and regarded teachers as authorities. They indicated that their teachers were still in a central and controlled position in the class. The teacher directed their actions most of time in the class, even stipulating which textbooks and study materials they should use.

We all know that a teacher's main task is to transmit knowledge to the students. In fact, most of our teachers can undertake this task very well. However, the approaches which they adopt are still too traditional. Currently, teachers are still the leaders and they control the whole class (Student 5).

[...]but in the actual class, most of the time, our teachers preferred to use traditional teaching methods to instruct and impart knowledge to us. Our teachers design the lesson and organize the class. From my point of view, these are teacher-centered approaches (Student 10).

When asked about the ideal relationships between students and teachers, all 24 students said that they hoped to be given subjectivity in learning, so that they can have more freedom to learn and have the ability to conduct self-regulated learning. In other words, the students want to be in centralized roles with teachers taking the backseat in the classroom. Besides, as future science teachers at schools, all of them professed a desire to be the guide in the class and to be the facilitator for the development of their students. They suggested that the teacher should only be as a guide, and not a controller, who directs the learning process and provide students with support and encouragement whenever needed.

I think the role of teachers should change from a transmitter and a figure of authority into a guide and a collaborator in the class. They should teach students how to learn, how to ask questions and resolve problems, but not directly transmit the knowledge to students[...]if I were a future science teacher, of course, I will let my students enjoy enough freedom to learn under my guidance (student 7).

Ideally, I hope that students can be in the central position in the class. In this way, students can have more freedom and take the initiative to learn. Teachers should act as assistants and guides to help us, but not control us[...] if were to teach science at school in the future, I would like to be a collaborator to my students and investigate scientific problems together with them (student 8).

6.4.3 Inquiry-Based Learning

To explore the experiences of student-teachers in learning science, the answers of all 24 students were compared. The results show that most of them had little experience in conducting scientific investigation by themselves or collaborating with others while learning science in university. They had barely experienced any inquiry-based science activities. When asked about their attitudes towards Inquiry-Based Learning, 8 student-teachers stated that if they were science teachers, they may not use Inquiry-Based Learning so often, for it's not easy to instruct or instruct, given how much freedom there is in such techniques. At the same time, these student-teachers thought that not all science topics are suitable for this method of teaching.

> *Although I admit that Inquiry-Based Learning is an effective way to encourage students to learn science. It is kind of an exploration process. But I think not all subjects or topics are suitable for Inquiry-Based Learning. If you don't prepare well or if you lack the ability to deal with inquiry-based activities,* Inquiry-Based *Learning will not benefit you at all (Student 12).*

> *Presently, most teachers still follow the traditional method of indoctrination to teach students in my university. In fact, the government has issued some important policies and carried out many long-time reforms to improve the teaching methods of teachers and come up with better ways for students to learn. But most teachers are still not willing to change their style of teaching, which makes our learning a very passive process (Student 14).*

Most of the student-teachers have expressed that they hope to acquire scientific knowledge in an inquiry-based way, i.e. through planning scientific investigations by themselves or through collaboration with others. They expressed that they hope to have more freedom to carry out scientific investigations by themselves. They suggested that their teachers could be their guides, organizers and supporters to help them engage in Inquiry-Based Learning. They hope that their teachers can encourage them to put forward questions and ideas, reflect on questions by themselves, and give them enough time to think of suitable answers (Chinn, 2007).

I prefer the Inquiry-Based Learning as a way to learn science. Inquiring is a process in which you try, modify and finally acquire knowledge. Inquiry-Based *learning can train students in critical thinking and equip them with the ability to pose questions and solve problems by themselves (Student 11).*

To me, Inquiry-Based Learning means scientific inquiry about something unknown. I think I experienced it before. When I was a primary school student, my teacher once gave us an assignment, which was to observe how caterpillars turn into butterflies. The teacher asked us to draw the changes of the caterpillar from the beginning until the end. Finally, we presented the observation findings and our teacher explained the theory to us. I think this is a kind of inquiry-based way. It is useful for students to understand scientific knowledge. And you see, I still remember this lesson even though it was so many years ago (Student 17).

6.4.4 Pedagogical Content Knowledge

When examining the PCK of student-teachers, all student-teachers responded to questions using the content of “Solar system and Universe” as examples. As future science teachers, they have already acquired some experience in teaching. When asked to share their knowledge on how to instruct, it turns out that 12 out of 24 student-teachers would like to make use of different media ways to start a lesson. 8 students indicated that they would like to start a lesson by posing questions. Another 4 students preferred to use reviews about the previous lesson to begin the new class.

When I start a lesson, normally I use different media instruments, such as power point slides or videos, to arouse the students’ interest to learn. I will select some excellent examples for students to observe, thus motivating them to start a discussion on the topic (Student 15).

When it comes to recognizing the students’ understanding of the lesson, all the student-teachers claimed that they can point out the success and difficulties of this lesson. When asked about assessment skills and concept-checking methods, 15 student-teachers stated that they prefer to use written examinations to test their future students.

Scores are indications of the students' academic competence. They are the mark of students' academic achievement and indicate the students' current situation and potential in the study of science (Student 21).

If a student often obtains higher scores in tests, he or she will have more enthusiasm to learn this course (Student 22).

I would prefer to ask the students a series of oral or written questions. If the students can answer most of the questions, it is safe to say that they have a good grasp of the knowledge. Besides, I also assess my students by asking them to explain some daily cases using the knowledge which they acquired. This is useful in correlating theory and practice (Student 14).

I did an internship as a science teacher in a primary school for three months. In that period, I always assessed my students in two ways: by observing their performances in class and by looking at the results of their homework. The homework can take the form of an observation activity, or make something by themselves, or written work. Different topics suit different types of homework (Student 13).

Regarding knowledge on goals and objectives, all the science student-teachers indicate that they could achieve the educational goals and objectives planned for them. They also hope that their students can obtain both knowledge and ability after the learning process.

The planned goals can normally be achieved, at least partially in the aspect of gaining subject matter knowledge. On this topic about the solar system and the universe, the objectives for students are: classifying objects in the solar system as stars, gas giants, terrestrial objects or other, representing the size of the planets in the solar system as a model and explaining in scientific language the origin of the solar system. I think my students can achieve at least the first two goals (Student 18).

6.4.5 Content Knowledge

In the aspect of declarative knowledge, results showed that all of the student-teachers acquired a lot of knowledge in biology, physics and chemistry. They also attended several courses on how to teach in order to become qualified teachers in the future.

> *As a teacher, the most basic requirement is to have adequate knowledge in the subject matter so that you can conduct classes. Additionally, a qualified teacher also needs to be trained in pedagogy. This means that you must know how to impart knowledge to your students in an effective manner. This is more important and complex (Student 21).*

Regarding the acquisition of procedural knowledge, which teaches students how to understand and explain knowledge, most of the student-teachers said that they may not conduct lessons in scientific reasoning. When asked if they would use some methods to prove their findings, some student-teachers said that they had experience in using experiments to test their hypotheses. They emphasized on experimentation as an important method in learning science.

> *Professional courses, such as Physics, chemistry, geography and Life Sciences, are all compulsory. These courses aim to assist us in having enough theoretical knowledge. However, I think that acquiring methodological knowledge is equally important as acquiring theoretical knowledge. If I could design the course curriculum, I hope to have more courses on how to conduct scientific research. For instance, Inquiry-Based Learning is a method which is quite often used to learn science, but we don't even know what it is (Student 2).*

6.5 Findings in Educators' Interviews

6.5.1 Pedagogical Practices

In terms of how educators teach sciences in the class, all the student-teachers emphasized on the importance of knowledge in subject matter. They think that regardless of which subject, content knowledge is the foundation. Of course, they also emphasized that in science, making use of different materials and tools to instruct experiments and hand-on activities are equally important.

> *All aspects of the content are important. Practice needs the guidance of theory. They interact with each other. I always advise my students to first learn the knowledge in the textbook carefully […] for science education, professional basic subjects (such as Physics, Chemistry, Life Sciences) and professional key modules (such as science education) are the most important. Besides, to become a teacher, training in educational subjects (such as teacher education, microteaching) are also needed (Teacher 2).*

> *From my point of view, hands-on courses are the most important. I was the instructor for a course on experiments. My course was very popular among my students as they prefer putting theory into practice. They think that conducting experiments can improve their hands-on abilities (Teacher 4).*

When asked about the ideal curriculum for Science Education, 2 teachers stated that they hope to attend more courses related to the sciences. Another 2 teachers stated that they hope to improve on their teaching methods.

> *If I could design the curriculum for Science Education, I hope to include some subjects on the nature and history of science. Our current science courses are too concentrated on subjects of the natural science, but not on science itself. I think that to learn science well, it is more effective if students learn about its origins and the ways in which science progressed (Teacher 4).*

> *Good science teaching promotes learning through collaborative methods. This kind of collaborative learning can take the form of group discussions and group activities. But sometimes, the group work is not so efficient due to the number of students and the size of the classroom. I need to organize the classroom (Teacher 1).*

6.5.2 Teachers' Beliefs

When asked about their opinion on the roles of their teachers in the class, all of the student-teachers replied that most of time the teachers control the content and the schedule of the lessons. All of them also agreed that the teachers were in a central position in the classroom.

Currently, most of teachers are still the leaders of the class. Students still play the role of the passive receivers. In fact, I was already aware this problem earlier. I found some of my students were lacking enthusiasm in being active participators in their learning journey (Teacher 3).

In the real class, most of time, I still use the traditional method to teach. I think that this is a suitable method for me to use, even though I know that this method is problematic. You see, we have so many subjects for students to learn. In order to finish the teaching tasks, sometimes I have to use the "infusion" way, which helps to impart knowledge to my students quickly and logically (Teacher 6).

When asked what they considered as an ideal role of the teacher and student in the class, 4 of them said referred to the recent reform on education and suggested that the ideal role of a teacher should be as a guide or assistant to student; while the ideal role of a student should be centralized in the classroom.

The ideal role of a teacher? Of course, as a guide. Helping students to acquire professional knowledge and guide them in developing themselves should be the priorities. But in fact, I think that the traditional role is not easy to change for both teachers and students. The current relationship between them is deeply influenced by our conventions (Teacher 5).

I think that students should be in a central position. He/she therefore can then take more initiatives during the learning process. The teacher should act as a supporter to help the students, not to control them (Teacher 1).

6.5.3 Inquiry-Based Learning

When asked about their thoughts on the educators' attitudes towards Inquiry-Based Learning, all of the student-teachers agreed that Inquiry-Based Learning is an effective way for the teaching and learning of sciences.

Of course, I admit that Inquiry-Based Learning plays an important role in science education. However, I think that not all subjects or topics are suitable to be taught in this way. For instance, some theoretical courses are unsuitable for Inquiry-Based Learning because certain concepts require too much time and effort to *inquire into. Moreover, Inquiry-Based Learning is sometimes just a form of teaching and learning technique. There was once when I tried to engage my students in scientific inquiry. I presented a theme and asked them to pose some relevant questions. However, I observed that there were some students who just kept silent and listened to the others. They didn't understand how Inquiry-Based Learning worked and so didn't know how to take part in it (Teacher 6).*

Therefore, Inquiry-Based Learning is, in my opinion, a way to guide students to into learning about the unknown by means of asking questions. In this learning process, teachers should guide students in investigating the unknown [...] according to this, students can cooperate with one another to discuss problems and carry out investigation to solve the problems (Teacher 1).

When asked how they conducted Inquiry-Based Learning in the class, 2 teachers stated that they allow very little independent thinking when they conduct scientific inquiries due to the limitation in time and the conditions of the students. Another 2 teachers replied that they applied Inquiry-Based Learning in their class, but not too often, as they doubt the effectiveness of Inquiry-Based Learning in all science topics.

Inquiry-Based classes are not so easy to conduct. It may require teachers to spend lots of time to prepare for the lesson in advance. Currently, most teachers in China are not willing to apply this technique as it is too time-consuming. As such, Inquiry-Based Learning is seen as a rather difficult method of teaching the class. Some students are passive learners and express no interest in it (Teacher 4).

Different people have different opinions about Inquiry-Based Learning. For me, it means scientific inquiry. In other words, using inquiry methods to investigate scientific concepts [...] Last summer, I opened an optional course named Inquiry-Based Experiments. The purpose of this course is to offer assistance to my students to do experiment, to help them find out the best experiment techniques. My role was to guide, while they explored by themselves (Teacher 3).

6.5.4 Pedagogical Content Knowledge

Regarding Pedagogical Content Knowledge, all 6 educators stated that they can make use of different media channels, materials and tools to instruct sciences at the university level so that students learn how to understand scientific concepts and apply theory into reality.

> *[…] Thirdly, a video would be shown to students on the teaching strategies and then put into practice by the teacher. Fourthly, let students discuss the strategies presented in the video. According to the video, students could see how other teachers taught science conceptions (Teacher 3).*

When it comes to recognizing how much knowledge their students have understood from the lessons, all 6 educators stated that they can locate the students' difficulties in learning. They claimed that they have the ability to help students solve their problems.

> *Through asking questions, observation, giving homework and tests, I could gain some sense as to whether my students have understood what I had taught. From there, I decide if I should go over a certain topic again, and how much time to spend on it again. Sometimes, you know, I did go too fast or deviate too far during the class. Some students might not have grasp the knowledge (Teacher 6)*

When asked about their ability to evaluate their own classes, all 6 educators claimed that they are able to assess the extent of their students' understanding. 3 teachers said that they prefer to use written examinations as a form of assessment. Another 3 teachers said that they prefer to assess their students by oral questions.

> *I think that content knowledge should be the most important domain we need to focus on. Unit or chapter quizzes, mid-term and final tests are ways to assess the students' performance in content learning. I don't see any other ways to evaluate (Teacher 2)*

> *I would put forward some questions to the students orally. If the students can answer most of questions, they demonstrate a grasp of the knowledge. Besides, I would also require students to explain some daily cases using the knowledge that they have acquired. This is good for relating theory with practice (Teacher 1).*

Prior to each experiment, I usually like to take a few minutes to ask a couple of questions about theories or knowledge that have been discussed in previous classes. Of course, these questions must be related to the lab activity. If the students show that they have misunderstood or forgotten, or even do not know at all, I'll go through the concepts with them again to make sure that they got the knowledge. Doing so, that assessment can help the students in their lab work. Otherwise, if we go over the relevant knowledge in the middle of the lab work, it would waste our time in the lab and make it ineffective (Teacher 3)

Where goals and objectives are concerned, all 6 teachers stated that they can help their students to achieve the study objectives, both in knowledge and ability.

At least 80% of the students can reach learning goals… for my students, the first goal is to grasp the basic operating skills of the experiments. The second goal is to have the ability to perform experiments independently. Then, it is to know how to put experiments into practice, making them useful for daily life (Teacher 4).

6.5.5 Content Knowledge

For the declarative knowledge section, all 6 educators stated that they are trained in natural sciences. They specialized in at least one domain of biology, physics or chemistry.

I graduated from Sichuan University with a doctoral degree in chemistry. Presently, I teach chemistry courses to students who major in Science Education. At the same time, I also teach students who major in chemistry. I am qualified enough to teach students in both departments. (Teacher 1)

In terms of clarity of explanations, all 6 teachers are confident in their own abilities to help their students understand the scientific concepts.

For example, once, I taught a lesson on how to create the best conditions for your experiments. The topic of discussion was "how eggs were produced". Many of my students had thought that chickens could hatch out of normal chicken eggs under appropriate condition, like temperature and pressure. They didn't know that the eggs must first be fertilized. I asked them to test their hypotheses by bringing a *couple of eggs to school to hatch. Of course, no chickens hatched from those eggs. Then, I provided some fertilized eggs I bought from a farm. You can guess the result. After that, I let them watch a video of a chicken farm. Sometimes, if budget allows, I even take them to the farm to see in person how a chicken hatches from an egg (Teacher 3).*

6.6 Summary

6.6.1 Findings in Pedagogical Practices, Teachers' Beliefs, Inquiry-Based Learning and Content Knowledge

Interview questions on Pedagogical Practices, Teachers' Beliefs, Inquiry-Based Learning and Content Knowledge concentrated on the following:

(1) What do you think, in terms of content and method, are the best for the teaching and learning of sciences?
(2) What are the respective roles of teachers and students in the class?
(3) Have you experience Inquiry-Based Learning before?
(4) How do you understand Inquiry-Based Learning?

The findings in these areas will be summarized based on these four questions. After comparing the answers of the educators and the student-teachers, both groups reflect the pre-service science teacher programs at their universities reflect the importance of Content Knowledge. The curricula at their universities offer both the declarative and procedural knowledge for students to learn science. For instance, the main science courses at their universities are chemistry, physics, biology and earth science. They all regard these are basic scientific content knowledge and key elements for the teaching and learning of sciences. They especially emphasize the basic content knowledge as essentials. Only know that something is what, they can know how to make use of it. Besides, they consider hand-on work to be very important in the teaching and learning of sciences, which can assist students to know how to conduct science and deep understand science.

But still there are some different opinions between teacher educators and student-teachers. Some teachers emphasize on the theoretical courses as they are significant in science education. Such theoretical courses include the philosophy of science and the history of science. On the other hand, the students pay less attention to these courses because from their points of view, this knowledge is too boring and useless.

Regarding to the Pedagogical Practices, all the participants agreed that both theoretical methods and methodological methods were applied in their science teaching and learning at universities. Concerning to the theoretical methods, the most frequent used method is still the traditional one – infusion method. The teachers controlled the classroom and the students follow their teachers to learn. The knowledge is not founded by the students themselves but told by the teachers. Considering the methodological methods, the teachers provided various tools and the science experiments for students to learn. The students experienced the hand-on activities.

Both educators and student-teachers regard Inquiry-Based Learning as an effective method in the teaching and learning of sciences. It is meaningful for students to experience the process of knowledge creation by themselves. However, most of the students, and even some of the teachers, are not familiar with Inquiry-Based Learning. Their knowledge on it is limited. For instance, some simply think that inquiry is to explore the unknown. Some teachers even state that they are not willing to apply inquiry-based techniques as it requires more time for preparation and is not suitable for every topic. While they admit that Inquiry-Based Learning is helpful, most of them don't actually know how to conduct it correctly. The main challenges for them may be the lack of proper understanding.

Both educators and student-teachers pointed out that the present Chinese classroom is still very much traditional. Thus, with regard to the Teachers' Beliefs, all the participants stated it is still teacher-centred belief in current Chinese classroom environments. Teachers are the authorities in the class. Students are passive receivers who are under the control of their teachers. Both of them expressed the belief that teachers should be guides and supporters in the class, giving students more freedom to control over their own learning process. In other words, the classroom should be student-centred. In this way, students can feel the happiness of study and become more active to learn. However, some teachers stated that even they agreed this ideal relationship in the classroom, but the role of the teachers is not so easy to change as it is heavily influenced by the Chinese culture.

6.6.2 Findings in Pedagogical Content Knowledge

Pedagogical Content Knowledge of both the educators and the student-teachers are examined through inspection of these four categories: knowledge of instruction, knowledge of students' understanding; knowledge of assessment; knowledge of goals and objectives. Based on the answers of the educators and the student-teachers, it was discovered that educators and student-teachers shared one common feature in their curricular knowledge. Both of them emphasized on the importance of scientific content knowledge. They believe that good science teaching can't be carried out without adequate content knowledge. Besides, they tend to use the same type of instrument to assess students, such as written examination, test and oral questions. They believe that the test results are a good way to evaluate their students. Educators who participate in this study also share some common features in the ways they deal with students' mistakes. First, they tend to point out key concepts or ideas that will help or guide the students on finding solutions for the problems. This common trait reflects their shared understanding of the scientific problems.

Despite these similarities, educators and student-teachers of this study are different in terms of Pedagogical Content Knowledge in instruction. All the participants of this study mentioned the process of teaching science. However, only participants who are professionally trained in Inquiry-Based Learning are able to engage students in asking questions and solving problems in an inquiry-based method. Obviously, educators perform better than student-teachers in the process of implementing Inquiry-Based Learning in the science classroom. This study finds that educators tend to exhibit a student-directed perspective, while students tend to display a teacher-directed view.

Chapter 7 Conclusions and Implications

Based on the overall findings of questionnaires and interviews, this chapter presents the conclusions to the research questions and hypotheses in my study.

7.1 Conclusions

This section presents the major findings of the study and focuses mainly on Pedagogical Practices, Content Knowledge, Pedagogical Content Knowledge, Teachers' Beliefs and Inquiry-Based Learning, which form the theoretical framework for this study.

7.1.1 The Importance of PP, PCK and CK in Education Programs for Pre-Service Science Teachers

One of the main findings that answers the first research question that education programs for pre-service science teachers in China reveal the importance of Pedagogical Practices in training good and professional teachers, and the lack thereof which makes such education programs in China inadequate. This study also managed to elicit some useful suggestions from actual facilitators and participants of the programs on the ways of applying theoretical knowledge to develop the students' scientific knowledge. This problematizes the traditional way of adhering strictly to the textbooks without applying too many alternative methodological strategies that would help in learning sciences. The Chinese science curriculum standards suggest that science should also be learned by applying instruments, carrying out experiments and hands-on engagement in scientific activities. However, only a small number of student-teachers apply such methodological practices when acquiring scientific knowledge. Thus, the results may affect their prospective jobs when they begin teaching in schools. They may not be familiar with the application of methodological practices in the teaching of sciences. In fact, it may even be impossible for them to teach sciences in a comprehensive manner for they themselves lack the actual scientific skills and techniques.

Although the structures of education programs for pre-service teachers vary from university to university, they share two common characteristics. First of all, the education programs for pre-service science teachers are constructed with the objectives of including Pedagogical Content Knowledge, Content Knowledge and Pedagogical Practices. The emphasis on Content Knowledge helps pre-service teachers to acquire sufficient knowledge on the subject matter for future teaching of the subjects. Pedagogical Practices help to equip the pre-service teachers with a certain level of teaching skills before they graduate so that they will be sufficiently trained in classroom management. In order to achieve these objectives, education programs for pre-service science teachers are conducted primarily by science departments in Chinese universities, such as chemistry, physics and biology. Candidates are trained not only in pedagogical knowledge and teaching practices by educators but also in science and scientific research aspects by educators from the respective science departments. Such programs provide very comprehensive training for pre-service science teachers, thereby make them well-rounded in terms of academic backgrounds. In addition, credits for general courses such as English, politics and P.E, are required in all of the education programs for pre-service science teachers. This common feature indicates that training programs are designed to develop not only teachers' knowledge and skills with regard to a certain science subject but also their spirit and literacy in humanities, which will also have an effect on their future teaching.

7.1.2 Teachers' Beliefs in Education Programs for Pre-Service Science Teachers

The main findings that answer the second research question is that education programs for pre-service science teachers in China broadly reflected the Teachers' Beliefs. Student-teachers, however, still stick to rather traditional views of science as well as the teaching and learning of sciences. As Pajares (1992) pointed out, belief is a complicated. In order to gain a more comprehensive understanding of the Teachers' Beliefs, it is necessary to first investigate teaching practices (Thompson, 1992). Based on previous investigations on Pedagogical Practices, it was found that student-teachers experienced more theoretical rather than methodological training during their training programs. This is very typical of China. Their science courses at university had a direct effect on their understanding and their teaching of science.

Based on the surveys in this study, all the teachers agree that the best way to teach is by centralising the students. In other words, the teachers should only act as the guides to assist the students in their learning journey. However, the reality is that the Chinese class is still one that is extremely teacher-centered. Students are still very much passive receivers and listeners. This contradiction may be a consequence of Chinese traditional culture – Confucianism, which has deeply influenced Chinese education for many centuries.

Furthermore, some educators refer to experimental learner-centered approaches as appropriate teaching strategies. However, it was shown from the evidences that they still use a traditional infusion approach to transfer knowledge to their students. The main reason for this is the lack of laboratory equipment, inferior teaching facilities, and the students' negative attitude towards science.

The educators in this study believe that science should ideally be taught in a student-centered approach. Most of them also believed that learning should be initiated by the students and that the teachers should only guide the learning process. The responses given by the students also suggest that a student-centered method is beneficial towards knowledge acquisition. However, when implementing this approach in the class, most of them found it was not so easy to get rid of their old learning habits and cultivate new ones. In fact, it seems that they have already gotten used to the old one and they are reluctant to accept this new approach.

7.1.3 Students' Experiences with Inquiry-Based Learning in Education Programs for Pre-Service Science Teachers

In response to the third research question, my study has proven that education programs for pre-service science teachers has incorporated Inquiry-Based Learning into the curriculum. However, making it an integral part of the curriculum will still require a lot of effort and time as my study has shown that many educators and student-teachers are still resistant or still harbour misconceptions about it. Inquiry refers to a series of intellectual processes through which students generate scientific questions, understand scientific ideas and conduct scientific investigation to study natural enigmas (NRC, 1996). It is meaningful for student-teachers to regulate their learning independently and in an inquiry-based manner. However, it must be kept in mind that even though students can self-regulate their learning process, they may still experience some difficulties in executing Inquiry-Based Learning without the guidance of their teachers.

Most of the educators surveyed in this study believe that the inquiry process is an important and effective component of a method to teach sciences. However, the teachers, for the most part, neither feel prepared to implement inquiry techniques nor do they have the necessary skills to manage inquiry activities. In addition, many teachers feel that they do not have the requisite background knowledge to effectively implement such teaching techniques. In addition, the teachers surveyed also believe that it takes too much time to develop and implement inquiry lessons. They not only struggle with managing classroom inquiry activities, but they are also concerned that students will not be able to manage their time effectively during an inquiry lesson.

There are some conflicting statements among those surveyed. Nearly all the teachers agree that inquiry is an important tool in the classroom and that it is an effective teaching method. However, more than 60 percent of the teachers were concerned that they are not prepared to use this teaching technique and that they require extensive training to be prepared to teach this way. Teachers seem to understand the importance of inquiry in sciences but unfortunately, they lack the necessary knowledge and strategies to implement it. Another contradictory statement is that teachers believe in the importance of collaboration in science and yet, they are concerned about how the students would behave during collaborative activities and do not trust that the students are able to effectively manage their time. Teachers also feel that students should design their own lab work, but at the same time, they also subscribe to the idea that students should perform labs with known outcomes so as to minimise any possible errors.

It is believed that the culture of today's science classrooms does not provide a favourable environment for inquiry-based teaching to take place. The researchers believe that issues such as the sizes of the class, the demands of the curriculum, the extent of the teacher's knowledge, and the limitation of time are all valid restrictions in the implementation of inquiry techniques.

7.1.4 Correlation between Pedagogical Practices and Teachers' Beliefs, Inquiry-Based Learning and Content Knowledge

The findings for the fourth research question suggested that Pedagogical Practices is significantly correlated to Teachers' Beliefs, Inquiry-Based Learning and Content Knowledge. Many studies have illustrated the relationship between Teachers' Beliefs and Pedagogical Practices. For example, as Mansour (2009) says, to understand the experiences of in-service or pre-service teachers will be an important task for educators of teachers, prior to the designing of programs for in-service and pre-service science teachers. It is important for both reformers and researchers to understand the complexity of the relationship between beliefs and practice. In this study, the Pedagogical Practices of student-teachers were found to be related to their beliefs. As future science teachers in schools, they must have stronger beliefs that teaching sciences can, and should, be controlled by the students themselves. This study also examines their Inquiry-Based Learning at university, it was found that students who believe teaching should be controlled by themselves have experienced more self-regulation learning at university. This indicates that beliefs could possibly play a major role in the decision-making process of those in charge of pedagogical tasks. Vice versa, Pedagogical Practices of teachers also exert an effect on their beliefs.

In this study, Pedagogical Practices are also found to be related to Inquiry-Based Learning. As the future science teachers at school, student-teachers prefer to apply both theoretical and methodological knowledge when learning sciences at university. However, they inclined towards using slightly more theoretical knowledge than methodological knowledge. Besides, when student-teachers learn sciences at university, they experienced more self-regulation. This indicates that they have had chances and the abilities to plan and arrange their own studies at university. This gives them enough freedom to explore and inquire into learning sciences. According to the US National Science Education Standards (NSES) (NRC, 1996), inquiry is not only a learning goal but also a teaching method. Nowadays in China, recent reforms in the national science curricula also attach importance to Inquiry-Based Learning. These reforms about science education identify Inquiry-Based Learning as an essential learning method to help students actively participate in science activities and cooperate with others. Consequently, student-teachers are encouraged to use Inquiry-Based Learning to learn science at university. They can not only gain a deeper understanding of the subject matter knowledge, but also acquire the knowledge for tackling complex scientific problems that occur in the real world.

7.1.5 Correlation between Teachers' Beliefs and Inquiry-Based Learning

Many proofs have illustrated a correlation between Teachers' Beliefs and Inquiry-Based Learning in the study of science education. Their beliefs could have an effect on their way of learning at university and of teaching in schools. Vice versa, each experience has an effect on one's beliefs. In this study, Teachers' Beliefs were found to have significant correlations with Inquiry-Based Learning. As the future science teachers in schools, student-teachers who believe that the teaching of sciences should be controlled by students are those who have experienced a higher exposure to self-regulated learning at university. Meanwhile, student-teachers who believe that the teaching of sciences should be controlled by teachers are often the ones who learnt by blindly absorbing everything that their teachers teach.

This indicates that Teachers' Beliefs and Inquiry-Based Learning correlated with each other closely and positively. It is thus unsurprising that the student-teachers' understandings of inquiry influence their future teaching methods and shape the way they conduct their classes at schools. Teachers should become facilitators, providing encouragement and support to enable the students to experience the process of learn by themselves. In this way, students could generate their own research questions, formulate their own research instruments, solve the questions in their own way and finally acquire the knowledge by themselves from this learning experience. Compared with the knowledge acquired directly from the teachers, this kind of learning experience can help students to understand the knowledge more deeply.

7.2 Implications

Since 2001, education for pre-service science teachers in China has been developing for more than 15 years. Ever since, thousands of science teachers have benefited from the education programs and the universities are now able to meet the demands for professional science teachers. However, in recent years, the rate at which science education is developing has slowed down considerably. This is due to several reasons, out of which insufficient recruitment, difficulty in job hunting and misunderstanding of science education, are the few main factors. Some effective measures should also be taken to improve the quality of education for pre-service science teachers, so as to prepare better qualified science teachers.

This study firstly suggests that one of the imperatives of education programs for pre-service science teachers is to transform the central role of the teacher into a secondary one and the secondary role of the student into a central one, in order to construct an inquiry-based classroom. Teachers should teach less and facilitate more so that students can self-regulate their learning process in the class. They should also offer more student-centered activities and approaches to ignite and maintain the students' interests in learning science. This will help to improve the teaching and learning of sciences.

Secondly, the study has identified that both educators and student-teachers have a very superficial understanding of Inquiry-Based Learning that is based only on its literal meaning. In fact, many of them still abide by the traditional way of teaching and learning sciences, which can be quite ineffective and impractical. For instance, teachers are under the assumption that conducting experiments by simply following the procedures is a form of Inquiry-Based Learning. There is a lack of profound understanding in the ways which Inquiry-Based Learning works. Therefore, this study suggests that both educators and student-teachers need to acquire more knowledge in scientific inquiry. It is necessary to distinguish the differences between Inquiry-Based Learning and hands-on learning. it is important for them to clarify the definition of Inquiry-Based Learning and provide more opportunities for pre-service teachers to practice these techniques and skills.

Thirdly, the study suggests that the quality of training programs for pre-service science teachers in China should be improved. It is necessary to take some measures promote the science-related content knowledge, the pedagogical knowledge to learn science and the assessment system to identify the students' achievements in their studies.

Moreover, efforts on improving education programs for pre-service teachers should focus on the adjustment of the curriculum. It was discovered that the present structure of science courses is not quite reasonable in the sense that the modules are structured in an inappropriate slant towards whichever department that is hosting the program. For instance, if science education was offered by the department of physics, there would be more physics modules than any other science modules. It is necessary to plan a precise and reasonable curriculum structure which is more balanced in the subjects that it offers.

Furthermore, efforts on improving education programs for pre-service teachers should also focus on the adjustment of the teacher's certificate. In China, for example, if you were going to be a Chinese teacher, you must acquire the teacher's certificate in the subject of Chinese, which is the same as other subjects, such as English, mathematics, chemistry and even P.E. Each subject has its own teacher's certificate. But Science– this subject is an exception. It doesn't have its own teacher's certificate till now, which means there is no science special teacher's certificate. Instead, the science teachers in current China hold the teacher's certificate in the subject of chemistry, biology, physics or even mathematics. This kind of situation is not good at preparing the professional science teachers and makes people feel that science is not the necessary subject like Chinese, English and mathematics. This as a result prevents the development of science education in China. This is also the important reason why the developing of Science Education at university slows down recently. Thus, it is very necessary and important to establish the Science its own teacher's certificate.

Finally, science education as a major is still faced with strong misunderstandings in the country. Many Chinese don't really understand what it is and attach little or no importance to it. That is the main reason for the slowing down of development in education for science teachers in recent years. The government should adopt other effective measures to raise the value and status of science, which still comes across as inferior as compared to Chinese and Mathematics. Until this problem is addressed, it would be difficult for Chinese universities (or Chinese folks, as a matter of fact) to take science education seriously.

Reference

Abell, S. K. (2008). Twenty years later: Does pedagogical content knowledge remain a useful idea? *International Journal of Science Education*, 30(10), 1405-1416.

Alexander, R. J. (2000). *Culture and pedagogy: international comparisons in primary education*. Oxford: Blackwell.

Alexander, R. (2004). Still no pedagogy? Principle, pragmatism and compliance in primary education, *Cambridge Journal of Education,* 34(1), 7-33.

Anderson, R. D. (2002). Reforming science teaching: What research says about inquiry. *Journal of Science Teacher Education,* 13(1), 1-12.

Ball, D. L., & McDiarmid, G. W. (1990). The subject-matter preparation of teachers. In W. R. Houston and M. H. J. Sikula (Eds.), *Handbook of research on teacher education* (pp. 437- 449). New York: Macmillan.

Barrett D., & Green K. (2009). Pedagogical content knowledge as a foundation for an interdisciplinary graduate program. *Science Educator*, 18(1), 17-28.

Beijaard, D., Meijer, P. C., & Verloop, N. (2004). Reconsidering research on teachers' professional identity. *Teaching and Teacher Education,* 20(2), 107-128.

Bramald, R., Hardman, F., & Leat, D. (1995). Initial teacher trainees and their views of teaching and learning. *Teaching and Teacher Education*, 11(1), 23-31.

Bryman, A. (1988). *Quantity and quality in social research.* London, Boston: Unwin Hyman publications.

Central Committee of the Communist Party of China (CCCPC). (1985). *Decision for educational infrastructure reform*. Beijing: Ministry of Education of China. (Official document). (In Chinese).

Charmaz, K. (2006). *Constructing grounded theory: A practical guide through bqualitative analysis.* London: Sage.

Corcoran, T., & Goertz, M. (1995). Instructional capacity and high performance schools. *Educational Researcher*, 24(9), 27-31.

Department of Education, Employment and Workplace Relations (2009a). *Towards a national quality framework for early childhood education and care: The report of the expert panel on quality early childhood education and care*. Commonwealth of Australia.

Dewey, J. (1933). *How we think: A restatement of the relation of reflective thinking to the educative process.* Boston: D.C. Heath.

Flick, U. (2009). *An Introduction to Qualitative Research* (4th ed.). Thousand Oaks, CA, : Sage Publications Ltd.

Gess-Newsome, J. (1999). Secondary teachers' knowledge and beliefs about subject matter and their impact on instruction. In J. Gess-Newsome & N. Lederman (Eds.), *Examining pedagogical content knowledge* (pp. 51-94). Dordrecht: Kluwer Academic Publishers.

Grossman, P. L. (1990). *The making of a teacher. Teacher knowledge and teacher education*. New York, NY: Teachers College Press.

Harlen, W., & James, M. (1997). Assessment and learning: Differences and relationships between formative and summative assessment. *Assessment in Education,* 4(3), 365-379.

Hayes, M. T. (2002). Elementary preservice teachers' struggles to define inquiry-based science teaching. *Journal of Science Teacher Education,* 13(2), 147-165.

Heinz, J., Lipowski, K., Gröschner, A., & Seidel, T. (Eds.). (2012). Indicators and instruments in the context of inquiry-based science education. Münster: Waxmann.

Henze, I., van Driel, J. H., & Verloop, N. (2008). Development of experienced science teachers’ pedagogical content knowledge of models of the solar system and the universe. *International Journal of Science Education*, 30(10), 1321-1342.

James, M & Pollard, A. (2011). TLRP's ten principles for effective pedagogy: rationale, development, evidence, argument and impact, *Research Papers in Education*, 26(3), 275-328.

Krueger, R. A. & Casey, M. A. (2000). *Focus groups: A practical guide for applied research* (3rd ed.). Thousand Oaks, CA: Sage.

Lee, E., Brown, M. N., Luft, J. A., & Roehrig, G. H. (2007). Assessing beginning secondary science teachers' PCK: Pilot year results. *School Science and Mathematics*, 107(2), 52-60.

Lemke, J. L. (1990). *Talking Science: Language, Learning and Values.* Norwood, NJ: Ablex.

Liang, L. L., Liu, X. F. & Fulmer, G. W. (Eds.) (2017). *Chinese Science Education in the 21st Century: Policy, Practice, and Research*. Dordrecht: Springer.

Liao, B. Q. (2013). *Science Education*. Beijing: Science Press.

Lietzmann, W. (1919). *Methodik des mathematischen Unterrichts, I. Teil: Organisation, Allgemeine Methode und Technik des Unterrichts*. Leipzig: Quelle & Meyer.

Linn, M. C., Davis, E. A., & Bell, P. (2004). *Internet environments for science education*. Mahawah, New Jersey: Taylor & Francis.

Magnusson, S., Krajcik, J., & Borko, H. (1999). Nature, sources and development of pedagogical content knowledge. In J. Gess-Newsome & N. G. Lederman (Eds.), *Examining pedagogical content knowledge* (pp. 95-132). Dordrecht: Kluwer Academic Publishers.

Mansour, N. (2009). Science teachers' beliefs and practices: issues, implications and research agenda. *International Journal of Environmental & Science Education,* 4(1), 25-48.

Ministry of Education (MOE) of PRC. (2001a). *An outline for the basic education curriculum reform (trial version)*. Beijing: Ministry of Education of China. (Official document), No. 17. (In Chinese)

Ministry of Education (MOE) of PRC. (2011a). *Teacher professional standards.* Retrieved from: http://www.moe.edu.cn/publicfiles/business/htmlfiles/moe/s6127/201112/127830.htm. (In Chinese)

Ministry of Education (MOE) of PRC. (2011b). *K-12 teacher qualification examinations standards*. Beijing, PRC: Higher Education Press. (In Chinese)

National Research Council. (1996). *National science education standards.* Washington, D. C.: National Academy Press.

National Research Council. (2000). *Inquiry and the national science education standards.* Washington, DC: National Academy Press.

Nespor, J. (1987). The role of beliefs in the practice of teaching. *Journal of Curriculum Studies,* 19(4), 317-328.

Niemi, R, Heikkinen, HLT & Kannas, L. (2010). Polyphony in the classroom: reporting narrative action research reflexively, *Educational Action Research*, 18(2), 137-149.

OECD Programme for International Student Assessment (OECD PISA). (2006). PISA released items-science. Retrieved from: http://www.oecd.org/pisa/38709385.pdf

Organisation for Economic Co-operation and Development (OECD). (2016). *Education in China: A Snapshot.* OECD Publishing, Paris. Retrieved from: https://www.oecd.org/china/Education-in-China-a-snapshot.pdf

Pajares, F. (1992). Teachers' beliefs and educational research: Cleaning up a messy construct. *Review of Educational Research,* 62(3), 307-332.

Rakoczy, K., Buff, A. & Lipowsky, F. (2005). Befragungsinstrumente. In E. Klieme, C. Pauli & K. Reusser (Eds.), Dokumentation der Erhebungs-und Auswertungsinstrumente zur schweizerisch-deutschen Videostudie "Unterrichts qualität, Lernverhalten und mathematisches Verständnis" (Teil 1). Frankfurt a. M.: GFPF/DIPF.

Robinson, C. & Taylor, C. (2007). Theorizing student voice: values and perspectives, *Improving Schools*, 10(5), 5-17.

Samuelowicz, K., & Bain, J. D. (1992). Conceptions of teaching and learning held by academic teachers. *Higher Education*, 24(1), 93-111.

Sang, G. Y., Valcke, M., van Braak, J., & Tondeur, J. (2009). Investigating teachers' educational beliefs in Chinese primary schools: socioeconomic and geographical perspectives. *Asia-Pacific Journal of Teacher Education*, 37(4), 363-377.

Santau, A. O., Secada, W., Maerten-Rivera, J., Cone, N., Lee, O. (2010). US urban elementary teachers' knowledge and practices: Relationship between science instruction and English language development. *International Journal of Science Educatio*n, 32(15), 2007-2032.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, 15(2), 4-14.

Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review*, 57(1), 1-22.

Speer, N. (2005). Issues of methods and theory in the study of mathematics teachers' professed and attributed beliefs. *Educational Studies in Mathematics*, 58(3), 361-391.

Spronken-Smith, R., Angelo, T., Matthews, H., O' Steen, B. & Robertson, J. (2007). *How effective is inquiry-based learning in linking teaching and research?* Paper prepared for an International Colloquium on International Policies and Practices for Academic Enquiry, Marwell, Winchester, UK, 19-21 April 2007. Retrieved from: http://portal-live.solent.ac.uk/university/rtconference/colloquium_papers.aspx

The National People's Congress (NPC). (1986). *Compulsory education act of the people's republic of China*. Retrieved from: http://www.gov.cn/flfg/2006-06/30/content_323302.htm (In Chinese).

The National People's Congress (NPC). (1993). *Teacher Law of the People's Republic of China*. Retrieved from: http://www.gov.cn/banshi/2005-05/25/content_937.htm (In Chinese).

The National People's Congress (NPC). (1995). *Education act of the people's republi c of China.* Retrieved from: http://www.moe.edu.cn/s78/A02/zfs__left/s5911/moe_ 619/201512/t20151228_226193.html (In Chinese).

Thompson, A. (1984). The relationship of teachers' conceptions of mathematics teaching to instructional practices. *Educational Studies in Mathematics, 15*(2), 105-127.

Thompson, A. (1992). Teachers' beliefs and conceptions: A synthesis of the research. In D. Grouws (Eds.), *Handbook of research on mathematics teaching and learning* (pp. 127-146). Macmillan, New York.

United Nations Development Programme (UNDP). (2015). *Human Development Re-port 2015*. Retrieved from: http://hdr.undp.org/sites/default/files/2015_human_d evelopment_report_0.pdf

Van Driel, J., Verloop, N., & De Vos, W. (1998). Developing science teachers' pedagogical Content Knowledge. *Journal of Research in Science Teaching*, *35*(6), 673-695.

Ware, S. A. (1992). *The Education of secondary Science Teachers in Developing Countries*: status and issues. Education and Employment Division. Population and Human Resources Department. PHREE Background Paper Series, Document PHREE 92/68. Washington, D.C.: World Bank.

Woolley, J. D., Boerger, E. A., Markman, A. (2004). A visit from the candy witch: Children's belief in a novel fantastical entity. *Developmental Science*, *7*(4), 456-468.

Yin, R. K. (1989). *Case Study Research: Design and Methods* (2nd ed.). London: Sage Publications.

Appendix 1:

Questionnaire Cover Letter

Dear students,

My name is Xuejiao Jia. I am a doctoral student at the Centre for Research in Primary Education of Freie Universität Berlin. My research direction is teacher education and science education. This study is sponsored by China Scholarship Council (CSC). I am at the point in my studies where I require your help.

This study will examine pre-service science teacher education in China. Science education in your university is well renowned for the excellent science teacher educators and student-teachers, who devote themselves to make science education in China better and more professional. Thus, my study is designed to collect data in your university.

The purpose of this questionnaire is to gather background information about science education in your university, and to understand your views about teacher's knowledge, teacher's belief and teaching methods in science education.

To fill this questionnaire will cost 20-25 minutes of your time. Your response is of the utmost importance to us. The validity of this investigation depends on the extent to which your responses are open and frank, so please answer honestly and in as much detail as possible. Your responses will be used for research purposes only and will remain confidential

Thank you for taking part in this research and for agreeing to fill this questionnaire.

Should you have any queries or comments regarding this survey, you are welcome to contact me via telephone or e-mail.

Yours sincerely

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Personal Data:

In this section we would like to know some basic information about you and your studying experience.

1. You are

Male	Female

2. You are studying at

University	Department

3. Your major is

4. Which grade are you in?

Grade 1	Grade 2	Grade 3	Grade 4

Section A: Pedagogical Practices (student)

On the following you will find some statements about science learning practices. There will be no best answer for each statement. Besides, there will be no individual judgment and comparison of sample participants, as well as the sample universities. Please take easy to choose!

In your science lessons at university of the last term, please indicate how often did you have the opportunity to do the followings.

In my science lessons at university of the last term...	**never or almost never**	**in some lessons**	**in most lessons**	**in every lesson**
A1. ...I explained the reasoning behind an idea.				
A2. ...I used science process skills (e.g., hypothesize, organize, infer, analyze, evaluate, describe patterns, make models or simulations).				
A3. ...I applied science concepts to explain natural events or real-world situations.				
A4. ...I used basic measurement tools (e.g., ruler, thermometer, scale/balance, timer, graduated cylinder).				
A5. ...I talked about things I did at home that were similar to what I did in science class (e.g., measurement, mixture, energy sources).				
A6. ...I used every day household items (e.g., plastic cups or containers, food coloring, light bulbs, batteries).				
A7. ...I analyzed data using tables, charts, or graphs.				
A8. ...I discussed my prior knowledge or experience related to the science topic or concept.				
A9. ...I memorized science vocabulary.				
A10. ...I wrote about what was observed and why it happened.				

Note: The test questions about Pedagogical Practices were adopted from the study of Santau, A.O. et al. (2010). US urban elementary teachers' knowledge and practices: Relationship between science instruction and English language development. The source cited from Heinz, J. et al. (2012). *Indicators and instruments in the context of inquiry-based science education* (pp. 80-81). Münster: Waxmann.

Section B: Teachers' Beliefs (student)

In very recent days, you will be a science teacher at school. On the following pages you will find a number of statements by teachers on teaching and learning science.

There will be no best answer for each statement. Besides, there will be no individual judgment and comparison of sample participants, as well as the sample universities.

We are interested in your own personal opinion. Please do choose what you really think or believe!

Please indicate to what extent you agree with the following statements.

In science lessons at schools...	**strongly disagree**	**disagree**	**agree**	**strongly agree**
B1. ...students will learn science best if they discover science-related questions and problems themselves.				
B2. ...letting students discuss their own approaches to find answers to science-related questions and problems supports their learning.				
B3. ...science should be taught at schools in such a way, that students can discover connections themselves.				
B4. ...one should allow students to think of ways to solve science-related questions and problems themselves, before the teacher demonstrates how this is done scientifically correct.				
B5. ...students should often be given opportunities to work on science-related questions and problems in pairs or small groups.				
B6. ...many science-related problems can be solved by students without the help from grown-ups.				
B7. ...students are generally not able to recognize scientific connections themselves.				
B8. ...one should generally demand of students to solve science problems the way they were taught.				
B9. ...teachers should teach precise ways to solve science problems to students.				
B10. ...students need precise instructions on how to solve scientific problems.				
B11. ...students should solve different concrete science problems, which are set in different contexts, one after the other rather than all together.				
B12. ...effective teachers will demonstrate how a science problem is to be solved.				

B13. ...students should often be offered opportunities to follow their teacher's scientifically correct way of problem solving (demonstration auf science problems or "thinking aloud" of the teacher).				
B14. ...students learn best from the demonstrations and explanations of their teachers.				
B15. ...practicing typical scientific ways of problem-solving is essential to successful thinking and problem-solving in the field of science.				
B16. ...before spending time on solving concrete science problems, the students had better practice typical ways of solving science problems.				

Note: The test questions about Teachers' Beliefs were adopted based on the study of Rakoczy, Buff & Lipowsky (2005). Befragungsinstrumente. In E. Klieme, C. Pauli & K. Reusser (Eds.), *Dokumentation der Erhebungs-und Auswertungsinstrumente zur schweizerisch-deutschen Videostudie "Unterrichtsqualität, Lernverhalten und mathematisches Verständnis" (Teil 1)*. Frankfurt a. M.: GFPF/DIPF.

The Author translated the test questions into English.

Section C: Inquiry-Based Learning (student)

On the following you will find some statements about science learning. There will be no best answer for each statement. Besides, there will be no individual judgment and comparison of sample participants, as well as the sample universities.

We are interested in your own personal opinion. please do choose what you really think!

Please indicate to what extent you agree with the following statements.

In our science lessons at university…	strongly disagree	disagree	agree	strongly agree
C1. ...we are encouraged to discover science-related questions and problems ourselves.				
C2. ...in order to support our science learning, we are allowed to discuss our own approaches to find answers for science-related questions and problems.				
C3. ...science is taught at our universities in such a way, so that we can discover connections ourselves.				
C4. ...we are allowed to think of ways to solve science-related questions and problems ourselves, before our teachers demonstrate how this is done scientifically correct.				
C5. ...we are given opportunities to work on scientific-related questions and problems in pairs or small groups.				
C6. ...we are demanded to solve science problems by the way we are taught.				
C7. ...we need precise instructions to solve scientific problems				
C8. ...we are allowed to solve different concrete science problems, which are set in different contexts, one after the other rather than together.				
C9. ...our teachers demonstrate for us how a science problem is to be				

solved.				
C10. ...we are often offered opportunities to follow our teachers' scientifically correct ways of problem solving.				
C11. ...we learn best from the demonstrations and explanations of our teachers.				
C12. ...in order to make us successfully think and solve problem in the field of science, our teachers lets us practice typical scientific ways of problem-solving.				
C13: ...we practice typical ways of solving science problems before we spend time on solving concrete science problem.				

Note: The test questions about Inquiry-Based Learning were designed by the author based on the study of Rakoczy, Buff & Lipowsky (2005). Befragungsinstrumente. In E. Klieme, C. Pauli & K. Reusser (Eds.), *Dokumentation der Erhebungs-und Auswertungsinstrumente zur schweizerisch-deutschen Videostudie "Unterrichtsqualität, Lernverhalten und mathematisches Verständnis"(Teil 1)*. Frankfurt a. M.: GFPF/DIPF.

The Author translated the test questions into English.

Section D: Content Knowledge (student)

In very recent days, you will be a science teacher at school. This section would like to find out the level of knowledge of future science teachers in China. There will be no individual judgment and comparison of sample participants, as well as the sample universities.

Our interests will not focus on the individual score, and only looking for the mean score of the whole participants in this study. Please take easy to do these questions!

Please choose ONLY ONE answer with √ for each question.

D1. Which statement explains why daylight and darkness occur on Earth?

A The Earth rotates on its axis. ☐

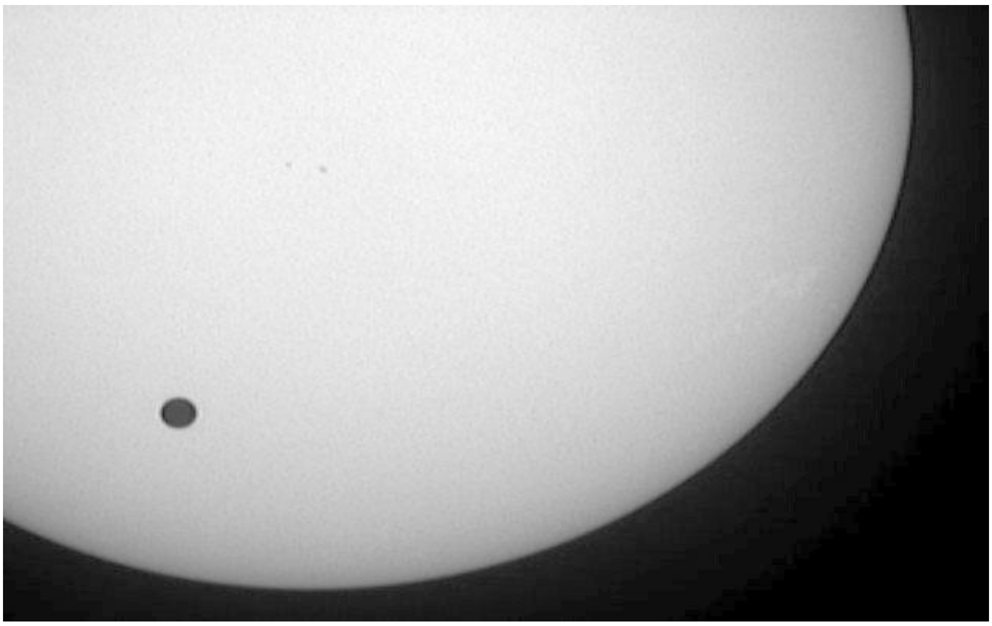
B The Sun rotates on its axis. ☐

C The Earth's axis is tilted. ☐

D The Earth revolves around the Sun. ☐

On 8 June 2004, the planet Venus could be seen passing in front of the Sun when viewed from many places on Earth. This is called a "transit" of Venus and happens when its orbit takes Venus between the Sun and Earth. The previous transit of Venus occurred in 1882 and another took place in 2012.

Below is a picture of the transit of Venus in 2004. A telescope was pointed at the Sun and the image projected onto a white card. Based on these information, please answer questions **D2 and D3.**



D2. Why was the transit observed by projecting the image onto a white card, rather than by looking directly through the telescope?

A The Sun's light was too bright for Venus to show up. ☐

B The Sun is big enough to see without magnification. ☐

C Viewing the Sun through a telescope may damage your eyes. ☐

D The image needed to be made smaller by projecting it onto a card. ☐

D3. When viewed from Earth, which one of the following planets can be seen in transit across the face of the Sun at certain times?

A Mercury ☐

B Mars ☐

C Jupiter ☐

D Saturn ☐

Xiaoming is working on repairs to an old house. He has left a bottle of water, some metal nails, and a piece of timber inside the boot of his car. After the car has been out in the sun for three hours, the temperature inside the car reaches about 40 ºC. Based on these information, please answer questions **D4.**

D4. What happens to the objects in the car? Circle "Yes" or "No" for each statement.

Does this happen to the object(s)?	**Yes or No?**
They all have the same temperature.	Yes or No?
After some time the water begins to boil.	Yes or No?
After some time the metal nails begin to glow red.	Yes or No?

For drinks during the day, Li Mei has a cup of hot coffee, at a temperature of about 90 ºC, and a cup of cold mineral water, with a temperature of about 5 ºC. The cups are of identical type and size and the volume of each drink is the same. Li Mei leaves the cups sitting in a room where the temperature is about 20 ºC. Based on these information, please answer question **D5**.

D5. What are the temperatures of the coffee and the mineral water likely to be after 10 minutes?

A 70 ºC and 10 ºC ☐

B 90 ºC and 5 ºC ☐

C 70 ºC and 25 ºC ☐

D 20 ºC and 20 ºC ☐

Tobacco smoke contains many harmful substances. The most damaging substances are tar, nicotine and carbon monoxide. Tobacco smoke is inhaled into the lungs. Tar from the smoke is deposited in the lungs and this prevents the lungs from working properly. Tobacco smoking increases the risk of getting lung cancer and some other diseases. Based on these information, please answer question **D6 and D7.**

D6. Which one of the following is a function of the lungs?

A To pump oxygenated blood to all parts of your body ☐

B To transfer some of the oxygen that you breathe to your blood ☐

C To purify your blood by reducing the carbon dioxide content to zero ☐

D To convert carbon dioxide molecules into oxygen molecules ☐

D7. Is the risk of getting the following diseases increased by tobacco smoking? Circle "Yes" or "No" in each case.

Is the risk of contracting this disease increased by smoking?	Yes/No
Bronchitis	Yes / No
HIV/AIDS	Yes / No
Chicken pox	Yes / No

Zhang San likes to look at stars. However, he cannot observe stars very well at night because he lives in a large city. Last year Zhang San visited the countryside where he observed a large number of stars that he cannot see when he is in the city. Based on these information, please answer question **D8**.

D8. Why can many more stars be observed in the countryside than in large cities?

A The moon is brighter in cities and blocks out the light from many stars. ☐

B There is more dust to reflect light in country air than in city air.

C The brightness of city lights makes many stars hard to see.

D The air is warmer in cities due to heat emitted by cars, machinery and houses.

Xiaohong uses a telescope with a large diameter lens in order to observe stars of low brightness. Based on these information, please answer question **D9**.

D9. Why does using a telescope with a large diameter lens make it possible to observe stars of low brightness?

A The larger the lens the more light is collected.

B The larger the lens the more it magnifies.

C Larger lenses allow more of the sky to be seen.

D Larger lenses can detect the dark colours in stars.

D10. Which one of the following statements best applies to the scientific theory of evolution?

A The theory cannot be believed because it is not possible to see species changing.

B The theory of evolution is possible for animals but cannot be applied to humans.

C Evolution is a scientific theory that is currently based on extensive evidence.

D Evolution is a theory that has been proven to be true by scientific experiments.

The higher the altitude the more slowly windmills rotate at the same wind speed. Based on these information, please answer question **D11**.

D11. Which one of the following is the best reason why the blades of windmills rotate more slowly in higher places at the same wind speed?

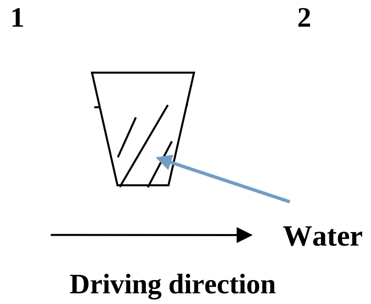
A The air is less dense as altitude increases.

B The temperature is lower as altitude increases.

C Gravity becomes less as altitude increases.

D It rains more often as altitude increases.

A bus is driving along a straight stretch of road. The bus driver, named Ray, has a cup of water resting on the dashboard:



Suddenly Ray has to slam on the brakes. Based on these information, please answer question **D12**.

D12. What is most likely to happen to the water in the cup?

A The water will stay horizontal. ☐

B The water will spill over side 1. ☐

C The water will spill over side 2. ☐

D The water will spill but you cannot tell if it will spill at side 1 or side 2. ☐

Note: The test questions about Content Knowledge were literally taken from the PISA science test questions in 2006. Retrieved from: http://www.oecd.org/pisa/38709385.pdf

Appendix 2:

关于职前科学教师教育的调查问卷

亲爱的同学，

您好！

我叫贾雪姣，是柏林自由大学基础教育研究中心的博士生，研究方向是教师教育和科学教育，博士课题由中国国家留学基金管理委员会资助。

我的博士课题拟调查研究中国职前阶段的科学教师教育。贵校的科学教育专业拥有优秀的师资，培养出了许多优秀的科学教师，使得中国的科学教育专业发展地更好更专业。因此，本研究拟在贵校进行调查研究以及收集数据。

本问卷拟收集关于职前科学教师教育的相关数据。具体来说，您作为一名科学教育专业的学生，未来的中小学科学教师，是如何看待科学教育的？您将如何培养未来的学生？您对教师知识、教师信念以及教学方法的观点又是什么？

本问卷大概需要您 20-25 分钟的时间来完成。本问卷调查的有效性与您答案的真实性密切相关，您的答案对本次研究非常重要。因此，请根据您的实际情况，真实回答这些问题。您的答案只用作研究，个人信息以及答案会被严格保密。

对于本次问卷调查，如果您有任何问题，欢迎随时通过电话或邮件联系我。

非常感谢您参与本次研究并填写本问卷！！

诚挚地

贾雪姣

柏林自由大学博士生

邮箱: innocencejia@hotmail.com

手机（德国）: XXXXX

个人信息:

通过这部分，我们希望了解一些您的个人基本情况和学习经历。

1. 您的性别是（请选择）

男	女

2. 您的学习单位是（请填写出具体的大学和学院名称）

大学	学院

3. 您的专业是（请填写出具体的专业名称）

4. 您的年级是（请选择）

1 年级	2 年级	3 年级	4 年级

A 部分: 学习实践 (学生)

下列陈述是关于科学这门学科的一些课堂学习实践。请根据您的实际情况作出选择。请注意，下列各个陈述并没有最佳的答案。此外，本研究也不会对问卷的参与者以及参与学校进行个人评判和比较。请根据您上学期的科学课程学习情况，选择出下列您所经历过的学习实践。请根据您的实际情况用“√”作出选择。

在我上学期的科学课程学习中......	**从不或几乎不**	**在一些课堂中**	**在大多数课堂中**	**在每节课堂中**
A1. ......我解释推理了每个科学观点背后的东西。				
A2. ......我使用了一些科学技能（例如：假设、组织、推断、分析、评估、描述模式、建模或者模拟）来学习科学。				
A3. ......我运用了一些科学概念去解释自然事件或真实世界的情况。				
A4. ......我使用了一些基本测量工具（例如：尺子、温度计、天平、计时器、量筒）来学习科学。				
A5. ......我通过讨论在家所经历的一些科学实践（例如：测量、混合、能源资源）来学习科学。				
A6. ......我使用了一些日常家庭用品（例如：塑料杯子或者容器、食品着色剂、灯泡、电池）来学习科学。				
A7. ......我使用表格、图表或者曲线图来分析数据，学习科学。				
A8. ......我通过讨论我已有的相关科学知识或者经验来学习科学。				
A9. ......我记忆了科学词汇。				
A10. ......我记录了我所观察到的科学问题以及它产生的原因。				

Note: The test questions about Pedagogical Practices were adopted from the study of Santau, A.O. et al. (2010). US urban elementary teachers' knowledge and practices: Relationship between science instruction and English language development. Test questions retrieved from Heinz, J. et al. (2012). *Indicators and Instruments in the context of inquiry-based science education* (pp. 80-81). Muenster: Waxman. The author translated the test questions into Chinese.

B 部分: 教师信念 (学生)

不久的将来，您可能会成为一名小学的科学教师。在下面，您会发现其他科学教师所提出的一些关于科学这门学科的教学和学习观点。

请注意，每一个陈述并没有最佳的答案，我们只对您的个人想法和观点感兴趣。此外，本研究也不会对问卷的参与者以及参与学校进行个人评判和比较。

请根据您最真实的想法和观点，用“ √ ”作出选择。

在小学的科学课中......	**非常不同意**	**不同意**	**同意**	**非常同意**
B1. ......假如学生能够自己发现科学问题，那么他们能够将科学学得最好。				
B2. ......让学生通过讨论发现解决科学问题的方法，这有利于学生的科学学习。				
B3. ......小学的科学课应该以这样一种方式被教授——让学生自己发现科学内部的相关联系。				
B4. ......在教师对科学问题进行论证之前，教师应该允许学生先提出自己的观点和方法。				
B5. ......应该让学生经常有机会以小组学习的方式来讨论和研究科学问题。				
B6. ....在没有教师的帮助下，学生能够自己解决许多科学问题。				
B7. ......一般情况下，学生不能自己发现科学内部的相关联系。				
B8. ......一般情况下，教师应该要求学生通过他/她所教授的方法来解决科学问题。				
B9. ......教师应该教授学生解决科学问题的正确方法。				
B10. ......解决科学问题时，学生需要正确的指导。				
B11. ......学生在解决不同背景下产生的科学问题时，应逐一解决而非将这些问题混淆在一起解决。				
B12. ......好的教师会论证科学问题的解决过程。				

B13. ......应该经常让学生有机会练习教师所运用的科学问题解决方法（例如：论证科学问题、放声思维方法）。				
B14. ......学生通过教师的论证和解释可以学得最好。				
B15. ......如果想在科学领域中成功地思考和解决问题，有必要对典型的科学问题解决方法进行练习。				
B16. ......在解决具体的科学问题之前，学生最好先对典型的科学问题解决方法进行练习。				

Note: The test questions about Teachers' Beliefs were adopted based on the study of Rakoczy, Buff & Lipowsky (2005). Befragungsinstrumente. In E. Klieme, C. Pauli & K. Reusser (Eds.), *Dokumentation der Erhebungs-und Auswertungsinstrumente zur schweizerisch-deutschen Videostudie "Unterrichtsqualität, Lernverhalten und mathematisches Verständnis" (Teil 1)*. Frankfurt a. M.: GFPF/DIPF.

The Author firstly translated the questions into English, then into Chinese.

C 部分: 探究性学习 (学生)

下列陈述是关于科学这门学科的一些学习方法。

请注意，每一个陈述并没有最佳的答案，我们只对您的个人想法和观点感兴趣。此外，本研究也不会对问卷的参与者以及参与学校进行个人评判和比较。

请根据您最真实的想法和观点，用“√”作出选择。

在我们的大学科学课中......	**非常不同意**	**不同意**	**同意**	**非常同意**
C1. ......我们会自己去发现科学问题来进行科学学习。				
C2. ......为了更好地进行科学学习，我们会进行自我讨论，自己发现解决科学问题的方法。				
C3. ......我们通过发现科学内部的相关联系，来进行科学学习。				
C4. ......在老师论证科学问题之前，我们会提出自己的观点和方法。				
C5. ......我们经常有机会以小组学习的方式来讨论和研究科学问题。				
C6. ......我们使用老师教的方法来解决科学问题。				
C7. ......解决科学问题时，我们需要老师的正确指导。				
C8. ......我们会对不同背景下产生的科学问题进行逐一地解决，而非将这些问题混淆在一起解决。				
C9. ......老师会为我们论证科学问题的解决过程。				
C10. ......我们经常有机会，练习老师教授给我们的科学问题解决方法。				
C11. ......我们能够通过老师的论证和解释学得最好。				
C12. ......为了让我们在科学领域中成功地思考和解决问题，老师会让我们对典型的科学问题解决				

方法进行练习。				
C13: ......在解决具体的科学问题之前，我们会对典型的科学问题解决方法进行练习。				

Note: The test questions about Inquiry-Based Learning were designed by the author based on the study of Rakoczy, Buff & Lipowsky (2005). Befragungsinstrumente. In E. Klieme, C. Pauli & K. Reusser (Eds.), *Dokumentation der Erhebungs-und Auswertungsinstrumente zur schweizerisch-deutschen Videostudie "Unterrichtsqualität, Lernverhalten und mathematisches Verständnis"(Teil 1)*. Frankfurt a. M.: GFPF/DIPF.

The Author firstly translated the questions into English, then into Chinese.

D 部分: 学科内容知识 (学生)

在非常近的将来，您可能会成为一名小学科学教师。这个部分期望发现中国未来科学教师的科学知识水平。请注意，本研究不会对问卷的参与者以及参与学校进行个人评判和比较。

此外，本研究的兴趣点并不在于个人的分数，而是在于所有参与者的整体平均分。请放心做这些题！

本部分共有 12 道题目（D1-D12），每个题目有且只有一个答案，请用“√”选出您的答案。

D1. 下列哪一项叙述可以解释为什么地球会有白昼和黑夜？

A 地球绕着轴心自转。 ☐

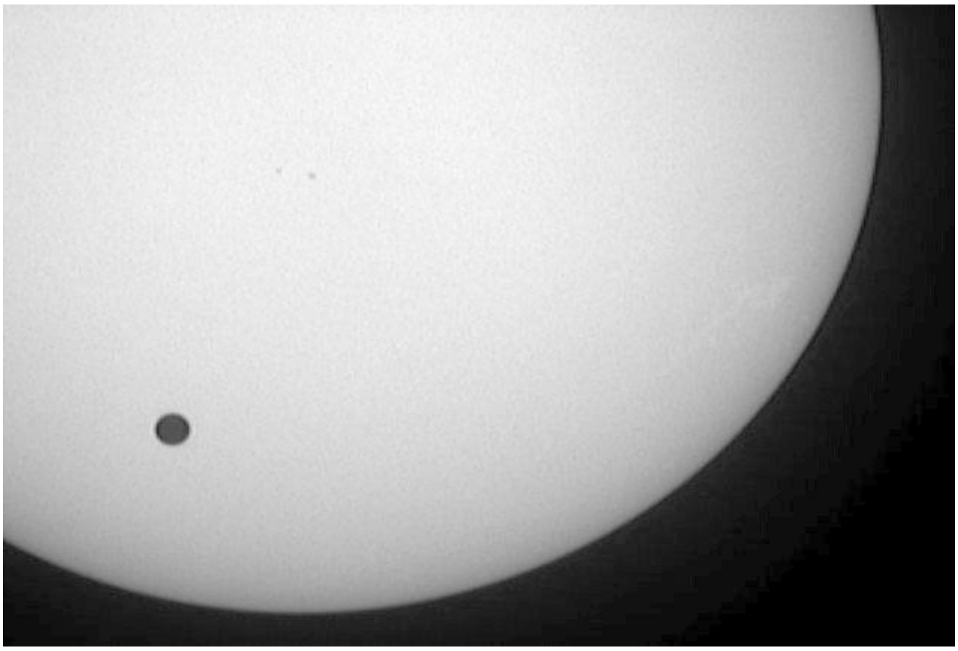
B 太阳绕着轴心自转。 ☐

C 地轴是倾斜的。 ☐

D 地球绕着太阳公转。 ☐

2004年6月8日，在地球上许多地方都可以看到金星经过太阳。这个现象被称作为“金星凌日”，它产生的原因在于金星运行到地球和太阳的中间，这时地球、金星、太阳会在一条直线上，这时从地球上可以看到，金星就像一个小黑点一样在太阳表面缓慢移动。上一次的“金星凌日”发生在1882年，最近的一次发生在2012年。

下面是2004年“金星凌日”的图片。一架天文望远镜指向太阳，影像被投影在一张白色卡片上。根据上述信息，请回答问题**D2**和**D3**。



D2. 为什么要通过把影像投影在白色的卡片上，而不是直接通过天文望远镜来观测"金星凌日"?

A 太阳的光太亮以至于让金星不能露出来。 ☐

B 太阳大到足以不用放大就能看到。 ☐

C 通过天文望远镜观测太阳可能会伤害你的眼睛。 ☐

D 将影像投影在卡片上，需要将影像弄小一点。 ☐

D3. 当从地球上观测时，在特定某个时间，下列哪一颗行星能够被看见，从太阳面前穿过?

A 水星 ☐

B 火星 ☐

C 木星 ☐

D 土星 ☐

小明正在修理一座旧房子。他在他的汽车行李箱里留下了一瓶水、一些金属钉子和一块木材。汽车在太阳下晒了三个小时之后，车里的温度达到了40ºC左右。根据这些信息，请回答问题**D4**。

D4. 汽车里的物体都发生了什么?请就下列各项陈述，圈出"是"或"否"

汽车里的物体发生了这个情况吗?	**是或否?**
所有物体的温度都一样。	是或否?
在一定时间之后，水开始沸腾。	是或否?
在一定时间之后，金属钉子开始发热发红。	是或否?

白天喝饮料的时候，李梅要了一杯热咖啡，温度大约是90ºC，以及一杯冷的矿泉水，温度大约是5ºC。这两个杯子的样式、尺寸和容量完全相同。李梅把这两个杯子放在一间温度大约是20ºC的房间里。根据这些信息，请回答问题**D5**。

D5. 十分钟之后，咖啡和矿泉水的温度可能是多少度?

A 70 ºC and 10 ºC ☐

B 90 ºC and 5 ºC ☐

C 70 ºC and 25 ºC ☐

D 20 ºC and 20 ºC ☐

香烟的烟雾里里包含了许多有害的物质，其中最有害的物质是焦油、尼古丁和一氧化碳。香烟的烟雾会被吸入到肺里，香烟里的焦油会被储存在肺里，这些会阻碍肺功能的正常工作。吸烟增加了肺癌和一些其他疾病的发生率。根据这些信息，请回答问题**D6**和**D7**。

D6. 下列哪一项叙述了肺的功能？

A 把含氧血泵入身体的各个部分。 ☐

B 把你吸入的氧气传输到你的血液里。 ☐

C 通过把二氧化碳含量减少到零，来净化你的血液。 ☐

D 把二氧化碳分子转变为氧分子。 ☐

D7. 吸烟会增加下列疾病发生的风险吗？请对下列各项疾病，圈出"是"或"否"

吸烟会增加下列疾病发生的风险吗？	**"是"或"否"？**
支气管炎	"是"或"否"？
艾滋病	"是"或"否"？
水痘	"是"或"否"？

张三喜欢观测星星。但是，由于他住在大城市里，他在夜晚的时候不能很好地观测星星。去年，张三去了农村，在那里，他观测到了许多他不能在城市里观测到的星星。根据这些信息，请问答问题**D8**。

D8. 为什么在农村可以比在城市里观测到更多的星星？

A 城市里的月亮更亮，遮挡住了许多星星的光亮。 ☐

B 比起城市的空气，农村的空气有含更多的尘埃，由此可以去反射光亮。 ☐

C 城市里灯光的亮度使得许多星星很难被观测到。 ☐

D 汽车、机器设备和住宅排放出的热量，使得城市的空气更暖和。 ☐

为了在低亮度的情况下观测星星，小红使用了一个大口径透镜的天文望远镜来观测星星。根据这些信息，请回答问题**D9**。

D9. 为什么使用大口径透镜的天文望远镜可以在低亮度的情况下观测到星星？

A 透镜越大，收集到的光亮越多。 ☐

B 透镜越大，其放大率也越高。 ☐

C 大点的透镜可以看到更多的天空。 ☐

D 大点的透镜能够探测到星星里的暗色。 ☐

D10. 下列哪一个叙述最适用于进化论?

A 进化论不能被相信，因为不能看见物种的演变。 ☐

B 进化论对于动物来说是可能的，但是进化论并不适用于人类。 ☐

C 基于目前大量的证明，进化论是一种科学的理论。 ☐

D 通过科学的实验，进化论已经被证明是一种正确的理论。 ☐

在相同的风速之下，高度越高，风车旋转的速度越慢。根据这些信息，请回答问题**D11**。

D11.下列哪一个叙述是上述现象的最佳的答案？

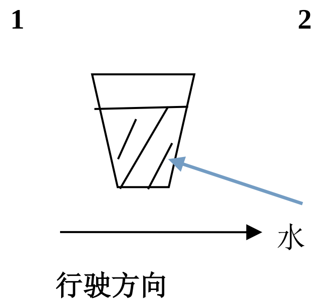
A 空气的密度随着高度的增加而变小。 ☐

B 温度随着高度的增加而变低。 ☐

C 重力随着高度的增加而减小。 ☐

D 雨量随着高度的增加而增加。 ☐

一辆公交车正沿着笔直的道路行驶，名叫李明的公交车司机，将一杯水放在仪表板上。



突然间，李明必须猛力踩煞车。

D12. 杯中的水最可能发生哪种情形呢？

A 水会保持水平。 ☐

B 水会从1那一侧溅出来。 ☐

C 水会从2那一侧溅出来。 ☐

D 水会溅出来，但无法判断会从1那一侧或2那一侧溅出来。 ☐

Note: The test questions about Content Knowledge were literally taken from the PISA science test questions in 2006. Retrieved from: http://www.oecd.org/pisa/38709385.pdf

The author translated the test questions into Chinese.

Appendix 3:

Questionnaire Cover Letter

Dear teachers,

My name is Xuejiao Jia. I am a doctoral student at the Centre for Research in Primary Education of Freie Universität Berlin. My research direction is teacher education and science education. This study is sponsored by China Scholarship Council (CSC). I am at the point in my studies where I require your help.

This study will examine pre-service science teacher education in China. Science education in your university is well renowned for the excellent science teacher educators and student-teachers, who devote themselves to make science education in China better and more professional. Thus, my study is designed to collect data in your university.

The purpose of this questionnaire is to gather background information about science education in your university, and to understand your views about teacher's knowledge, teacher's belief and teaching methods in science education.

To fill this questionnaire will cost 20-25 minutes of your time. Your response is of the utmost importance to us. The validity of this investigation depends on the extent to which your responses are open and frank, so please answer honestly and in as much detail as possible. Your responses will be used for research purposes only and will remain confidential

Thank you for taking part in this research and for agreeing to fill this questionnaire.

Should you have any queries or comments regarding this survey, you are welcome to contact me via telephone or e-mail.

Yours sincerely

Xuejiao Jia

Xuejiao Jia

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Personal Data:

In this section we would like some information about you and your teaching experience.

1. You are

Male	Female

2. Which age group are you in?

25-30y	31-35y	36-40y	41-45y	46-50y	Over 50y

3. Your title is

Professor	Associate professor	Lecturer	Other

4. You are working in

University	Department

5. How many years have you been in the teaching profession?

0-2y	3-5y	6-10y	11-15y	16-20y	Over 20y

6. Your Highest degree is

Bachelor	Master	Doctor	Other

7. The major of your highest degree is

8. Where did you get your highest degree?

Section A: Pedagogical Practices (teacher)

On the following you will find some statements about science teaching practices. There will be no best answer for each statement. Besides, there will be no individual judgment and comparison of sample participants, as well as the sample universities. Please take easy to choose!

In your most recent teaching assignment, please indicate how often did you do the followings in your science lessons at universities.

In my most recent teaching assignment...	never or almost never	in some lessons	in most lessons	in every lesson
A1. ...I lectured to explain science concepts.				
A2. ...I used my students' mistakes to generate class discussion.				
A3. ...I used multiple modes of representation (e.g., oral, written, gestural, graphic) to communicate science ideas.				
A4. ...I presented science facts quickly and efficiently.				
A5. ...I used simple language to focus on key science vocabulary.				
A6. ...I conducted an experiment and had my students observe rather than participate.				
A7. ...I used worksheets to reinforce basic skills.				
A8. ...I talked with one of my students one-on-one to assess his or her communication of science ideas.				
A9. ...I created small groups of my students to work together in science class.				
A10. ...I encouraged my students to write about science ideas or prepare their needed experiment materials.				

Note: The test questions about Pedagogical Practices were adopted from the study of Santau, A.O. et al. (2010). US urban elementary teachers' knowledge and practices: Relationship between science instruction and English language development. The source cited from Heinz, J. et al. (2012). *Indicators and instruments in the context of inquiry-based science education* (pp. 80-81). Münster: Waxmann.

Section B: Teachers' Beliefs (teacher)

On the following pages you will find a number of statements by teachers on teaching and learning science.

There will be no best answer for each statement. Besides, there will be no individual judgment and comparison of sample participants, as well as the sample universities.

We are interested in your own personal opinion. Please do choose what you really think or believe!

Please indicate to what extent you agree with the following statements.

In science lessons at university...	**strongly disagree**	**disagree**	**agree**	**strongly agree**
B1. ...students will learn science best if they discover science-related questions and problems themselves.				
B2. ...letting students discuss their own approaches to find answers to science-related questions and problems supports their learning.				
B3. ...science should be taught at schools in such a way, that students can discover connections themselves.				
B4. ...one should allow students to think of ways to solve science-related questions and problems themselves, before the teacher demonstrates how this is done scientifically correct.				
B5. ...students should often be given opportunities to work on science-related questions and problems in pairs or small groups.				
B6. ...many science-related problems can be solved by students without the help from grown-ups.				
B7. ...students are generally not able to recognize scientific connections themselves.				
B8. ...one should generally demand of students to solve science problems the way they were taught.				
B9. ...teachers should teach precise ways to solve science problems to students.				
B10. ...students need precise instructions on how to solve scientific problems.				
B11. ...students should solve different concrete science problems, which are set in different contexts, one after the other rather than all together.				
B12. ...effective teachers will demonstrate how a science problem is to be solved.				

B13. ...students should often be offered opportunities to follow their teacher's scientifically correct way of problem solving (demonstration auf science problems or "thinking aloud" of the teacher).				
B14. ...students learn best from the demonstrations and explanations of their teachers.				
B15. ...practicing typical scientific ways of problem-solving is essential to successful thinking and problem-solving in the field of science.				
B16. ...before spending time on solving concrete science problems, the students had better practice typical ways of solving science problems.				

Note: The test questions about Teachers' Beliefs were adopted based on the study of Rakoczy, Buff & Lipowsky (2005). Befragungsinstrumente. In E. Klieme, C. Pauli & K. Reusser (Eds.), *Dokumentation der Erhebungs-und Auswertungsinstrumente zur schweizerisch-deutschen Videostudie "Unterrichtsqualität, Lernverhalten und mathematisches Verständnis" (Teil 1)*. Frankfurt a. M.: GFPF/DIPF.

The Author translated the test questions into English.

Section C: Inquiry-Based Learning (teacher)

On the following you will find some statements about science teaching. There will be no best answer for each statement. Besides, there will be no individual judgment and comparison of sample participants, as well as the sample universities.

We are interested in your own personal opinion. please do choose what you really think!

Please indicate to what extent you agree with the following statements.

In my science lessons at university…	**strongly disagree**	**disagree**	**agree**	**strongly agree**
C1. ...in order to make my students learn science best, I encourage them discover science-related questions and problems themselves.				
C2. ...in order to support my students' science learning, I allow them to discuss their own approaches to find answers to science-related questions and problems.				
C3. ...science is taught at my universities in such a way, so that my students can discover connections themselves.				
C4. ...I allow my students to think of ways to solve science-related questions and problems themselves, before I demonstrate how this is done scientifically correct.				
C5. ...I give my students the opportunities to work on scientific-related questions and problems, in pairs or small groups.				
C6. ...I demand my students solve science problems by the way they are taught.				
C7. ...I teach precise instructions to my students to solve science problems.				
C8. ...I let my students solve different concrete science problems, which are set in different contexts, one after the other rather than together.				
C9. ...I demonstrate how a science problem is to be solved for my students.				

C10. ...I often offer opportunities for my students to follow my scientifically correct ways of problem solving.				
C11. ...I make my students learn best from my demonstrations and explanations.				
C12. ...in order to make my students successfully think and solve problem in the field of science, I let them practice typical scientific ways of problem-solving.				
C13: ...I make my students practice typical ways of solving science problems before they spend time on solving concrete science problem.				

Note: The test questions about Inquiry-Based Learning were designed by the author based on the study of Rakoczy, Buff & Lipowsky (2005). Befragungsinstrumente. In E. Klieme, C. Pauli & K. Reusser (Eds.), *Dokumentation der Erhebungs-und Auswertungsinstrumente zur schweizerisch-deutschen Videostudie "Unterrichtsqualität, Lernverhalten und mathematisches Verständnis"(Teil 1)*. Frankfurt a. M.: GFPF/DIPF.

The Author translated the test questions into English.

Section D: Content Knowledge (teacher)

This section would like to find out the level of knowledge of science teacher educators in China. There will be no individual judgment and comparison of sample participants, as well as the sample universities.

Our interests will not focus on the individual score, and only looking for the mean score of the whole participants in this study. Please take easy to do these questions!

Please choose ONLY ONE answer with √ for each question.

D1. Which statement explains why daylight and darkness occur on Earth?

A The Earth rotates on its axis. ☐

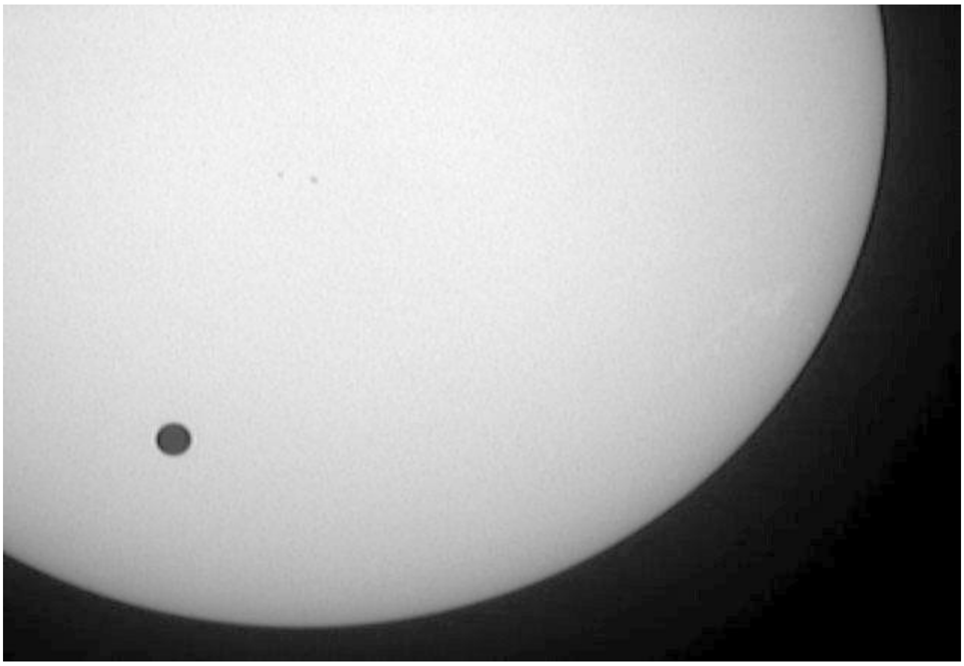
B The Sun rotates on its axis. ☐

C The Earth's axis is tilted. ☐

D The Earth revolves around the Sun. ☐

On 8 June 2004, the planet Venus could be seen passing in front of the Sun when viewed from many places on Earth. This is called a "transit" of Venus and happens when its orbit takes Venus between the Sun and Earth. The previous transit of Venus occurred in 1882 and another took place in 2012.

Below is a picture of the transit of Venus in 2004. A telescope was pointed at the Sun and the image projected onto a white card. Based on these information, please answer questions **D2 and D3.**



D2. Why was the transit observed by projecting the image onto a white card, rather than by looking directly through the telescope?

A The Sun's light was too bright for Venus to show up. ☐

B The Sun is big enough to see without magnification. ☐

C Viewing the Sun through a telescope may damage your eyes. ☐

D The image needed to be made smaller by projecting it onto a card. ☐

D3. When viewed from Earth, which one of the following planets can be seen in transit across the face of the Sun at certain times?

A Mercury ☐

B Mars ☐

C Jupiter ☐

D Saturn ☐

Xiaoming is working on repairs to an old house. He has left a bottle of water, some metal nails, and a piece of timber inside the boot of his car. After the car has been out in the sun for three hours, the temperature inside the car reaches about 40 ºC. Based on these information, please answer questions **D4.**

D4. What happens to the objects in the car? Circle "Yes" or "No" for each statement.

Does this happen to the object(s)?	**Yes or No?**
They all have the same temperature.	Yes or No?
After some time the water begins to boil.	Yes or No?
After some time the metal nails begin to glow red.	Yes or No?

For drinks during the day, Li Mei has a cup of hot coffee, at a temperature of about 90 ºC, and a cup of cold mineral water, with a temperature of about 5 ºC. The cups are of identical type and size and the volume of each drink is the same. Li Mei leaves the cups sitting in a room where the temperature is about 20 ºC. Based on these information, please answer question **D5**.

D5. What are the temperatures of the coffee and the mineral water likely to be after 10 minutes?

A 70 ºC and 10 ºC ☐

B 90 ºC and 5 ºC ☐

C 70 ºC and 25 ºC ☐

D 20 ºC and 20 ºC ☐

Tobacco smoke contains many harmful substances. The most damaging substances are tar, nicotine and carbon monoxide. Tobacco smoke is inhaled into the lungs. Tar from the smoke is deposited in the lungs and this prevents the lungs from working properly. Tobacco smoking increases the risk of getting lung cancer and some other diseases. Based on these information, please answer question **D6 and D7.**

D6. Which one of the following is a function of the lungs?

A To pump oxygenated blood to all parts of your body ☐

B To transfer some of the oxygen that you breathe to your blood ☐

C To purify your blood by reducing the carbon dioxide content to zero ☐

D To convert carbon dioxide molecules into oxygen molecules ☐

D7. Is the risk of getting the following diseases increased by tobacco smoking? Circle "Yes" or "No" in each case.

Is the risk of contracting this disease increased by smoking?	**Yes/No**
Bronchitis	Yes / No
HIV/AIDS	Yes / No
Chicken pox	Yes / No

Zhang San likes to look at stars. However, he cannot observe stars very well at night because he lives in a large city. Last year Zhang San visited the countryside where he observed a large number of stars that he cannot see when he is in the city. Based on these information, please answer question **D8**.

D8. Why can many more stars be observed in the countryside than in large cities?

A The moon is brighter in cities and blocks out the light from many stars. ☐

B There is more dust to reflect light in country air than in city air. ☐

C The brightness of city lights makes many stars hard to see. ☐

D The air is warmer in cities due to heat emitted by cars, machinery and houses. ☐

Xiaohong uses a telescope with a large diameter lens in order to observe stars of low brightness. Based on these information, please answer question **D9**.

D9. Why does using a telescope with a large diameter lens make it possible to observe stars of low brightness?

A The larger the lens the more light is collected. ☐

B The larger the lens the more it magnifies. ☐

C Larger lenses allow more of the sky to be seen. ☐

D Larger lenses can detect the dark colours in stars. ☐

D10. Which one of the following statements best applies to the scientific theory of evolution?

A The theory cannot be believed because it is not possible to see species changing. ☐

B The theory of evolution is possible for animals but cannot be applied to humans. ☐

C Evolution is a scientific theory that is currently based on extensive evidence. ☐

D Evolution is a theory that has been proven to be true by scientific experiments. ☐

The higher the altitude the more slowly windmills rotate at the same wind speed. Based on these information, please answer question **D11**.

D11. Which one of the following is the best reason why the blades of windmills rotate more slowly in higher places at the same wind speed?

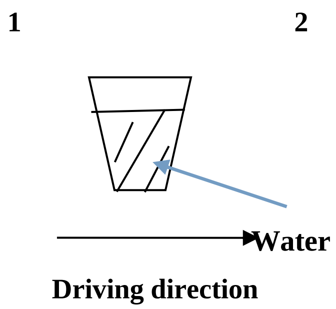
A The air is less dense as altitude increases. ☐

B The temperature is lower as altitude increases.

C Gravity becomes less as altitude increases.

D It rains more often as altitude increases.

A bus is driving along a straight stretch of road. The bus driver, named Ray, has a cup of water resting on the dashboard:



Suddenly Ray has to slam on the brakes. Based on these information, please answer question **D12**.

D12. What is most likely to happen to the water in the cup?

A The water will stay horizontal.

B The water will spill over side 1.

C The water will spill over side 2.

D The water will spill but you cannot tell if it will spill at side 1 or side 2.

Note: The test questions about Content Knowledge were literally taken from the PISA science test questions in 2006. Retrieved from: http://www.oecd.org/pisa/38709385.pdf

Appendix 4:

关于职前科学教师教育的调查问卷

尊敬的老师，

您好！

我叫贾雪姣，是柏林自由大学基础教育研究中心的博士生，研究方向是教师教育和科学教育，博士课题由中国国家留学基金管理委员会资助。

我的博士课题拟调查研究中国职前阶段的科学教师教育。贵校的科学教育专业拥有优秀的师资，培养出了许多优秀的科学教师，使得中国的科学教育专业发展地更好更专业。因此，本研究拟在贵校进行调查研究以及收集数据。

本问卷拟收集关于职前科学教师教育的相关数据。具体来说，您作为一名大学的科学教师，培养未来中小学科学教师的教育者，是如何看待科学教育的？您是如何培养您的学生？您对教师知识、教师信念以及教学方法的观点又是什么？

本问卷大概需要您 20-25 分钟的时间来完成。本问卷调查的有效性与您答案的真实性密切相关，您的答案对本次研究非常重要。因此，请根据您的实际情况，真实回答这些问题。您的答案只用作研究，个人信息以及答案会被严格保密。

对于本次问卷调查，如果您有任何问题，欢迎随时通过电话或邮件联系我。

非常感谢您参与本次研究并填写本问卷！！

诚挚地

贾雪姣

柏林自由大学博士生

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手机（德国）: +XXXXX

个人信息

通过这个部分，我们希望了解一些您的个人基本情况和教学经历。

1. 您的性别是（请选择）

男	女

2. **您在下列哪个年龄组？**（请选择）

25-30 岁	31-35 岁	36-40 岁	41-45 岁	46-50 岁	大于 50 岁

3. 您的教龄有（请选择）

0-2 年	3-5年	6-10年	11-16年	16-20年	超过20年

4. 您的职称是（请选择）

教授	副教授	讲师	其他（请填写）

5. 您的工作单位是（请填写出具体的大学和学院名称。）

大学	学院

6. 您的最高学位是（请选择）

学士学位	硕士学位	博士学位	其他（请填写）

7. 您获取最高学位时所修的专业是（请填写出具体的专业名称）

8. 您获取最高学位的学校是（请填写出具体的学校名称）

A 部分: 教学实践 （教师）

下列陈述是关于科学这门学科的一些教学实践。

请根据您的实际情况作出选择。请注意，下列各个陈述并没有最佳的答案。此外，本研究也不会对问卷的参与者以及参与学校进行个人评判和比较。请放心作出选择！

请根据您最近的科学课程教学情况，选择出下列您所经历过的教学实践。请根据您的实际情况用“√”作出选择。

在我最近的科学课程教学中......	**从不或几乎不**	**在一些课堂中**	**在大多数课堂中**	**在每一堂课中**
A1. ......我对相关科学概念进行了讲授和解释。				
A2. ......我根据学生所犯的错误展开了课堂讨论。				
A3. ......我使用了多种表现方法（例如：口头、书面、手势、图表）来传达科学概念。				
A4. ......我快速并且有效地呈现和介绍了科学事实。				
A5. ......我使用了简单的语言强调核心科学词汇。				
A6. ......我做了一个实验，让我的学生仔细观察而不是参与其中。				
A7. ......我使用了学习计划表来加强学生的基本技能。				
A8. ......我跟我的学生进行了一对一的交流和讨论，由此来评价他/她对科学概念的掌握程度。				
A9. ......在我的科学课堂中，我让学生分小组进行学习。				
A10. ......我鼓励我的学生写出他/她的科学想法，并且帮助他们准备了所需的实验材料。				

Note: The test questions about Pedagogical Practices were adopted from the study of Santau, A.O. et al. (2010). US urban elementary teachers' knowledge and practices: Relationship between science instruction and English language development. The source cited from Heinz, J. et al. (2012). *Indicators and instruments in the context of inquiry-based science education* (pp. 80-81). Münster: Waxmann.

The author translated the test questions into Chinese.

B 部分：教师信念（教师）

在下面，您会发现其他科学教师所提出的一些关于科学教学和学习的想法和观点。

请注意，每一个陈述并没有最佳的答案，我们只对您的个人想法和观点感兴趣。

此外，本研究也不会对问卷的参与者以及参与学校进行个人评判和比较。

请根据您最真实的想法和观点，用“√”作出选择。

在大学的科学课中......	非常不同意	不同意	同意	非常同意
B1. ......假如学生能够自己发现科学问题，那么他们能够将科学学得最好。				
B2. ......让学生通过讨论发现解决科学问题的方法，这有利于学生的科学学习。				
B3. ......科学课应该以这样一种方式被教授——让学生自己发现科学内部的相关联系。				
B4. ......在教师对科学问题进行论证之前，教师应该允许学生先提出自己的观点和方法。				
B5. ......应该让学生经常有机会以小组学习的方式来讨论和研究科学问题。				
B6. ....在没有教师的帮助下，学生能够自己解决许多科学问题。				
B7. ......一般情况下，学生不能自己发现科学内部的相关联系。				
B8. ......一般情况下，教师应该要求学生通过他/她所教授的方法来解决科学问题。				
B9. ......教师应该教授学生解决科学问题的正确方法。				
B10. ......解决科学问题时，学生需要正确的指导。				
B11. ......学生在解决不同背景下产生的科学问题时，应逐一解决而非将这些问题混淆在一起解决。				
B12. ......好的教师会论证科学问题的解决过程。				
B13. ......应该经常让学生有机会练习教师所运用的科学问题解决方法（例如：论证科学问题、放声思维方法）。				

B14. ......学生通过教师的论证和解释可以学得最好。				
B15. ......如果想在科学领域中成功地思考和解决问题，有必要对典型的科学问题解决方法进行练习。				
B16. ......在解决具体的科学问题之前，学生最好先对典型的科学问题解决方法进行练习。				

Note: The test questions about Teachers' Beliefs were adopted based on the study of Rakoczy, Buff & Lipowsky (2005). Befragungsinstrumente. In E. Klieme, C. Pauli & K. Reusser (Eds.), *Dokumentation der Erhebungs-und Auswertungsinstrumente zur schweizerisch-deutschen Videostudie "Unterrichtsqualität, Lernverhalten und mathematisches Verständnis" (Teil 1)*. Frankfurt a. M.: GFPF/DIPF.

The Author firstly translated the test questions into English, then into Chinese.

C 部分: 探究性学习 （教师）

下列陈述是关于科学这门学科的一些教学方法。

请注意，每一个陈述并没有最佳的答案，我们只对您的个人想法和观点感兴趣。

此外，本研究也不会对问卷的参与者以及参与学校进行个人评判和比较。

请根据您最真实的想法和观点，用“ √ ”作出选择。

在我的大学科学课中......	非常不同意	不同意	同意	非常同意
C1. ......为了让学生可以将科学学得最好，我鼓励他们自己发现科学问题。				
C2. ......为了支持学生进行科学学习，我允许他们进行自我讨论，从而发现解决科学问题的方法。				
C3. ......我通过让学生发现科学内部的相关联系，来展开科学教学。				
C4. ......在论证科学问题之前，我允许学生提出自己的观点和方法来解决科学问题。				
C5. ......我的学生有机会以小组学习的方式来讨论和研究科学问题。				
C6. ......我要求学生用我教给他们的方法来解决科学问题。				
C7. ......我传授正确的指导给学生，帮助他们解决科学问题。				
C8. ......我让学生对不同背景下产生的科学问题进行逐一地解决，而非将这些问题混淆在一起解决。				
C9. ......我会为了学生去论证科学问题解决的过程。				
C10. ......我经常提供机会给学生，让他们练习我教给他们的科学问题解决方法。				
C11. ......我通过论证和解释让学生学得最好。				
C12. ......为了让学生在科学领域中成功地思考和解决问题，我会让他				

们对典型的科学问题解决方法进行练习。				
C13. ......在学生解决具体的科学问题之前，我会让他们对典型的科学问题解决方法进行练习。				

Note: The test questions about Inquiry-Based Learning were designed by the author based on the study of Rakoczy, Buff & Lipowsky (2005). Befragungsinstrumente. In E. Klieme, C. Pauli & K. Reusser (Eds.), *Dokumentation der Erhebungs-und Auswertungsinstrumente zur schweizerisch-deutschen Videostudie "Unterrichtsqualität, Lernverhalten und mathematisches Verständnis"(Teil 1)*. Frankfurt a. M.: GFPF/DIPF.

The Author firstly translated the test questions into English, then into Chinese.

D 部分: 学科内容知识（教师）

这个部分期望发现当前中国科学教师教育者的科学知识水平。

请注意，本研究不会对问卷的参与者以及参与学校进行个人评判和比较。此外，本研究的兴趣点并不在于个人的分数，而是在于所有参与者的整体平均分。

请放心做这些题！

本部分共有 12 道题目（D1-D12），每个题目有且只有一个答案，请用"√"选出您的答案。

D1. 下列哪一项叙述可以解释为什么地球会有白昼和黑夜？

A 地球绕着轴心自转。 ☐

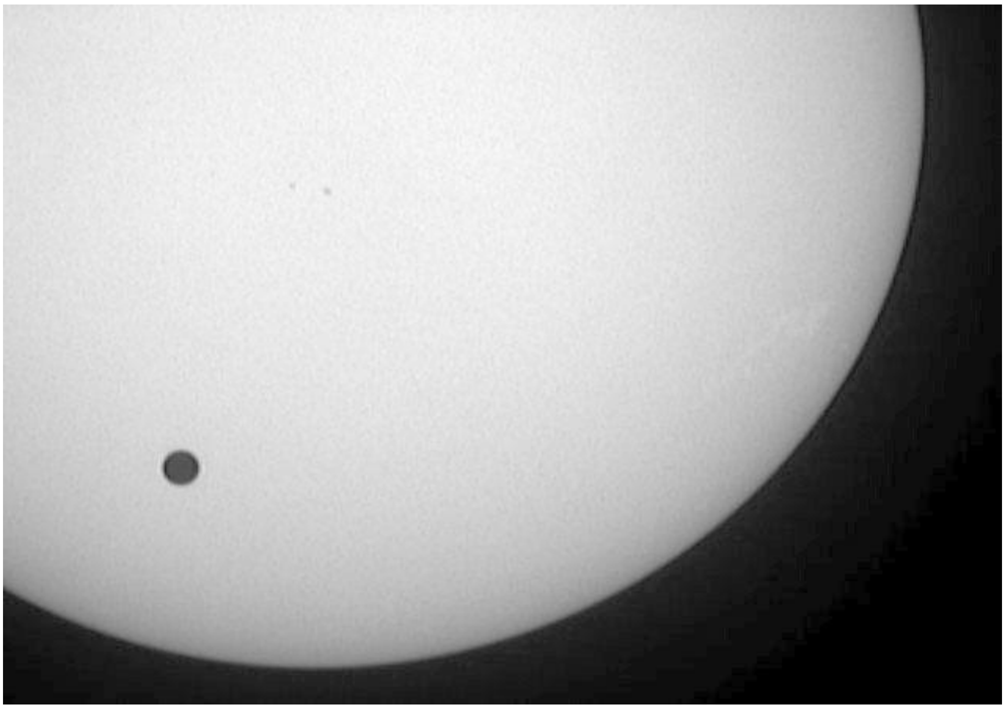
B 太阳绕着轴心自转。 ☐

C 地轴是倾斜的。 ☐

D 地球绕着太阳公转。 ☐

2004年6月8日，在地球上许多地方都可以看到金星经过太阳。这个现象被称作为"金星凌日"，它产生的原因在于金星运行到地球和太阳的中间，这时地球、金星、太阳会在一条直线上，这时从地球上可以看到，金星就像一个小黑点一样在太阳表面缓慢移动。上一次的"金星凌日"发生在1882年，最近的一次发生在2012年。

下面是2004年"金星凌日"的图片。一架天文望远镜指向太阳，影像被投影在一张白色卡片上。根据上述信息，请回答问题**D2**和**D3**。



D2. 为什么要通过把影像投影在白色的卡片上，而不是直接通过天文望远镜来观测“金星凌日”？

A 太阳的光太亮以至于让金星不能露出来。 ☐

B 太阳大到足以不用放大就能看到。 ☐

C 通过天文望远镜观测太阳可能会伤害你的眼睛。 ☐

D 将影像投影在卡片上，需要将影像弄小一点。 ☐

D3. 当从地球上观测时，在特定某个时间，下列哪一颗行星能够被看见，从太阳面前穿过？

A 水星 ☐

B 火星 ☐

C 木星 ☐

D 土星 ☐

小明正在修理一座旧房子。他在他的汽车行李箱里留下了一瓶水、一些金属钉子和一块木材。汽车在太阳下晒了三个小时之后，车里的温度达到了40ºC左右。根据这些信息，请回答问题**D4**。

D4. 汽车里的物体都发生了什么？请就下列各项陈述，圈出“是”或“否”

汽车里的物体发生了这个情况吗？	**是或否？**
所有物体的温度都一样。	是或否？
在一定时间之后，水开始沸腾。	是或否？
在一定时间之后，金属钉子开始发热发红。	是或否？

白天喝饮料的时候，李梅要了一杯热咖啡，温度大约是90ºC，以及一杯冷的矿泉水，温度大约是5ºC。这两个杯子的样式、尺寸和容量完全相同。李梅把这两个杯子放在一间温度大约是20ºC的房间里。根据这些信息，请回答问题**D5**。

D5. 十分钟之后，咖啡和矿泉水的温度可能是多少度？

A 70 ºC and 10 ºC ☐

B 90 ºC and 5 ºC ☐

C 70 ºC and 25 ºC ☐

D 20 ºC and 20 ºC ☐

香烟的烟雾里里包含了许多有害的物质，其中最有害的物质是焦油、尼古丁和一氧化碳。香烟的烟雾会被吸入到肺里，香烟里的焦油会被储存在肺里，这些会阻碍肺功能的正常工作。吸烟增加了肺癌和一些其他疾病的发生率。根据这些信息，请回答问题**D6**和**D7**。

D6. 下列哪一项叙述了肺的功能？

A 把含氧血泵入身体的各个部分。 ☐

B 把你吸入的氧气传输到你的血液里。 ☐

C 通过把二氧化碳含量减少到零，来净化你的血液。 ☐

D 把二氧化碳分子转变为氧分子。 ☐

D7. 吸烟会增加下列疾病发生的风险吗？请对下列各项疾病，圈出"是"或"否"

吸烟会增加下列疾病发生的风险吗？	**"是"或"否"？**
支气管炎	"是"或"否"？
艾滋病	"是"或"否"？
水痘	"是"或"否"？

张三喜欢观测星星。但是，由于他住在大城市里，他在夜晚的时候不能很好地观测星星。去年，张三去了农村，在那里，他观测到了许多他不能在城市里观测到的星星。根据这些信息，请问答问题**D8**。

D8. 为什么在农村可以比在城市里观测到更多的星星？

A 城市里的月亮更亮，遮挡住了许多星星的光亮。 ☐

B 比起城市的空气，农村的空气有含更多的尘埃，由此可以去反射光亮。 ☐

C 城市里灯光的亮度使得许多星星很难被观测到。 ☐

D 汽车、机器设备和住宅排放出的热量，使得城市的空气更暖和。 ☐

为了在低亮度的情况下观测星星，小红使用了一个大口径透镜的天文望远镜来观测星星。根据这些信息，请回答问题**D9**。

D9. 为什么使用大口径透镜的天文望远镜可以在低亮度的情况下观测到星星？

A 透镜越大，收集到的光亮越多。 ☐

B 透镜越大，其放大率也越高。 ☐

C 大点的透镜可以看到更多的天空。 ☐

D 大点的透镜能够探测到星星里的暗色。 ☐

D10. 下列哪一个叙述最适用于进化论?

A 进化论不能被相信，因为不能看见物种的演变。 ☐

B 进化论对于动物来说是可能的，但是进化论并不适用于人类。 ☐

C 基于目前大量的证明，进化论是一种科学的理论。 ☐

D 通过科学的实验，进化论已经被证明是一种正确的理论。 ☐

在相同的风速之下，高度越高，风车旋转的速度越慢。根据这些信息，请回答问题**D11**。

D11.下列哪一个叙述是上述现象的最佳的答案？

A 空气的密度随着高度的增加而变小。 ☐

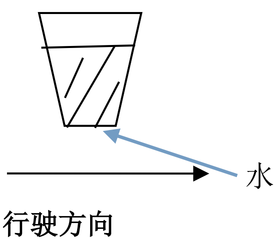
B 温度随着高度的增加而变低。 ☐

C 重力随着高度的增加而减小。 ☐

D 雨量随着高度的增加而增加。 ☐

一辆公交车正沿着笔直的道路行驶，名叫李明的公交车司机，将一杯水放在仪表板上。

1　　　　　　　　**2**



突然间，李明必须猛力踩煞车。

D12. 杯中的水最可能发生哪种情形呢？

A 水会保持水平。 ☐

B 水会从1那一侧溅出来。 ☐

C 水会从2那一侧溅出来。 ☐

D 水会溅出来，但无法判断会从1那一侧或2那一侧溅出来。 ☐

Note: The test questions about Content Knowledge were literally taken from the PISA science test questions in 2006. Retrieved from: http://www.oecd.org/pisa/38709385.pdf

Appendix 5:

Semi-structured interview with science student-teachers

Introduction

Thank you for taking part in this research and for agreeing to be interviewed. My name is Xuejiao Jia. I am a doctoral student at Center for Research in Primary Education of Freie Universität Berlin. My research direction is teacher education and science education. This study is sponsorted by China Scholarship Council (CSC). I am at the point in my studies where I require your help.

My PhD research will examine pre-service science teacher education in China. Science education in your university is well renowned for the excellent science teacher educators and student-teachers, who devote themselves to make science education in China better and more professional. Thus, my study is designed to collect data in your university.

The purpose of this interview is to gather background information about science education in your university, and to understand your views about teachers' practices, teachers' belief and teaching methods in science education.

Please remember that there are no right or wrong answers. The validity of this investigation depends on the extent to which your responses are open and frank, so please answer honestly and in as much detail as possible. Your responses will be used for research purposes only. They will remain confidential and will not be attributed to you by name. I would like to record the interview, with your consent.

1. Please tell me about your experience as a student of science education.

a. Why did you choose the major of science education?

2. What do you consider to be characteristic of good science teaching at schools?

a. Pretty soon you will teach science at schools. What is important for your own teaching?

b. Which content areas do you consider to be most important?

c. Which teaching methods do you want to use?

3. What do you think is the teacher's role in a science classroom?

4. What do you think is the student's role in a science classroom?

5. How well do you think your pre-service teacher education courses (both science and science education) prepared you?

a. What are some things you feel well prepared to do？

b. What are things you feel you are not very prepared?

6. What do you think needs a teacher to have learned at the university for teaching science at school?

a. Which subject or subject area or skill do you consider to be most important in your university courses?

b. What do you hope to gain from your teachers' science education program?

7. What do you think is the very best way to motivate your future students to learn science? Why?

8. There is an idea called "Inquiry-Based Learning". The word "inquiry" may have different meanings to different people. Can you describe for me, in your own words, what "inquiry" means to you?

a. Do you remember experiencing "Inquiry-Based Learning" in any of your high school classes or university courses? Can you describe such a class or course for me?

b. What are the advantages and disadvantages of "Inquiry-Based Learning" from your point of view? Can you describe an example?

c. How much freedom would you give your future students to investigate problems of their own choosing?

5. Is there anything you would like to add, related to anything that we talked about today?

Note: The interview questions in this appendix were designed by the author.

Appendix 6:

Pedagogical Content Knowledge for science student-teachers

Shulman (1986) proposed Pedagogical Content Knowledge (PCK), which is a specialized knowledge that distinguishes teachers from subject matter specialists. PCK is a fundamental component of the knowledge base for teaching. This data collection consists of a semi-structured interview to view the PCK in a specific topic- **'Models of the Solar System and the Universe' or other their familiar topics.**

General phrasings of the interview questions

PCK elements	Questions about teaching XXX topic
a. Knowledge about instructional strategies	1. In what activities, and in what sequence, did your students at school participate in the context of this topic? Please explain your answer
	2. What was (were) your role(s) as a teacher, in the context of this topic? Explain your answer
b. Knowledge about students' understanding	3. Did your students at school have any specific previous knowledge in the context of this topic? Explain your answer
	4. What was successful for your students at school? Explain your answer
	5. What difficulties do you see in teaching this special topic? Explain your answer
c. Knowledge about ways to assess students' understanding	6. On what, and how, did you assess your students at school in the context of this topic? Explain your answer
	7. Did your students at school reach the learning goals with regard to this topic? How do you know? Explain your answer
d. Knowledge about goals and objectives of the topic in the curriculum	8. What was (were) your main objective(s) in teaching the topic of 'Models of the Solar System and the Universe'? Explain your answer 9. Which competencies should the students have gained from learning this topic?

Note: The interview questions about Pedagogical Content Knowledge were literally taken from the study of Henze, van Driel & Verloop (2008). Development of experienced science teachers' pedagogical content knowledge of models of the solar system and the universe. *International Journal of Science Education, 30*(10), 1321-1342.

Appendix 7:

半结构访谈——学生

介绍

亲爱的同学，

您好！

我叫贾雪姣，是柏林自由大学基础教育研究中心的博士生，研究方向是教师教育和科学教育，博士课题由中国国家留学基金管理委员会资助。

我的博士课题拟调查研究中国职前阶段的科学教师教育。贵校的科学教育专业拥有优秀的师资，培养出了许多优秀的科学教师，使得中国的科学教育专业发展地更好更专业。因此，本研究拟在贵校进行调查研究以及收集数据。

本访谈拟收集贵校科学教师教育相关方面的数据。具体来说，您作为一名科学教育专业的学生，未来的中小学科学教师，是如何看待科学教育的？您如何培养未来的学生？您对教师知识、教师信念以及教学方法的观点又是什么？

本次访谈大约需要您 45-60 分钟的时间来完成。请注意，对于本次访谈的任何问题，您的答案并没有正确或者错误之分。本次访谈的有效性与您答案的真实性密切相关，您的答案对本次研究非常重要。因此，请根据您的实际情况，真实回答这些问题。您的答案只用作研究，并且会被严格保密。在我以后的论文撰写中，也不会提及您的个人信息。在您的同意之下，我将会对本次访谈进行录音。

非常您参加本次研究并同意接受访谈！！

访谈问题：

1. 请告诉我你作为一名科学教育专业的学生的经历。

   a. 你为什么会选择科学教育这个专业？

2. 你认为，中小学里好的科学教学具有哪些特点？

   a. 不久的将来，你将在中小学教科学。你认为，对于你以后的科学教学来说，哪些方面比较重要？
   b. 对科学这门课来说，你觉得哪些课程内容最重要？
   c. 你比较倾向于使用哪些教学方法？

3. 在小学的科学课堂总，你认为教师的角色是什么？

4. 在小学的科学课堂中，你认为学生的角色是什么？

5. 你认为，你所接受的职前科学教师教育课程对你的培养如何？

a. 你认为，哪些方面做得很好，将你培养的很好?

b. 哪些还存在不足，对你的培养不够?

6. 为了以后能在中小学教科学，你认为，在大学里未来的科学教师需要学习哪些知识？

a. 在你的大学课程里，你认为哪些课程或者技能最重要？

b. 通过你接受到的科学教师教育课程，你希望能够获得什么知识或者技能？

7. 关于激励你未来的学生学习科学这门课程，你认为最佳的方法是什么？为什么？

8. 有一个概念叫"探究性学习"。不同的人可能对"探究"有不同的理解。你能用你自己的语言描述对"探究"的理解吗？

a. 你曾经在高中或大学的课程中经历过"探究性学习"吗？如果有，你能为我描述一节这样的课吗？

b. 你认为，"探究性教学"具有什么样的优点和缺点？你能举例分别描述一下吗？

c. 对于你未来的学生，你会给他们多大的自由，让他们用自己的方法去探究问题？

9. 关于我们今天的访谈，你还有其他方面想补充或提及的吗？

Note: The interview questions in this appendix were designed by the author.

The author translated the interview questions into Chinese.

Appendix 8:

学科教学知识（PCK）——学生

1986 年舒尔曼提出“学科教学知识”这个概念。学科教学知识是一种特殊的知识，它将教师从课本知识中分离出来，学科教学知识是教学知识的基础组成部分。本次调查将采用半结构访谈方式来研究未来小学科学教师的学科教学知识。访谈将以一个具体的主题“太阳系与宇宙的模型”进行，或者以学生熟悉的某个主题进行。

访谈问题

PCK 的要素	关于 XXX 主题的教学问题
A. 关于教学策略的知识	1. 在什么活动中、以什么顺序，你的学生会参与到这个主题的相关背景中去？请解释你的答案。
	2. 在这个主题的背景下，作为一名小学科学教师，你的角色是什么？请解释你的答案。
B. 关于学生理解的知识	3. 关于这个主题，你的学生之前有任何具体的背景知识吗？请解释你的答案。
	4. 你认为，你学生成功的方面是什么？请解释你的答案。
	5. 在教这个特定的主题或者其他主题时，对于你来说，困难的方面是什么？请解释你的答案。
C. 关于评价学生理解的知识	6. 在这个主题或者其他主题的背景下，你是如何评价你的学生的？请解释你的答案。
	7.关于这个主题，你的学生达到了预期的学习目标了吗？你是如何知道的？请解释你的答案。
D. 关于课程目标的知识	8. 在教“太阳系与宇宙的模型”这个主题或者其他主题时，你的主要教学目标是什么？请解释你的答案。 9. 通过学习这个主题，你的学生应该获得什么能力？

Note: The interview questions about Pedagogical Content Knowledge were literally taken from the study of Henze, van Driel & Verloop (2008). Development of experienced science teachers' pedagogical content knowledge of models of the solar system and the universe. *International Journal of Science Education, 30*(10), 1321-1342.

The author translated the interview questions into Chinese.

Appendix 9:

Semi-structured interview with science teacher educator

Introduction

Thank you for taking part in this research and for agreeing to be interviewed. My name is Xuejiao Jia. I am a doctoral student at Center for Research in Primary Education of Freie Universität Berlin. My research direction is teacher education and science education. This study is sponsored by China Scholarship Council (CSC). I am at the point in my studies where I require your help.

My PhD research will examine pre-service science teacher education in China. Science education in your university is well renowned for the excellent science teacher educators and student-teachers, who devote themselves to make science education in China better and more professional. Thus, my study is designed to collect data in your university. The purpose of this interview is to gather background information about science education in your college, and to understand your views about teachers' practices, teachers' belief and teaching methods in science education.

Please remember that there are no right or wrong answers. The validity of this investigation depends on the extent to which your responses are open and frank, so please answer honestly and in as much detail as possible. Your responses will be used for research purposes only. They will remain confidential and will not be attributed to you by name. I would like to record the interview, with your consent.

1. Please tell me about your experience as a teacher of science education.

a. Why did you choose to be a science teacher educator at university?

2. Please tell me, how do you judge your curriculum plan/guideline?

a. How strict do you have to follow this curriculum plan/guideline?

b. How much freedom do you have for making ideas and decisions?

c. What do you think is missing/ lacking in your curriculum plan/guideline?

3. What do you consider to be characteristic of good science teaching at schools?

a. You might be giving marks when students prepare lessons for schools. What do you consider to be most important for the students to show in their lessons?

b. Which content areas do you consider to be most important?

c. Which teaching methods do you want your students to use?

4.What do you think is the teacher's role in a science classroom?

5.What do you think is the student's role in a science classroom?

6. What do you think needs a teacher to have learned at the university for teaching science at school?

a. Which subject or subject area or skill do you consider to be most important in your university courses?

b. What do you hope to pass on in your science education program?

7. What do you think is the very best way to motivate students to learn science? Why?

8. There is an idea called "Inquiry-Based Learning". The word "inquiry" may have different meanings to different people. Can you describe for me, in your own words, what "inquiry" means to you?

a. Do you remember using "Inquiry-Based Learning" in any of your university courses? Can you describe such a course for me?

b. What are the advantages and disadvantages of "Inquiry-Based Learning" from your point of view? Can you describe an example?

c. How much freedom would you give your students to investigate problems of their own choosing?

9. If you could design a new teacher education program for science teaching, which elements would be of greatest importance to you? Can you please explain the reason?

10. Is there anything you would like to add, related to anything that we talked about today?

Note: The interview questions in this appendix were designed by the author.

Appendix 10:

Pedagogical Content Knowledge for science teacher educator

Shulman (1986) proposed Pedagogical Content Knowledge (PCK), which is a specialized knowledge that distinguishes teachers from subject matter specialists. PCK is a fundamental component of the knowledge base for teaching. This data collection consists of a semi-structured interview to view the PCK in a specific topic '**Models of the Solar System and the Universe' or one of their familiar topics.**

General phrasings of the interview questions

PCK elements	Questions about teaching XXX topic
a. Knowledge about instructional strategies	1. In what activities, and in what sequence, did your students at university participate in the context of this topic? Please explain your answer
	2. What was (were) your role(s) as a teacher, in the context of this topic? Explain your answer
b. Knowledge about students' understanding	3. Did your students at university need any specific previous knowledge in the context of this topic? Explain your answer
	4. What was successful for your students at university? Explain your answer
	5. What difficulties do you see in teaching this specific topic? Explain your answer
c. Knowledge about ways to assess students' understanding	6. On what, and how, did you assess your students at university in the context of this topic? Explain your answer
	7. Did your students at university reach the learning goals with regard to this topic? How do you know? Explain your answer
d. Knowledge about goals and objectives of the topic in the curriculum	8. What was (were) your main objective(s) in teaching this topic? Explain your answer 9. Which competencies should the students have gained from learning this topic?

Note: The interview questions about Pedagogical Content Knowledge were literally taken from the study of Henze, van Driel & Verloop (2008). Development of experienced science teachers' pedagogical content knowledge of models of the solar system and the universe. *International Journal of Science Education, 30*(10), 1321-1342.

Appendix 11:

半结构访谈——教师

介绍

亲爱的老师，

您好！

我叫贾雪姣，是柏林自由大学基础教育研究中心的博士生，研究方向是教师教育和科学教育，博士课题由中国国家留学基金管理委员会资助。

我的博士课题拟调查研究中国职前阶段的科学教师教育。贵校的科学教育专业拥有优秀的师资，培养出了许多优秀的科学教师，使得中国的科学教育专业发展地更好更专业。因此，本研究拟在贵校进行调查研究以及收集数据。

本访谈拟收集贵校科学教师教育相关方面的数据。具体来说，您作为一名大学的科学教师，培养未来的中小学科学教师的教育者，是如何看待科学教育的？您如何培养您的学生？您对教师知识、教师信念以及教学方法的观点又是什么？

本次访谈大约需要您 45-60 分钟的时间来完成。请注意，对于本次访谈的任何问题，您的答案并没有正确或者错误之分。本次访谈的有效性与您答案的真实性密切相关，您的答案对本次研究非常重要。因此，请根据您的实际情况，真实回答这些问题。您的答案只用作研究，并且会被严格保密。在我以后的论文撰写中，也不会提及您的个人信息。在您的同意之下，我将会对本次访谈进行录音。

非常您参加本次研究并同意接受访谈！！

访谈问题：

1. 请告诉我，您作为一名科学教育专业教师的经历。

a. 您为什么会选择成为一名科学教育专业的教师？

2.请告诉我，您如何评价贵校科学教育专业的课程大纲？

a. 在多大程度上，您必须得按照课程大纲进行教学？

b. 您有多大的自由来制定教育方面的决定？

c. 关于贵校科学教育专业的课程大纲，您认为哪些方面做得不够好，需要弥补？

3.您认为，中小学里好的科学教学具有哪些特点？

a. 当您的学生去中小学实习教学的时候，您应该对他们进行过观察或者评价。您认为，当他们在中小学进行教学的时候，课堂中最需要呈现的是什么？

b. 对科学这门课来说，您认为哪些课程内容最重要？

c. 您希望您的学生使用哪些教学方法？

4. **在大学的科学课堂中，您认为教师的角色是什么？**

5. **在大学的科学课堂中，您认为学生的角色是什么？**

6. **为了以后能在中小学教科学，您认为，在大学里，未来的科学教师需要学习哪些知识？**

a. 关于大学课程，您认为哪些课程或者技能最重要？

b. 通过贵校的科学教师教育，您希望传给您的学生什么样的知识或者技能？

7. **关于激励您的学生学习科学，你认为最佳的方法是什么？为什么？**

8. **有一个概念叫 "探究性学习"。不同的人可能对"探究"有不同的理解。您能用您自己的语言描述一下，您对"探究"的理解吗？**

a. 您曾经在高中或大学的课程中经历过 "探究性学习" 吗？如果有，您能为我描述一节这样的课吗？

b. 您认为 "探究性学习" 具有什么样的优点和缺点？您能举例分别描述一下吗？

c. 对于您的学生，您会给他们多大的自由，让他们用自己的方法去探究问题？

9. **如果您能自己设计一个教师培养方案，对您来说，哪些因素最重要？您能解释一下原因吗？**

10. **关于我们今天的访谈，你还有其他方面想补充或提及的吗？**

Note: The interview questions in this appendix were designed by the author.

The author translated the interview questions into Chinese.

Appendix 12:

学科教学知识（PCK）——教师

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	2.在这个主题的背景下，作为一名大学科学教师，你的角色是什么？请解释你的答案。
B. 关于学生理解的知识	3.关于这个主题，你的学生之前有任何具体的背景知识吗？请解释你的答案。
	4.你认为，你的学生成功的方面是什么？请解释你的答案。
	5.在教这个特定的主题或者其他主题时，对于你来说，困难的方面是什么？请解释你的答案。
C. 关于评价学生理解的知识	6. 在这个主题或者其他主题的背景下，你是如何评价你的学生的？请解释你的答案。
	7.关于这个主题，你的学生达到了预期的学习目标了吗？你是如何知道的？请解释你的答案。
D. 关于课程目标的知识	8.在教“太阳系与宇宙的模型”这个主题或者其他主题时，你的主要教学目标是什么？请解释你的答案。 9.通过学习这个主题，你的学生应该获得什么能力？

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