Mainland Chinese Students’ Metacognition, Including their Conceptions of Learning: A Phenomenographic Study in Hebei and Shandong Provinces

by

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Abstract

There is little empirical study in the literature to study Mainland Chinese students' metacognition including their conceptions of learning. This research seeks to fill this gap by seeking to understand and describe Mainland Chinese students' metacognition including their conceptions of learning science and the origins of these conceptions and learning processes. 96 students from 11 middle schools in two provinces in northern China were interviewed and their lived experiences of learning science were recorded and transcribed. Phenomenography was the major methodology applied to search for the common themes and at the same time the variation among the students in conceiving science learning. Seven categories of conceptions of learning science emerged from the phenomenographic analysis: 'listening to the teacher,' 'attending to exams,' 'memorizing,' 'understanding,' 'doing problems,' 'hard work,' and 'improving oneself.' Three of the seven categories, i.e., 'listening to the teacher,' 'attending to exams,' and 'hard work,' are not found in the literature of conceptions of learning, and these three categories of conceptions of learning are reflections of the Chinese culture that values hard work, advocates respect for teachers, and holds a long history of imperial examinations. The outcome space of the conceptions of learning is proposed as a holistic structure in which the seven categories of conceptions of learning share equivalent positions, in contrast to the commonly found hierarchical structure in the literature in which the categories are arranged hierarchically from low levels to high levels. The variation in conceiving science learning among the participants resides in the two or more subcategories of each of

the seven categories. The origins of these conceptions of learning reported by the students are learning experiences, parents, teachers, peers, and cultural values.

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Chapter 1 Introduction

1.1 Background of the study

To learn science well is a key goal of science education worldwide even though a consensus on what constitutes 'good' science learning may vary across contexts. This point will be elaborated in Chapter 2. Learning science well is very important for Chinese students. The popular Chinese saying, "a person would not be afraid of going anywhere if he/she has learnt science well" (学会数理化，走遍天下都不怕) reflects the stress that Mainland Chinese place on successful science learning. It has been proposed by Chinese leaders since the formation of the PRC that science will assist China and contribute to her prosperity (Wei and Thomas, 2006). Not surprisingly, science has a prominent position in the Mainland Chinese school curriculum. Students must achieve a pass standard to be eligible for graduation. Hence science achievement is much sought after as part of the provincial high school certificate examinations. That is to say, students' science learning achievement strongly influences their future education options and their future vocations.

In Mainland Chinese schools a substantial amount of time is devoted to the science curriculum. On average, the time spent on science instruction in schools is at least ten hours per week. There is also considerable time spent after school hours doing homework. The total number of hours studying science outside school can be as high as twenty (Ye et al., 2000). The science education literature suggests that Mainland Chinese students excel at recalling factual knowledge of science and are skillful at solving algorithmic content-based problems (Bao et al., 2009). It has been suggested that Chinese students do well in comparative assessments of science learning compared to their counterparts in other countries, e.g., the United States of America (PISA, 2010; Su and Su, 1994; Wang, 1998; Ye et.al., 2000). A further indication of Chinese students' capacity to achieve in science learning is evidenced by the large enrolment of Chinese students in graduate programs in science or engineering faculties in Western universities (Mackie, 2005; Lewin, 2009).

Despite the claims referred to above that suggest Mainland Chinese students excel at learning science, one should not necessarily infer that Mainland Chinese students are more able learners of science than those in other countries. The Mainland Chinese population is the largest in the world and it might be therefore expected that it will have a large number of successful achievers across all fields, including science learning. The large population has the potential to skew perceptions of the achievement profiles of Mainland Chinese students in the Western literature. Further, it is often reported that rote learning is an important technique by which many Chinese students learn science (Liu, 2006; Su & Su, 1994). It is known from studies in science education that rote learning alone often results in poor conceptual understanding of scientific concepts, short periods of retaining scientific knowledge, and low levels of application of a students' scientific knowledge into their everyday life. The fact that no Mainland Chinese scientist has won Nobel Prize is often raised by extreme Chinese patriots as evidence of the infertility of science education in Mainland China. This is despite the substantial contributions made by Mainland Chinese scientists to the world scientific community. In fact, the contribution of

Chinese scientists to world science has been growing exponentially (Zhao & Leydesdorff, 2006). Nevertheless, their contribution to the science community still lags behind other countries, even though China has 42 million personnel qualified at tertiary level to enable them to work and conduct research in science and technology (Ministry of Science and Technology, 2009). While Chinese history may have contributed to the achievement of contemporary Chinese scientists, the nature of science education in Mainland China should also be considered. Creativity is an indispensable requirement for scientists to be productive and it can be argued that creativity and higher-order thinking should be cultivated through science education. It has been contended, however, that Chinese schools seldom provide opportunities for students to develop creativity and higher-order thinking (Li, 2004; Su & Su, 1994).

According to many scholars, Chinese culture highly values effort and perseverance in learning science over intelligence and the mechanisms of learning how to learn (Li, 2004). As a consequence, teachers may ignore teaching students how to learn science and engaging students with the higher order thinking and metacognition that is associated with development of conceptual understanding. Some 'folk' beliefs in Mainland China promote the taken-for-granted view that students will learn well if they just learn (e.g., 只要功夫深，铁杵磨成针, which means so long as you have put in a great deal of effort, you can grind an iron rod into a needle). Consequently it has been suggested that many Mainland Chinese students equate science learning with remembering scientific concepts and doing drills as solving problems (Robinson & Kuin, 1999). Mainland Chinese students score high on examinations because they have worked relentlessly for long hours enduring perseverance and hardship. They may have memorized scientific information and gained skills in solving content-based problems, but their scientific reasoning ability reportedly remains under-developed (Bao et al. 2009).

Some scholars however have urged caution to overgeneralizing regarding the learning processes employed by Mainland Chinese students and students representative of other Confucian heritage populations, such as those in Hong Kong and Taiwan (Watkins and Biggs, 1996). These scholars, while not specifically referring to science learning in these cultural and geographic contexts, suggest that rote learning and memorization are elements of a more comprehensive strategy for learning employed by such populations. However, no specific studies have ever attended to strategies employed by Mainland Chinese students in learning science, the metacognition associated with learning using those strategies, or the origins of those strategies and associated metacognition. Research is required to attend to this void in the literature.

It is argued that how students learn and whether their learning is deemed as successful or otherwise is strongly influenced by the context, social and cultural, within which the learning and evaluation of that learning takes place. Gunstone (1994) has argued that all students are metacognitive to some extent, that is, they all possess some knowledge, control, and awareness of their learning and thinking processes and those of others. It is the extent to which students' metacognition is adaptive for their contexts that determines its efficacy, not any absolute value (Thomas, 1999a, 2002).

In other words, if an examination asks for nothing more than recall of factual information and algorithmic problem solving strategies that can be learned themselves through repetition and countless examples then students will strive to succeed in that context. Studies of metacognition should therefore consider beliefs, contexts, and cultures of students in order to ascertain the efficacy or otherwise of their cognitive and learning strategies and metacognition (Thomas, 2002, 2012). This view runs contrary to the orthodoxy of much scholarship that suggests that metacognition and cognitive and learning strategies can be evaluated according to some absolute, culturally independent scale.

One thing that is agreed upon is that teachers both intentionally and unintentionally teach students how to learn. Students also learn how to learn and what it means to learn in their everyday contexts. These contexts include their families and their peer groups. Students learn how to learn within their contexts even if what and how they learn remains tacit and not easily described by them or discussed with others. The contexts within which learning is executed will determine the philosophy of learning, learning approaches, strategies, and the underlying psychological processes (Vygotsky, 1978).

Within the Mainland Chinese education systems teachers do not have much exigency or time to explicitly teach their students how to learn. The pressure of executing the fixed curriculum and the onus of preparing students for multiple examinations is overwhelming. Only when students do not perform well in an examination might teachers feel the impetus to consider how their students learn and/or engage with the subjects' material. However, if teachers have limited knowledge and/or understanding of how students learning processes can be improved, then it is unlikely that their instruction to improve students' learning processes will be effective. In other words, if teachers know only what their cultural press suggests in terms of what learning is, how it takes place, and how it might be evaluated, then students will not be exposed to ideas that challenge their own preexisting metacognitive knowledge and beliefs about such matters. For example, it is well known that Mainland Chinese students generally exhibit high levels of motivation. Therefore instruction that seeks solely to motivate students is unlikely to result in enhancing learning processes in a population that is already highly motivated. Most Chinese students have been motivated by their parents, teachers, and their society in general.

Another contextual problem of instructing learning to learn and developing metacognition is the dogmatism of teachers. Dogmatism means "positiveness in assertion of opinion especially when unwarranted or arrogant" and "a viewpoint or system of ideas based on insufficiently examined premises" (Dogmatism, n.d.). Strongly dogmatic teachers would take instructional 'recipes' as absolute truth and ignore possible contextual constraints of their application. The reasons for Chinese teachers' dogmatism are social, historical, and political. Marxism has been the only philosophy taught at school since the foundation of People's Republic of China in 1949 and its role is not limited to socialist propaganda. Marxism is a worldview that conceives the world as universally materialistic and governed by universal laws (van der Linden, 1996; Wang, 2012). The notion of developing metacognition and students, learning to learn processes would be seen by teachers as more relevant if they had emerged from education and psychology studies originating through the research of Chinese scholars. However, most of the textbook knowledge about education and psychology in Mainland China was borrowed directly from the former Soviet Union from the 1950s and then increasingly from the West only after the 1980s. The same can be said of much of the science education curriculum material and frameworks that were selectively imported into Mainland China after its establishment in 1949 (Wei, 2009).

It is argued in this thesis that there is a need to consider the contexts within which students learn to reason and to think if we are to understand their reasoning and thinking, its origins and the metacognition associated with it. This creates something of dilemma for this study for it must be acknowledged from the outset that the very term 'metacognition' is itself a construction of Western culture and psychology and that it has not had a direct Chinese counterpart or equivalent until recent times. Only in the 1980s when the word metacognition became more visible in the western education literature, did the term 元认知 translated as 'above cognition' appear in Chinese education vocabulary. Therefore metacognition is used in this study as a placeholder concept to allow for the framing of the study, the methodology to be employed, and to enable communication using a shared language, in this case English.

Chinese culture has a history of five thousand years and is rich in educational theories and learning principles. Confucianism, as the core component of Chinese culture, provides numerous ideas and suggestions regarding teaching and learning. Confucian principles related to learning such as the idea of seeking for self-perfection (修身), learning to contribute to society (治国平天下), passion for learning (好学), promptness in action versus prudence in speech (讷于言敏于行), and respectful learning (尊师) are deeply manifest among Chinese teachers and students (Tweed & Lehman, 2002; Li, 2003). However there is very little empirical research emanating from Mainland China into their culture of learning and the applicability of Western education theories and how they relate or otherwise to established Confucian traditions (Cortazzi and Jin, 1996). This study aims to attend, in part, to contribute to this literature and empirical research.

1.2 Purpose of the study

The intent of this research is to explore Mainland Chinese learners' views of how they learn science, how they came to learn science as they describe, their views regarding what they consider influences/influenced their learning processes and the development of these processes, and to compare this corpus of data and resulting assertions with Western educational theories related to metacognition. In doing so, the adequacy or otherwise of existing theories of metacognition and their generalizabilty and predictive authority across cultural contexts will be also scrutinized. I explore if and how Chinese culture shapes Chinese learners' science learning processes and their metacognition, as it is commonly referred to in the West, related to those processes. Philosopher Balagangadhara (1994) defined culture as a tradition that can be identified in terms of a specific configuration of learning and meta-learning. Humans depend hugely on their cultural group's decisions and expectations regarding what they should learn and how they should learn it. As yet however, few, if any, empirical studies have explored how Mainland Chinese society's decisions and tacit/implicit expectations and requirements regarding how science learning should proceed, at both social and individual levels, influences how individuals learn science.

Learning to learn is a second-order learning phenomenon that encourages learners to possess and employ metacognitive knowledge and metacognitive abilities so that their learning will be reflective, strategic, intentional and collaborative (Dearden, 1976; James et al., 2007). The core concept of 'learning to learn' is metacognition, which is one of the hallmarks of contemporary Western psychological and educational learning theory. Metacognition has been being the focus of educational research around the world since the American Psychologist Flavell first introduced it in 1971 (Flavell, 1971, 1976). But no research, if any, has been done to verify or otherwise the applicability of contemporary metacognition theory, particularly the processes people use to learn science, the origins and antecedents of these processes, and the regulation of these processes in the Mainland Chinese learning context.

Metacognition is often simply defined as 'cognition about cognition', or 'thinking about thinking'. According to Flavell (1979, 1987), metacognition consists of metacognitive knowledge and metacognitive experiences. But the construct of metacognition is not universally agreed upon. Researchers from different backgrounds and cultures may possess different understandings of the construct of metacognition. More importantly, the context and culture within which students learn science may determine the construct of metacognition, in the Western meaning of the word, and/or any possible equivalent construct which relates to students knowledge, control and awareness of their thinking and learning processes and those of others (Thomas, 2006b, 2012).

Since metacognition is an important predictor of academic performance (Dunning et al., 2003; Thiede et al., 2003), and Chinese students' performance in science is reportedly good and less satisfactory in different aspects, that is, good at scientific knowledge and content-based problem solving skills but less satisfactory at scientific reasoning and creativity (Bao et al., 2009), it is reasonable to assume that Chinese students' metacognition might reflect preferences for knowledge and strategies related to particular learning processes that are adaptive for their contexts. Chinese students may be special and unique in their metacognitive knowledge, experiences, and abilities that shape their learning and academic performance in science. This study explores such metacognitive knowledge, metacognitive experiences, and metacognitive abilities, and try to identify and understand the similarities and differences between Chinese learners and their Western counterparts who are already widely referenced in the existing literature.

As well as the context influencing students' cognitive processes and metacognition, students' knowledge of learning and their conceptions of learning also determine how they engage with the content, their learning outcomes, and the context of learning that they themselves help to create (Meyer & Boulton-lewis 1999). Conceptions of learning are concerned with what the learner thinks the objects and processes of learning are, and reflect his/her experience of learning (Marton et al., 1993; Saljo, 1979; Thomas, 1999a, 2002). Metacognitive knowledge refers to individual's general and specific knowledge about how they learn and process information, including their knowledge of their own individual learning processes (Flavell, 1979). It has been decades since scholars started to study students' conceptions of learning, but after studying the literature on conceptions of learning and metacognition this researcher considers that few researchers ever linked conceptions of learning with metacognitive knowledge and thus proposes that students' conceptions of learning can be regarded as part of their metacognitive knowledge as suggested by Thomas (1999a, 1999b, 2002, 2006b). To study students' conceptions of learning within the category of metacognitive knowledge may be informative regarding the complicated processes of learning, in this case with reference to Mainland Chinese science learners.

The investigation of students' conceptions of learning science is an important element of the exploration of the metacognition of Mainland Chinese students, and it might be argued that such conceptions of learning are themselves worthy of study. The phenomenography literature suggests that students' conceptions of learning fall along a continuum from passive transmissionist perspectives to constructivist, transformative perspectives (Marton et al. 1993, Berry and Sahlberg 1996). Transmission conception/perspectives of learning are barriers to science learning and the development of adaptive metacognition. Transmissionist perspectives that might be consistent with a school's teaching practice and the learners' and their society's cultural beliefs can become entrenched and hard to change.

In sum, the purpose of the study is to investigate how Mainland Chinese students conceive science learning, how they describe their metacognition, and where they consider their conceptions of learning and metacognition originate. It is proposed that learning to learn is contextual and culturally influenced, and this study seeks to verify if and how Chinese culture influences their science learning conceptions and metacognition.

1.3 The significance of the study

The significance of studying how Mainland Chinese students learn to learn science lies in more fully understanding Mainland Chinese learners and scrutinizing Western learning theories including metacognition in the Chinese context. First of all, this study may have a direct contribution to the understanding of Chinese learners regarding science learning and metacognition. There are over 200 million students in Chinese schools, but not enough study has been undertaken to understand them, especially in the area of science education and metacognition. No study, to this researcher's knowledge, has examined Mainland Chinese students' metacognition including their conceptions of science learning.

Most influential learning theories including behaviorism, cognitivism, and constructivism have their origins in the West and usually these theories were directly imported to Chinese textbooks of psychology and education without validation for the Mainland Chinese context (Louise and Zheng, 2002; Yang, 2004). The doctrine of universalism in the world endorses the ‘intellectual borrowing’ of psychological and educational theories at the sacrifice of the plurality of perspectives and paths (Kothari, 1987). By scrutinizing the application of foreign learning theories, especially metacognition related to processes of science learning, to Mainland China this study coincides with the tradition of cross-cultural research testing the generality of exiting psychological knowledge and theories (Berry et al., 2002; Dawson, 1971; Whiting, 1968).

Chinese culture, represented largely by Confucianism, has a long tradition of valuing education and has its own principles of learning. These principles of learning may influence heavily teachers/students to teach/learn science, but they are seldom seen or discussed in the official guides of teaching/learning science, since these guides depend mainly on psychological and educational theories either from the former Soviet Union or from the West (Yang, 2004). By studying how Mainland Chinese learners learn science, the cultural heritage of learning may be found to be interacting with Western learning theories. Exploring the interaction between Chinese ways of learning science and Western learning theories may not only contribute to theorizing regarding science learning, but also to the practice of science education in Mainland China. In addition, the experiences of Mainland Chinese students learning science might benefit Western science learners in understanding and possibly adopting variations in approaches to learning science.

1.4 Research questions

The research seeks to understand and describe Mainland Chinese students' metacognition including their conceptions of learning science and the origins of these conceptions and learning processes. More specifically, answers to the following three questions will be explored:

1). What do Mainland Chinese students report as their metacognition including their conceptions of learning science?

2). What do Mainland Chinese students report as the origins of their conceptions of learning and science learning processes?

3) How do Mainland Chinese students report, if at all, that culture influences their metacognition including their conceptions of learning?

In the following Chapter, the literature of science learning, metacognition, and Chinese culture will be reviewed so that the empirical study of the research questions might be based on a sound theoretical foundation.

Chapter 2 Literature Review

2.1 Science learning

The first section of literature review consists of five sub-sections: the importance of learning science, the roadmaps to successful science education, current issues regrading science learning, metacognition as a key component in science learning, and how culture influences science education.

2.1.1 The importance of learning science

The content of science is full of beautiful things that are inspiring (Feynman, 1966). Feynman illustrates how the world looks very different after one learns science through the simple example that trees are made of air and when trees are burned they go back to air. The richness and excitement of comprehending the natural world can only be enjoyed in some ways after learning science. Science learning functions as a lens through which blurry facts about the world come into sharp focus.

In a world full of radical changes with respect to the social and natural environment, science is at the center of those changes by causing them, shaping them and responding to them (AAAS, 1993; 2010.). Students today who will be pillars of society tomorrow should be scientifically literate to understand how science influenced and shaped the changes, and most importantly, be prepared to respond to such changes. Science is the interconnected and validated ideas about our physical world that people have developed over the course of human history (Rutherford &

Ahlgren, 1991). Learning science is not only an intellectual and social endeavor to figure out how the world works, but also the process of empowering students with scientific knowledge and abilities to face any challenges ahead of them.

One aspect of scientific literacy gained through learning science is to understand the nature of science, the scientific enterprise, and the role of science in society and personal life (Laugksch, 2000; NAS, 1996; Project 2061, 2001). When people know how scientific knowledge is obtained and the possible limitations of scientific conclusions, they are more likely to react thoughtfully to scientific claims. They should be more able to engage intelligently in public discourse and debate about important issues that involve science and technology.

Contemporary life and work require people to be life-long learners, higher order thinkers, personal decision makers, and problem solvers (AAAS, 1993; 2010.). The process of scientific inquiry in learning science contributes in an essential way to developing these attributes. Science education not only enriches and empowers people, but also transforms and remolds them. Many countries, like the United States of America, Canada, and the People's Republic of China, place science education at a strategic height. A successful science education is regarded as a key to those countries' prosperities (Rudolph, 2002; Hodson, 2003; Gao, 2009).

2.1.2 Conceptualizing a roadmap for successful science learning

Although different countries may define the meaning of a successful science education in varying ways, it is the international trend to realize the drawbacks of traditional science education in which scientific knowledge was pumped or transmitted into the heads of students (Tytler, 2007). Worldwide reforms of science education try to replace the old practice of imparting scientific knowledge with more effective ways of teaching and learning depending on subtly different goals of science education taking into account the circumstances with each country in which reforms take place. Although reforms for the 'modernization' of science education have been advocated in Mainland China over the last thirty years, the traditional format of big class lectures and passive listening is still the routine approach of teaching and learning science for many Chinese science learners (Lin, 2010). The prevalent examinations continue to be the only acceptable means of assessment, and good scores represent good and successful science learning for Chinese science learners. Despite the seeming lack of change of pedagogy in both the West and Mainland China, there is some consensus as to general reform directions in science education. This section seeks to briefly outline such reform directions.

2.1.2.1 Scientific Inquiry

The US national science education standards emphasize the importance of scientific inquiry as an effective way to learn science. Learning science is proposed to be an active process in which students do 'something' instead of 'something' being done to them. According to the American science education standards, teachers should involve students in inquiry-oriented investigations, in which students ask questions, construct explanations from evidence, and communicate their ideas with their teacher and classmates. Inquiry, by definition, is the intentional process of diagnosing problems, critiquing experiments, distinguishing alternatives, planning investigations, researching conjectures, searching for information, constructing models, debating with peers, and forming coherent arguments (Linn, Davis, & Bell, 2004). In inquiry-based learning contexts students are expected to discover the fundamental and well-known principles of science by modeling the activities of professional researchers. Through inquiry-based learning students are purported not only to have a better understanding and grasp of conceptual and procedural knowledge but also to possess the flexible thinking skills and the epistemic practices of science that prepare students to be lifelong and metacognitive learners. Although some scholars (e.g., Kirschner et al., 2006) question the effectiveness of the inquiry-based pedagogy, evidence suggests that inquiry is a powerful and effective model of learning science (Hmelo-Silver et al., 2007). A report by the European Commission (2007) makes the recommendation to fully implement inquiry based methods for science education. In the Chinese national curriculum standards for science, scientific inquiry is also strongly emphasized among the three goals of science education which include learning scientific knowledge and skills, experiencing processes of scientific inquiry, and obtaining a scientific worldview and appropriate attitudes (Ministry of Education of PRC, 2001).

2.1.2.2 Conceptual Change

Conceptual change is central to science learning although competing views of conceptual change exist. One view of conceptual change is to synthesize models by assimilating new concepts with prior knowledge (Vosniadou, 2002). Chi and Roscoe (2002) conceive of conceptual change as repair of misconceptions in which naïve and faulty conceptions are repaired to scientific ideas. Ivarsson, Schoultz, and Saljo (2002) take a sociocultural perspective suggesting that human cognition takes place in a sociocultural context as an interactive process rather than a purely cognitive one. They propose that conceptual change is the appropriation of intellectual tools and that conceptual change occurs as a consequence of interactions between the learner, tools, and other people (Ivarsson et al., 2002).

Conceptual understanding of scientific concepts, principles and inquiry processes is essential for students to be able to engage in processes of argumentation where they make claims about scientific issues, support their claims with evidence, and consider alternative explanations. The literature suggests that the quality of an individual's understanding of a topic influences the quality and complexity of the arguments he/she constructs regarding that topic (Venville & Dawson, 2010; Sadler, 2004; von Aufschnaiter et al., 2008). It is suggested that students should have a threshold level of knowledge and understanding in order to engage productively in argumentation (Lewis and Leach, 2006). On the other hand, argumentation can also help students deepen their understanding of scientific concepts and principles (Venville & Dawson, 2010). Cartier et al (2001) argue that understanding in science develops through practice and that 'doing science to learn' embodies dialogic knowledge-building processes. By engaging in scientific inquiry and argumentation processes, students can actively develop their understanding of science by combining scientific knowledge with reasoning and thinking skills.

2.1.2.3 Problem Solving

Problem-solving abilities are required in science learning as well as in professional and daily life. Traditional teaching approaches generally depend heavily on practicing problem solving on a large number of problems, critically called in Chinese as 题海战术 (tactics of a sea of problems). Taconis and his colleagues (Taconis et al., 2001) conducted a meta-analysis of 22 articles published between 1985 to 1995 for the purpose of characterizing innovative problem-solving teaching strategies. They concluded that successful interventions stimulate the construction of an adequate knowledge base and demonstrate the skillful use of this knowledge in science problem solving. The American Benchmarks for Science Literacy (AAAS, 1993) stated that students' ability and inclination to solve problems effectively depend on their having particular knowledge, skills, and attitudes and that quantitative, communication, manual, and critical-response skills are essential for problem solving.

2.1.2.4 Higher-order thinking

Higher-order thinking skills are considered as an important goal of science education (Zohar and Dori 2003; Forster, 2004; Thomas, 2006a, b, 2012). According to Bloom's taxonomy, memorization and recall of information are classified as lower order thinking skills whereas understanding, applying, analyzing, synthesizing, and evaluating are classified as higher order thinking skills (Bloom, 1956). Most skills of scientific inquiry previously included as elements of the roadmap for a successful science education, such as formulating hypotheses, planning experiments, and drawing conclusions are classified as higher order thinking skills (NAS, 1996). Higher order thinking is also positively correlated with domain-specific knowledge and the aforementioned problem-solving skills (Chang, 2010). Scientific reasoning abilities play important roles in influencing the ability to 'do' science and to construct science concepts (Lawson et al. 2000).

2.1.2.5 Nature of Science

Teaching and learning about the 'nature of science' has become an explicit goal of science education around the world (Lau, 2009). The US benchmarks for scientific literacy (AAAS, 1993) advocate teaching and learning the nature of science so that students can make informed decisions regarding scientific issues. Teaching and learning of the nature of science was not mentioned in the Chinese science curriculum until the new standards for science education was published in 2001 (Ministry of Education PRC, 2001). However, the standards did not define clearly what the nature of science is and how it should be taught. The goals of establishing a scientific worldview and encouraging scientific inquiry found in the Chinese standards may be seen as being related to the nature of science. Compared to the Western goal of democratic participation in social affairs, Chinese science education advocates patriotism and social responsibility that are valued explicitly in Chinese society.

2.1.3 Current issues in relation to students' science learning

This section seeks to identify and briefly outline important issues regarding students learning of science. Like the previous section, it is not meant to be an exhaustive treatise of all issues, but rather identifies some specific issues that might be considered prominent and relevant to considerations for this study.

2.1.3.1 Persistence of transmission pedagogies

Although it is almost universally agreed that constructivist inquiry is an ideal way to teach/learn science, teacher-centered didactic lectures are still common in many classrooms across the globe. An underlying belief of many teachers who insist on traditional 'spoon-feeding' pedagogies is that didactic lectures are most efficient, and often contextually appropriate and necessary. Teachers always expect their students to learn well what they teach. If some students do not learn well enough, they might be regarded as inattentive, less diligent or uni ntelligent. Those teachers may not realize that students will remember 70% what they say and 90% what they do, but only 20% what they hear (Metcalf, 1997). As the Chinese metaphor goes, 灌输给学生的知识如同咀嚼过的食物一样无味 (the directly told, well-prepared information sometimes tastes like chewed food that cannot stimulate appetite), so students may lose interest in learning science.

2.1.3.2 Curricular relevance and orientation

Another reason why students are not successful science learners and why some lose interest is that what they are asked to learn is either irrelevant or too difficult for them. The content and topics of school science, especially in the physical sciences, have remained virtually unchanged for decades despite massive advances in the field of science and technology (Thomas, 2009). Some of the content may be considered by both students and teachers as out of date and not having any practical value. If a science curriculum is mainly designed for the purpose of students learning the systematic knowledge of a scientific discipline so that they will be well prepared to go on to succeed in courses at university, then the curriculum might be found to be irrelevant to many students' everyday lives. In addition, overloaded science curricula may make learning difficult and be beyond the level of students' cognitive abilities and therefore scare away many otherwise potentially successful science students (Duggan & Gott, 2002).

2.1.3.3 The nature of assessment

As the world becomes a global village, examination-driven curricula have become a characteristic of science education in many countries, although not yet as characteristic and rampantly dictating as in China where all teaching and learning are directed by the university entrance examinations. The literature suggests that the Chinese examination system, and the multiple-choice tests employed worldwide, is better at assessing the reproduction of learned content rather than they are at capturing students' conceptual understanding and their use of problem-solving skills, their abilities, and their application of knowledge to new and authentic situations (Stewart, 2009). International testing such as TIMSS and PISA that compare academic achievements of students from different countries, and that are increasingly viewed as examples of authentic and meaningful assessment, are considered by some to have negative impact on science education directions in assessment because many important goals of science education including learning to how to learn, understanding the nature of science, authentic problem solving, and students' development and use of skills of scientific inquiry are typically ignored in such testing regimes. (Amrein & Berliner, 2002; Froumin, 2007; Sahlberg, 2006; Thomas, 2009).

2.1.3.4 A lack of attention to metacognition

In the present era of knowledge explosion, when knowledge acquired at school may become outdated or grow increasingly perishable, what students really need to know and be able to do by the end of their formal schooling is to learn how to learn (Black et al., 2006; James et al. 2007; Thomas, 2009; Toffler, 1970). The key element of learning to learn is metacognition which refers to what students know about how to learn science and how to be able to control their learning processes (McGuire, 2004; Hoffmann & McGuire, 2009; Thomas, 2009; Taylor, 1999). However, due to the 'hegemonic nature' of science education, metacognition has not been promoted to the prominent position that it deserves. In the curriculum documents such as the U.S. National Science Education Standards and Benchmarks for Science Literacy which function as a guide to science learning in the United States of America, and by default in many other countries, and that influenced the production of the Chinese standards for science education, not a word related to metacognition can be found. Although the document implies the importance of metacognition by ideas of awareness, planning, reflection, evaluation, etc., teachers might not infer the importance of developing and enhancing students' metacognition and thus will not prioritize and make explicit the fostering of metacognitive knowledge, control and awareness.

This study will particularly focus on metacognition and how students' metacognition, including their conceptions of learning, might be influenced by culture. This is not to say that the other issues identified above are not worthy of attention. In fact, as will be explored, their relevance to the context of Chinese science education is highly evident. However, it is now time to explore metacognition as a key component of science learning.

2.1.4 Metacognition as a key component of successful science learning

A goal of science learning is not only to develop knowledge and understanding but also to develop the ability of students to learn how to learn (Hattie, 2012). The capacities and habits that will enable individuals to continue learning after they leave school should be developed (Thomas, 2009). James and her colleagues (James et al., 2007) define learning to learn as a collection of good learning practices that encourage learners to be reflective, strategic, intentional and collaborative. Metacognitive knowledge of learning science, and an awareness and control of effective, context appropriate learning processes are essential for learning science well. Enhancing students' metacognition is commensurate with many agendas of contemporary science education (Thomas, 2006a, 2009, 2012).

Metacognition has been afforded high status as a feature of science learning since metacognition relates to a learner's self-knowledge and ability to learn how to learn (Georghiades, 2004). Flavell (1987) suggested that good schools should be hotbeds of metacognition development by providing opportunities for self-conscious learning. Being self-conscious means that the metacognitive learner is able to reflect and control their learning processes by being aware of what has been learnt and by understanding the relationship between the newly learnt and the already known. Since the 1980s, hundreds of research projects involving metacognition have been carried out. Many of these studies such as PEEL (Case & Gunstone, 2006; Gunstone, 1994) and CASE (Adey and Shayer, 1994) offered ample evidence that metacognition plays very important and positive roles in effecting and enhancing science learning.

Metacognition affects conceptual change, learning the nature of science, and the conducting scientific inquiry. As previously mentioned, conceptual change is a key issue for students to learn science well since concepts obtained directly from life may be either vague or naive, and also very resistant to change. Scientific concepts are the basis for problem solving, scientific inquiry, and communication with teachers and peers. Concepts learnt from life and experiences outside and inside schools should be modified as necessary to more canonically acceptable scientific concepts. The process of modification is not easy and needs metacognition to be most effective.

The metacognitive knowledge of knowing the necessity of conceptual change as a key element of learning science is a first step. Without being aware of potential differences of their own existing concepts and the canonically acceptable scientific concepts, students may have little or no motivation to change their views. The next step is to monitor one's own cognitive process of developing an understanding of a scientific concept. Students may have a false judgment of their understanding, the reason being that they do not monitor their thinking processes, nor do they ask themselves questions regarding their understanding of the detailed and possibly new information and/or where it fits or otherwise their existing schema. Baird et al. (1991) clearly articulate the importance of metacognition in conceptual change and claim that "adequate metacognition empowers the learner to undertake the constructivist processes of recognition, evaluation, and revision of personal views" (p. 164).

Learning the nature of science is, as stated previously, another important goal of science education world-wide (AAAS, 1993; McComas, 2003; Ministry of Education PRC, 2001; Peters, 2006). Despite the enormous impact of science on virtually every aspect of modern life, few individuals have an elementary understanding of how the scientific enterprise operates (McComas, 2003). Traditionally students are not encouraged to challenge any content from textbook and/or from their teachers, and this tradition is evident in many school and classroom learning environments. In this situation, students seldom have the chance to understand how scientific enterprises operate and what constitutes scientific knowledge. It is necessary for classroom learning environments to be metacognitively oriented to develop students' higher order thinking and metacognition, which will in turn help students understand the nature of science (Thomas, 2003, 2004). In metacognitively orientated classrooms instructors encourage their students to think about the processes of knowledge construction and to be more critical and alert regarding what they are being told and how they make sense of their experiences. Without the metacognitive awareness of their learning processes and the learning content, students are less likely to grasp the essence of the nature of science and knowledge construction.

Scientific inquiry is at the heart of contemporary science reform and is a fundamental process for science development. Students should develop metacognitive knowledge of how to conduct scientific inquiry in and outside of class. If students are to understand and be able to enact scientific inquiry, they must have the metacognitive skills necessary for planning the inquiry, monitoring and controlling its progress, and evaluating outcomes. Metacognitive experiences including those related to affective and cognitive dimensions accompany authentic inquiry processes. In addition, authentic and high quality scientific inquiry is not possible unless the learning and/or inquiry environment is highly metacognitively oriented (Thomas, 2006, 2009, 2012). A theoretical overview of metacognition will be provided in section 2.2 to orient and further elaborate the framework of this study.

2.1.5 How culture influences science learning

Science and science education are cultural enterprises which form a part of the wider cultural matrix of society (Maddock, 1981). To learn science can be regarded as a process of enculturation of science (Wolcott, 1991). To acquire the culture of science, students must travel between their everyday life-world to and from the world of science found in their science classroom. Ogawa (1995) proposed three types of science: personal science, indigenous science and Western modern science. Personal science is the result of personal beliefs and experiences with nature. Indigenous science is a system of knowledge developed by a given culture to classify and interpret the objects, activities, and events of its given universe. Processes of Western modern science, such as rational observation of natural events, classification, and problem solving, are woven into all aspects of indigenous cultures, such as indigenous agriculture, astronomy, navigation, mathematics, medical practices, engineering, military science, architecture, and ecology (Lemke, 2001).

The notion that Western science is a value free enterprise composed of objective and universal truths has been challenged. We can know nature only through culturally constituted conceptual or epistemological frameworks, enabled and limited by local cultural features such as discursive practices, institutional structures, interests, values, and cultural norms (Turnbull, 2000). In many educational settings Western modern science is taught at the expense of indigenous science, probably as a result of epistemological hegemony that has exalted Western science over all other ways of knowing. Some researchers (e.g., Good, 1995; Matthews, 1994) tend to dismiss personal and indigenous science as being fads or heresy. Other researchers (e.g., Aikenhead, 1996; Hodson, 1993; Lemke, 2001; Najike, 2004) propose that science is strongly influenced by culture and that acknowledging multicultural science is a pedagogical stepping stone to develop scientifically literate students.

Aikenhead (1996) developed the notion of the science teacher as a culture broker whose role is to facilitate students in ‘border-crossing’ from their own personal culture into the culture of school science. Aikenhead and Hisashi Otsuji (2000) found that the difficulty of crossing borders into school science differed for various student categories. It was a relatively smooth process only for a small minority of students described as “potential scientists.” For the vast majority of students, enculturation into Western science is experienced as an attempt of assimilation into a foreign culture, and many students tend to reject this assimilation (Aikenhead, 1996). When the culture of science is at odds with a student’s life-world, science instruction may disrupt the student’s worldview by trying to force him/her to abandon or marginalize his or her life-world concepts. This process can alienate students from their indigenous life-world and may cause them to choose coping or passive resistance mechanisms as silence, ingratiation, and/or evasiveness (Atwater, 1996). Thus, most science students need assistance from their teacher to guide them to ‘border cross’ and to acquaint themselves with the culture of school science.

The process of enculturation into school science involves more than the individual making sense of his or her personal experiences across the borders of their life worlds. Students are guided into the “new ways of seeing” which have been established and found to be fruitful by the scientific community. Teachers seek to create a learning environment in which Western scientific knowledge is presented as reasonable, useful, and worthy of incorporating into a personal framework of understanding. In this learning environment students are encouraged to go beyond the available evidence in everyday life. Students' everyday understanding of phenomena and events are challenged and they are asked to support the scientific view through the provision of experiences via experimentation, inquiry, literature-based research, and theoretical argument (Ryan, 2008).

The difficulty of and resistance to border crossing originates from individual's social contexts. A student's interest in science and his/her willingness to engage in conceptual change depend on community beliefs, acceptable identities, and the potential consequences for a student's life (Lemke, 2001). For example, to adopt the idea of evolution for a fundamental Christian is not only a matter of conceptual change, but also a complete transformation of his/her identity, which may have consequences for his/her relationship with his community, family, and friends. The attitude of the community, family members, and friends toward science can have a great influence on the student's interest and willingness to cross borders. A few examples from Chinese culture help to illustrate this position.

China's five-thousand-year civilization implies that Chinese indigenous science is rich and profound. One example is the concepts of 经络 (channels and collaterals), 穴位 (acupuncture point), and 气 (qi) relating to the science of human body which forms the basis of Chinese medicine. However Chinese indigenous scientific knowledge is excluded from the school science curriculum. This being said, because of the deep roots and practice of Chinese medicine in Chinese society, many students still possess such indigenous scientific knowledge. When they study the counterpart Western scientific knowledge, they may experience wonder, puzzlement, and possibly conflict.

Confucianism stands strong in Mainland China although the ‘new culture movement’ and ‘cultural revolution’ tried to exclude it from the core values of Chinese culture. One of the many manifestations of Confucianism in Chinese culture is the great importance attached to science learning and the strong emphasis on examinations. Thus students have to learn school science with great effort although school science may lack relevance to their everyday lives. The whole process of science education (although this is an education in Western science), including objectives, syllabus, textbooks, and instruction, has distinctly Chinese characteristics.

2.2 Metacognition

This section of literature review explores metacognition. The history of metacognition, its various definitions, a working model for metacognition, and social and cultural influences on metacognition are articulated and discussed.

2.2.1 History of metacognition

J. H. Flavell of Stanford University is generally acknowledged as the foundation researcher in j98I8 Flavell (1976) used the term “metacognition” in regard to the active monitoring and consequent regulation and orchestration of cognitive processes.

> Metacognition refers to one's knowledge concerning one's own cognitive processes or anything related to them, e.g., the learning-relevant properties of information or data. For example, I am engaging in metacognition if I notice that I am having more trouble learning A than B; if it strikes me that I should double check C before accepting it as fact." (Flavell, 1976, p. 232).

In 1979 and 1987, Flavell furthered his definition by proposing that metacognition consists of metacognitive knowledge, regulation, and metacognitive experiences. According to Flavell, metacognitive knowledge refers to knowledge of the person, the task and strategies. Regulation of cognition refers to a set of regulatory skills that help students control their learning processes. A metacognitive experience is an affective or cognitive awareness that is relevant to one's thinking processes.

Brown (1987) contributed to theorising about metacognition by distinguishing between knowledge about cognition and control of cognition. Brown (1987) stated that knowledge about cognition is more stable than control which may be affected by situations, patterns of arousal, and self-concept. Brown defined and promoted a metacognitive perspective for understanding cognitive development and improving student achievement.

However, before Flavell introduced the construct of metacognition in the late twentieth century, the core ideas of metacognition, such as knowledge about oneself and strategies, self-regulation, reflection, etc., could be found in many places, including China, even thousands of years ago. Confucian principles of learning contain and imply some ideas that can be associated with current conceptions of metacognition. One example is the suggestion, 君子日三省吾身 (a saint should reflect three times a day about himself). To reflect on a day's work implies that the person enacted a plan, executed the task, and evaluated the outcome. Another example is the request, 慎独 (to be watchful over oneself when being alone). Being watchful over oneself demands the person to monitor and control him/herself without any supervision. In the Art of War written by Sunzi in the sixth century BC, one strategy says 知己知彼，百战不殆 (knowing yourself and the enemy ensures success of each battle). This strategy is consistent with the idea that metacognitive knowledge involves knowing oneself.

Vygotsky and Piaget contributed to the theoretical foundations of of what was to become known as metacognition (Brown 1987; Flavell, 1992; Harris 1990; Pinard 1986). Vygotsky (1962) viewed meta-level awareness as being vital to cognitive development where children acquire voluntary control of initiating or inhibiting actions. Vygotsky proposed the conception of scaffolding as an instructional process through which students are assisted to reach a higher level of independent functioning by a gradual shift from other-control to self-control. The extensive, systematic work of Piaget on human development and learning has been linked to contemporary research in metacognition (Fox & Riconscente, 2008). Piaget argued in his theory of cognitive development that children after age 11 began to formulate abstract thinking and become more strategic about their thoughts. Children begin to think about thinking, to make hypotheses and reflect metacognitively on possible outcomes. Their thinking is consistent with some aforementioned science thinking processes and inquiries. It is believed that Flavell developed his ideas regarding metacognition as a consequence of his early work which introduced the research of Piaget to American psycholgoy (Flavell, 1963; Fox & Riconscente, 2008; Pandiscio & Orton, 1998).

2.2.2 Definitions of metacognition

Metacognition is a broad construct including two distinct aspects: knowledge about cognition and control of cognition (Flavell, 1979; Brown, 1987; Thomas, 2006; Veenman et al., 2006). Metacognitive knowledge refers to an individual's knowledge about the nature of cognitive tasks, about strategies for coping with such tasks, and of their own information-processing skills (Flavell, 1979). Metacognitive knowledge can be categorized as declarative, procedural, and conditional knowledge (Schraw, 1994; Thomas & McRobbie, 2001). Declarative metacognitive knowledge is propositional information stored in memory that describes entities and phenomena, their attributes, and the relations between entities and phenomena. Students' conceptions of learning are declarative and propositional in nature. Procedural metacognitive knowledge is knowing how to perform cognitive activities and relates to how to use learning strategies. Conditional metacognitive knowledge relates to knowing when and why to use these strategies. An individual's metacognitive knowledge about their learning processes can be maladaptive for the demands of their learning environments, and may be very resistant to change (Veenman et al., 2006, Thomas, 2009). For instance, a student may incorrectly attribute his/her repeated failure in exams to his/her bad luck or something else instead of his/her own ability to learn for exams.

Control of cognition refers to a set of regulatory strategies that help students control their learning processes. Three essential skills in regulating cognition control are planning, monitoring and evaluation (Veenman et al. 2006; Desoete 2008). Planning refers to the skill of thinking in advance of how, when, and why to act in order to realize a goal. Planning involves analyzing a task, retrieving relevant domain-specific knowledge, and sequencing problem solving steps. Monitoring is the self-regulated control of the actual performance to identify problems and to modify plans as necessary. Evaluation is the process by which students reflect on outcomes and the understanding emerging from the problem, the appropriateness of the plan, the execution of the solution method, and the adequacy of the answer. Control of cognition has a feedback mechanism and the process of skill acquisition takes time and effort (Veenman, 2006).

Metacognitive experiences are a component of metacognition that receive relatively little attention. Flavell (1987) defined a metacognitive experience as an affective or cognitive awareness that is relevant to and accompanies one's thinking processes. People engaging in cognitive tasks can experience various affects, such as interest, judgments of easiness and fluency in the cognitive processing of the task (Eflikdes, 2001; Efklides & Petkaki, 2005). A metacognitive experience, such as success or failure, frustration or satisfaction, and other responses emanating from the performance of a cognitive task, may determine one's interest or willingness to pursue similar tasks in the future. A metacognitive experience can also be a 'stream of consciousness' event in which other information, memories, or earlier experiences may be recalled as resources in the process of solving a current-moment cognitive problem (Flavell, 1979).

As for the nature of metacognition, some researchers (e.g., Brown, 1987; Flavell, 1976) have suggested that metacognition is some special cognitive activity and they tried to clarify its mechanism. Some researchers propose that the metacognitive activity is similar in many ways to other basic cognitive activity (e.g., Livingston, 1997; Lories, et al., 1998). The difference between cognition and metacognition is the target activity to be monitored and controlled (Kayashima & Inaba, 2003). The target of cognitive activity is in the outside world of a person, while the target of the metacognitive activity is in the inner world of the person who performs the activity.

2.2.2.1 Variations of definitions across contexts

Different scholars may have different understanding about metacognition because of tradition or location (Thomas, 1999b, 2006b). Some examples of this variation are as follows. Reeve and Brown (1985) refer to metacognition as an individuals' ability to understand and manipulate their own cognitive processes. They defined metacognition as separable processes in problem-solving that include processes of understanding what is required to understand their own capabilities, planning strategies that will allow them to reach the goal, and to monitor and coordinate these activities. Dunslosky and Thiede (1998) defined metacognition as higher-order mental processes, such as making plans, choosing appropriate skills and strategies, making estimates of performance, and calibrating the extent of learning. Weinert (1987) described metacognition as “second-order cognitions: thoughts about thoughts, knowledge about knowledge, or reflections about actions" (p. 8).

Metacognition is defined by Kuhn (2000) as cognition that reflects on, monitors, or regulates first-order cognition. She argued that metacognition emerges early in life, and develops to be more explicit, more powerful, and more effective. Kuhn and Pearsall (1998) divided metaknowing into metastrategic knowing and metacognitive knowing; the former refers to procedural knowing and the latter refers to declarative knowing.

Metacognitive skills have been viewed as the voluntary conscious control people have over their own cognitive processes (Brown, 1987). Lucangeli et al. (1998) and Desoete (2008) studied metacognitive skills important for successful learning including prediction, planning, monitoring and evaluation. Prediction refers to the skill of thinking about learning objectives, characteristics of successful learning and available time. The ability to predict enables students to potentially foretell task difficulties and be more efficient in allocating time and effort. Planning refers to the skill of thinking in advance of how, when, and why to act in order to realize a goal. Planning involves analyzing the task, retrieving relevant domain-specific knowledge, and sequencing problem solving steps (Dosoete, 2008). Monitoring is the self-regulated control over the actual performance to identify problems and to modify plans. Evaluation is the process in which students reflect on the outcome, the appropriateness of the plan, the execution the solution method, and the adequacy of the answer.

Metacognition is an abstract concept that may entail different preferences regarding its definition being used by various researchers, but overall it relates to thinking about thinking. Any process in which students examine the strategies, skills and procedures that they are using to learn science is metacognitive in nature. Classroom discussion can be a good example of a metacognitive experience if the teacher's questions can engage the students in reflecting on their thinking processes and evaluating their learning outcomes. Another example of metacognition in science education is the problem solving procedures in which metacognition plays a key role. The metacognitive behaviors in problem solving includes clarifying task requirements, thinking of appropriate strategy and making a plan of solving the problem, reviewing and checking the progress, judging and evaluating the solution.

Obviously there is some overlap between these definitions (Dinsmore et al., 2008). What typically happens in metacognition research is that a working model that sees metacognitive knowledge and metacognitive experiences as foundational aspects of metacognition is employed. Within the field of metacognition research there is an eclecticism that acknowledges variations across contexts and accepts that not all scholars will employ the same working model, although there will be overlap between all models employed (Thomas, 2009). The next section explains the working model of metacognition that will guide this study.

2.2.3 Working model

Since, as noted above, there are diverse understandings and definitions of metacognition, it is necessary to employ a working model of metacognition as a placeholder framework for the purpose of this study. This working model defines metacognition for this study and explains the relationship between the components of metacognition. With this working model of metacognition, it is possible to begin to evaluate students' metacognition according to whether they possess declarative, procedural, and conditional knowledge of science learning and learning processes (Thomas, 1999b). In addition, this working model will help understand the nature of metacognition. Metacognition as cognition about cognition is itself a form of cognition, just at a higher level. Cognition, just like metacognition, has many definitions. The basic meaning of cognition is a mental process or faculty of knowing, including aspects such as awareness, perception, reasoning, judgment and problem solving. Cognitive activities are subject to metacognition through ongoing monitoring and evaluation processes (Veenman et al., 2006). There is ample evidence suggesting that metacognition is as important as cognitive abilities in contributing to learning performance (Veenman et al., 2004, 2006; Hattie, 2009).

Two examples relevant to science education can serve to illustrate the distinction between cognition and metacognition (Thomas, 2009). One example is the conceptual change in which both cognitive and metacognitive processes are both involved. It is a cognitive process to receive, analyze and understand new information that is either presented by a teacher or arises from laboratory experiments or field trips. The cognitive process proceeds when the student retrieves their relevant knowledge and compares the existing knowledge with the new information. The metacognitive processes involved in conceptual change include the judgment of difficulty of understanding the new information, the conscious awareness of relating the existing relevant knowledge in his/her mind and its possible conflicts with the new information, the evaluation of processes related to, for example, assimilation and accommodation, and the results of the cognitive processes. Another example that involves both cognition and metacognition is memorization of science material, which is highly valuable for science learning and the development of science understanding although its importance is sometimes understated these days by some science teachers and science teacher educators. It is a cognitive process to put the information into memory or to retrieve it when needed. It is a metacognitive process to be aware of the availability of memorisation strategies such as the use acronyms and mnemonics to enhance the cognitive process, or to monitor, control and evaluate the process of memorization. The relationship between cognition and metacognition can be illustrated as show in Figure 2.2.1.

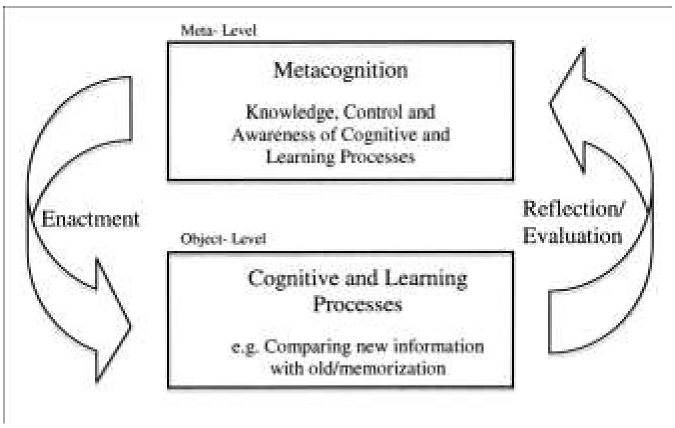

Figure 2.2.1 The relationship between metacognition and cognition (Thomas, 2001)

Figure 2.2.1 suggests that metacognition which is at a meta-level is superordinate to the cognitive and learning processes lying at the object level. Metacognitive knowledge, control and awareness of cognitive processes enhance the enactment of those processes. At the same time, the cognitive and learning processes provide a basis for reflection and evaluation of these processes and their potential improvement.

The nature of metacognition can also be visually displayed via a model shown as Figure 2.2.2, developed by Thomas (1999b). This hierarchy is consistent with the notion that metacognition may be developed hierarchically first from metacognitive knowledge, then awareness and control of students' learning processes (Thomas, 1999b; Loizidou & Koutselini, 2007; Schraw, 1994). The literature suggests that metacognition can be taught and enhanced first by explicitly teaching students as as to develop their metacognitive knowledge and awareness of their learning processes.

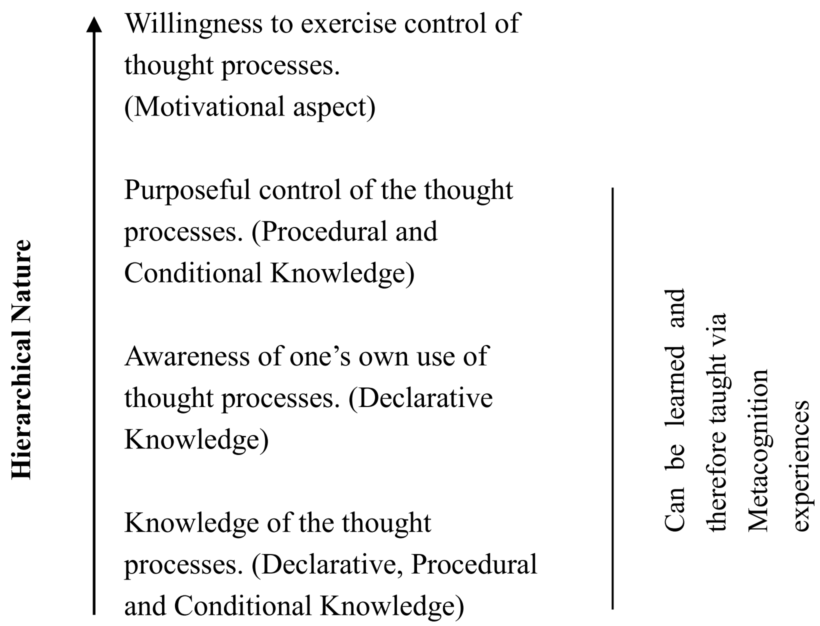

Figure 2:2.2 A hierarchy for metacognition (Thomas, 1999b)

As seen from the model in Figure 2.2.2, metacognition is composed of four components which are hierarchically related. The declarative, procedural and conditional knowledge of science learning are the essential part of metacognition which sits at the base of this hierarchy. Students' awareness of their own use of thought processes is located above the knowledge component. Students' metacognitive knowledge can be probed to understand their awareness of their own learning processes and the strengths and weaknesses of such processes. Above the awareness component of thought processes is the purposeful control over learning processes. As explained earlier, metacognitive control is an important element of metacognition. If a learner has the metacognitive knowledge and awareness of his/her learning processes, it is possible that he can purposefully control these processes to achieve learning goals. The working model also contains motivational aspects in the hierarchy because motivation and a willingness to exercise control over thinking and learning processes is a key, prerequisite component in effective science learning (Thomas, 1999; Thomas and McRobbie, 2001; Dweck & Leggett, 1998).

Researchers, such as Cano and Cardelle-Elawar (2004), Thomas (2002, 2006a), and Vermunt and Vermetten (2004), have stated the innate connections between metacognition and conceptions of learning. The definition and structure of conceptions of learning are discussed in detail in section 2.4. Basically conceptions of learning refer to students' ideas, knowledge, and beliefs about learning (Pratt, 1992; Vermunt and Vermetten, 2004). Conceptions of learning are metacognitive in nature, since these ideas are about the cognitive activities, i.e., learning activities. With these ideas about learning, students can evaluate, regulate, and control their learning activities (Purdie et.al., 1996).

Based on the working model of metacognition, metacognitive knowledge is the foundation of metacognition. In other words, the other components of metacognition, such as aware and control, are grounded on metacognitive knowledge. With the metacognitive knowledge, the person can be aware of and control the activities that the metacognitive knowledge relates to. For students, the activities that need to be aware of and control are their learning activities, that is to say, students' metacognitive knowledge is their knowledge of learning. On the other hand, the definition of conceptions of learning is also their knowledge of learning. Thus conceptions of learning belong to metacognition. The relationship between conceptions of learning and metacognition will become clearer after reviewing the literature of conceptions of learning, and this relationship is discussed in section 2.4.5.

2.2.4 Influences on metacognition

One limitation of current research on metacognition is that social influences on it are often neglected. The development of metacognition is at least in part a social process since both the metacognitive knowledge and skills are developed through social interactions with teachers, parents, or peer classmates. It is proposed in this study is that Chinese culture influences how Chinese students learn science for the following three reasons. Firstly, learning is culturally influenced. Secondly, culture can determine cognition, emotion, and motivation. Last but not least, culture has the potential to shape metacognition.

2.2.4.1 Definition of Culture

To understand how Chinese students learn to learn science and seek relevance for the particular construct of metacognition, the effect of Chinese culture on metacognition, and Chinese students' conceptions of learning, it is necessary to attempt to define culture and conceptualize its dimensions.

Culture was originally from the Latin word "cutura" meaning "to cultivate". The meaning of culture connotes that a person can be cultivated or directed to consider national ideals through education (Straub, 2002). As early as in 1871, Tylor defined culture as the complex whole which includes knowledge, beliefs, art, morals, laws, customs and any other capabilities and habits acquired by man as a member of society (Tylor, 1871). Apart from such omnibus definitions of culture encompassing all aspects that tell the differences between groups of people, some scholars perceive culture as the problem solving capabilities that a specific group gains through accumulated experience in the process of civilization (Ford, 1942; Schein, 1985; Moran and Stripp, 1991). Many scholars define culture as shared values that are an enduring organization of beliefs concerning preferable modes of conduct or end-state/s of existence along a continuum of relative importance (Rokeach, 1973; Geertz, 1973; Kroeber and Kluckhohn, 1952; Hofstede, 1980). Hofstede made one of many attempts to measure culture and his widely known value mapping includes five dimensions that are individualism–collectivism, power-distance, uncertainty-avoidance, masculinity–femininity, and long-term orientation. Hofstede's five dimensions of culture-level values have provided the conceptual impetus for numerous cross-cultural studies (Bond et al., 2004). Another attempt to measure culture is to evaluate the construct of social axioms that are generalized beliefs about oneself, the social and physical environment, or the spiritual world (Leung, et al., 2002, Bond et al., 2004).

2.2.4.2 The defining characteristics of Chinese culture

Chinese culture has evolved over five thousand years and has become one of the most influential cultures in the world. Traditional Chinese culture is mainly constituted according to Confucian, Taoist and Buddhist principles. Confucianism has played the major role in defining the behavior of Chinese people (Zhang, 2008; Guat Tin, 2008). Chinese culture is also being transformed by the Socialist regime and economic modernization in China.

Confucianism was based on the teachings and writings of the philosopher Confucius (Kong Zi), who was born in 551 BC in Qufu, Shandong Province in northeastern China. Confucianism is the ethical system and philosophical values that most influence the behaviors of the Chinese people. Since the Han dynasty Confucianism has been promoted as the national ideology and was the core content of imperial examinations that lasted about two thousand years.

Confucianism is not a static philosophy and was enriched and developed by later Confucian scholars such as Mencius, Xun Zi, Dong Zhongshu, Zhu Xi, and

Wang Yangming (Liu, 1973). In the Song dynasty (around 1000 AD), Zhu Xi integrated thoughts from Taoism and Buddhism and transformed Confucianism into Neo-Confucianism. Zhu Xi outlined 三纲五常 (three cardinal guides and five constant virtues), which was widely accepted in Song dynasty and the following Ming dynasty, and became the state ideology of Qing dynasty which lasted for 300 years (Tang, 2008). These principles have had long lasting effects on the Chinese people, and certainly on Chinese students as well.

三纲五常 (three cardinal guides and five constant virtues) can be regarded as the entire duty of people, including personal morality, correctness of social behavior, and harmony of interpersonal relationships, justice and sincerity (Liu, 1973). 三纲 (three cardinal guides), based on Confucius' 五伦 (five relationships), dictates the relationship between rulers and subjects, fathers and sons, husbands and wives. The sovereign guides the subject, the father guides the son, and the husband guides the wife. 三纲 (three cardinal guides) is in fact the theoretical basis for Chinese social hierarchy. Subordinates should not only listen to their superiors, but are also expected to sacrifice their individuality and even lives to serve their superiors. The superiors are expected to be virtuous and treat their underlings with loving hearts, but the privileges of rights and benefits may produce corruption for officials and abuse for men in their families. Some Western critics as well as many Chinese scholars (e.g. Feng, 1953; Ching, 1978; Steidlmeier, 1997) thus criticize the ancient Chinese ethics based on 三纲 (three cardinal guides) as violating human rights, equality, fairness, majority rule or other democratic principles. For the whole twentieth century, 三纲五

常 (three cardinal guides and five constant virtues) has been bitterly swiped at by scholars from both the Republic of China and the People's Republic of China. 三纲 (three cardinal guides) has been a derogatory term since the New Cultural Movement in the 1900s, but the notion of the social hierarchy is still deeply but probably more held unconsciously today by Chinese people (Li, 2007). The influences of 三纲 (three cardinal guides) manifest themselves from the intuitive respect and awe evident from inferiors to their superiors and from students to their teachers. The awe and respect accorded educators is not necessarily a bad thing. On the contrary, it may boost the process of internalization of knowledge and the necessary discipline for effective teaching and learning.

五常 (five constant virtues) refers to 仁 (benevolence), 义 (righteousness), 礼(courtesy), 智 (wisdom) and 信 (credibility). Although 五常 (five constant virtues) with 三纲 (three cardinal guides) have been heavily criticized and taken as feudal dregs for over a hundred years by many Chinese scholars (e.g., Cui, 2007; Fei, 1996), recently more and more scholars (e.g., Liu and Lin, 2006; Wang, 1996; Yang, 2009; Zhang, 2009) have regarded them as elements of Chinese cultural heritage that can play important roles in social life and education. As a matter of fact, the tradition of abiding by these principles is still encouraged and strongly held by many Chinese people.

No research has been found to study the influences of these core cultural values on science education. The reason for this lack of research may be that Confucianism, especially its core values 三纲五常 (three cardinal guides and five constant virtues), had been condemned in Mainland China until late last century. Up to now, the right word 三纲五常 is still a taboo for many Chinese researchers. But as mentioned earlier, Chinese culture and its core component Confucianism can be suggested to have been playing important roles in the processes of Chinese students' learning of science. For instance, the dominant Chinese contemporary ideas of education including life-long learning, pursuit for self-perfection, emphasis on moral education, and teachers' love for students can find their source in the Confucian virtue of 仁 (benevolence). In this sense the Confucian virtue of 仁 (benevolence) has the same altitude in Confucianism as 道 (tao, or path) in Taoism.

Taoism as a religion and philosophy that influenced China and the rest of the world originated from 老子 (Laozi) about 5th century BC and Zhuangzi (369 – 286 BC) two thousand years ago. Taoists believe everything is composed of 阴 (yin) and 阳 (yang) and the two opposing components are complementary to each other. According to Taoism, failures will not be always failures since Taoists think 失败是成功之母 (failure is mother of success) and 塞翁失马焉知非福 (misfortune may be an actual blessing). It is argued that students with the dialectic belief that failure will lead to success are more perseverant when they encounter difficulties in learning.

2.2.4.3 Confucian Principles of learning

Confucius is regarded by Chinese people as the Greatest Master (先师，directly translated as foremost teacher) perhaps because he put great emphasis on learning. In the first chapter of the Analects, the representative work of Confucianism, Confucius talked about the importance and enjoyment of learning. The outcome of this joyful learning is 内圣外王 (saint inside and king outside), which means the learner will become as knowledgeable as a sage and possess high morality and great abilities like a king. Confucius encouraged learners to serve their nation/king with their knowledge by becoming government officials. The Confucian notion of 学而优则仕 (He who excels in learning can be an official) is still maintained by Chinese people, although learning well no longer ensures an honorable career as a government official. Pragmatic learning often results with passiveness, labor, and hardship. The aphorism 书山有路勤为径 (bitterness is the boat through the sea of books) vividly describes how it is suggested Chinese students think of and execute learning (Gu, 2006). Although Confucius does not oppose the pragmatism of learning, what he favors is real learning out of internal motivation. The belief that every person can become saint is the source of persistent pursuit for self-perfection.

Love of learning is a core concept in Confucianism (Chen, 2005). Confucius said that it was easy to find a person with virtues of great loyalty and credibility, but difficult to find a person who loves learning as much as he does. Confucius regarded the love of learning as a very precious quality. Confucius talked about his passed-away student Yanhui as the best lover of learning among his seventy students. The beginning statement of the book *Dialects,* 学而时习之不亦乐乎 (how happy it is to learn and practice constantly), shows that Confucius treasured this virtue very much. Confucius said when he was fifteen he was determined to learn and when was thirty he succeeded in loving to learn. Confucius claimed that a person with virtues would turn to vices if the person did not love learning.

Confucius' notion of 有教无类 (teaching without distinction) promotes opportunities for students of all kinds to learn, but may result in problems due to the enrolment of troublemakers in the classroom. Chinese school principals often quote the following saying in staff meetings: 没有教不会的学生，只有不会教的老师 (There is no student who cannot learn well, there are only teachers who cannot teach well). Teachers face great challenges to discipline big classes and to teach different students differently (因材施教). Another notion of Confucius is that good pupils are to be brought up by strict teachers (严师出高徒). If teachers are not strict, they may not be able to smoothly perform their duties, especially if the classroom sits over 40 or over 60 students. Hue (2007) argues that the ultimate goal of discipline is to help students develop their abilities of self-management and take up the responsibility for their own behavior. Unfortunately for some people, discipline implies an authoritarian learning environment which may impede learning.

The idea of "Watchfulness when alone" (慎独) is a key factor to ensure the success of any person with any goals. Self-examination (自省) is strongly recommended by Confucius. He argued that a saint shall examine himself three times a day. There may be a problem for Chinese students to have the practice of this watchfulness when alone, because they are often under the eyes of their teachers in school and their parents after school.

Confucius emphasized the importance of the learning environment. The story of 孟母三迁 (Mencius mother moved three times to find a good place for his son's learning) is popular and the implications of the story are appreciated by most Chinese parents. At one neighborhood, Mencius' mother found that Mencius was attracted to the going-ons at a nearby coffin maker's and passed their time imitating the sorrow expressed by the families of the deceased. She decided it was not the environment for her child and so she moved. At another neighborhood, she found her neighbors were not interested in hard work and spent their days drinking. Not finding it suitable for her child, she moved again. In all she moved three times, until she was convinced that she had found the best environment in which to bring up her child. China does not have explicit bands of schools, but most parents know which schools are 'good' and try their best to take their children to these high-quality schools. Even after the children are in a good school, the parents will try to find a good teacher. This common sense is coherent with the idea that good environment ensures effective learning.

2.2.4.4 Learning is culturally influenced

Different cultural groups think, feel, and act in some ways similarly and in some ways differently to each other. It is well established that East Asians, Europeans, and Americans have distinct cultures due to different languages, different histories, and different geographical locations. Scholars (e.g., Lerman, 2001; Pelissier, 1991) propose that culture determines people's nature (what they are) by informing what and even how people should learn.

Traditional learning is often simply regarded as a personal endeavor to 'absorb' abstract and decontextualized information from textbooks and from teachers.

However, learning is more complicated a process than that of individual information acquisition and storage. Sociocultural factors are inherently involved in the development and enactment of learning processes. In different situations such as apprenticeship, workshop training, field trips, sports and music practice, etc., the focus and ways of learning are different (Anderson et al., 1996; Lave & Wenger, 1991). In contrast with the implicit views that knowledge is abstract and 'out of context', Lave and Wenger argue that learning is a function of activity, context, and the culture in which it is situated. Social interaction is a crucial component of learning processes that embody certain beliefs and behaviors. Collaborative social interaction and the social construction of knowledge is at the core of cognitive apprenticeship that supports science learning by enabling students to acquire and develop cognitive tools in authentic activities (Brown, Collins & Duguid, 1989).

The philosopher Balagangadhara (1994) developed a theory of culture that explains both what constitutes a culture and what influences differences between cultures. Balagangadhara highly emphasizes an underlying connection between culture and learning. In a sense he equates the two entities of culture and learning by defining culture as a tradition that can be identified in terms of a specific configuration of learning and meta-learning. Human beings depend hugely on the group's decision regarding what they should learn. The group decides what is being transmitted from the group's reservoir of knowledge, customs, traditions, etc. Each group makes choices that the group imposes and perpetuates on new and existing members. Learning is a balancing act between what a brain can do and what the group values and wants to pass on (Abbott and Ryan, 2000). Not only does the group decide what should be 'transmitted' to pupils, but it also decides on the processes of instruction. In doing so an important meta-message about how to learn is also implied. The group's reservoir and choices also contain elements constraining the mechanisms of transmission. In a word, culture dictates that different groups draw from different reservoirs, focus on different learning areas, and structure their learning and learning experiences differently.

As previously noted, Balagangadhara (1994) stated that cultural differences can be characterized by different ways of configuration of learning and meta-learning. In each configuration, one particular kind of learning activity will be dominant over other kinds of learning activities. For example, Balagangadhara suggests that Westerners tend to engage in conceptual learning, whereas Asians including Mainland Chinese are used to performative (practical) learning. Balagangadhara argues that the tradition and practice of Christianity created the Western configuration of learning that emphasizes theories and concepts. He argues that Christian rituals are based on theology and that every practice has an intention and meaning. Christian teaching that focuses on underlying meanings highly influenced other learning activities. As a result, conceptual learning became the dominant form of learning over other forms such as practical learning. Balagangadhara argues that in Asian culture orthopraxy dominates over orthodoxy, which means that rituals have the functional equivalent role as orthodox beliefs. Underlying beliefs do not play a significant role as an ultimate explanation of the ritual. Thus performative learning (practical learning) which pays more attention to performance than underlying reasons overshadows other kinds of learning.

One example of the performative learning overshadows conceptual learning is found in a field research conducted by the Nepalese anthropologist Pradhan in a Calvinist rural village in The Netherlands (Van Oord, 2005). The local villagers often asked Pradhan what he believed, but he found this question that was ‘normal’ for Westerners very difficult for him to answer. This was difficult for him because in Nepal only the priest and the head of the family participate in the rituals which may involve beliefs, while other people just watch and make their offerings. Pradhan contended that for Hindus the most important thing is not a person’s belief, but what he does. So what they learn is the performance instead of the concepts underpinning the performance. Another example of the performative learning over conceptual learning relates to a comment made by a manager from Europe about his Singaporean colleagues (Van Oord, 2005). The manager thought that Singaporeans solved problems without further thinking about the underlying mechanism of problem solving. Primatologist De Waal (as cited in Van Orrd, 2005) talked about the difference between Western and Japanese colleagues in the pursuit of scientific knowledge. De Waal complained that his Japanese colleagues emphasized data gathering procedures over the underlying ideas and the theoretical framework for data collection.

However, despite the aforementioned examples, the notion that Westerners mainly engage in conceptual learning while Asians primarily employ performative/practical learning may need further investigation (Bond, 1986). This notion might be as superficial as the perception that Asian students are characterized predominantly by rote learning. Rote learning is often pertrayed as equivalent to superficial learning without deep understanding. However, many Asian students practice learning in ways that might be considered as rote learning, yet with deeper understanding (Bond, 1986; Biggs, 1996; Watkins & Biggs, 1996). Nevertheless, calling for further evidence and more understanding about the differences of learning processes between Western and Asian students does not affect the tenet that learning processes including science learning may to be influenced by culture.

2.2.4.5 Culture influences psychological processes and structures

Culture has representational functions and prescriptive functions, that is to say, culture represents the collectively held understandings of individuals about the natural world and their social society, and prescribes normative standards for people to guide their behaviors and interactions with other social members (Cole, 1995). The notion that the basic nature of psychological processes and structures are universally identical fails to consider the role that cultural experience plays in shaping psychological processes and structures (Markus & Kitayama, 1991; Nisbett & Miyamoto, 2005; Ji et al., 2004). Individuals' psychological processes and structures cannot be fully divorced from their cultural experiences and their interpretations of these experiences (Durkheim, 1976).

The difference in psychological processes between Westerners and Asians including Mainland Chinese may be explained by the cultural differences of the construals of the self, of others, and by the interdependence of the self and others (Markus & Kitayama, 1991). European American culture typically emphasizes attending to the self, the appreciation of one's difference from others, and the importance of asserting the self (Durkheim, 1976). East Asian cultures typically emphasize attending to others, and fitting in and maintaining a harmonious interdependence with others. For East Asians including Mainland Chinese, the self and its inner attributes may be replaced by the sense of belonging to a social relation and this 大公无私（no self except others）is appreciated and advocated by Confucianism which is still the essence of Asian cultures including Mainland Chinese culture (Allen, 1985; Oyserman et al., 2002; Wang, 2007;).

The construals of the self and others are a part of the repertoire of the self control schemata that dictate students' motivation and their interpersonal processes (Cantor & Kihlstrom, 1987). Students with interdependent selves have more social motives to meet expectations of significant others, less attention to their own inner needs or desires, and assume different forms in self-enhancement, self-verification, and self-actualization (Markus & Kitayama, 1991). Bond (1986) reported that the motivation of Chinese students reflects group-oriented traditions or interdependence and they show relatively high levels of need for abasement, high socially oriented achievement and low levels of individually oriented achievement.

The psychological processes and structure of the human mind are shaped by social and cultural factors (Durkheim, 1976; Moscovici & Markova, 2006; Sewell, 1989). For example, Nisbett and Miyamoto (2005) found that Westerners tend to engage in context-independent and analytic perceptual processes by focusing on salient objects independently of their context, while East Asian people are inclined to engage in context-dependent and holistic perceptual processes by attending to the relationship between objects and the context. Norenzayan and his colleagues (2002) also found differences in perception between East Asian students and American students. East Asian students perceived similarities according to their holistic judgment of family resemblance, whereas American students perceived similarities according to detailed features (Norenzayan et al., 2002). Abel and Hsu (1949) found different patterns of attention among Chinese and Americans. Chinese tended to perceive the blots in a blot test as a whole pattern, while Americans tended to focus on the detailed parts of the blots (Abel and Hsu, 1949). Masuda and Nisbett (2006) also noticed the differences in psychological processes between Americans and Japanese. When looking at images of buildings Americans detected more changes in the focal objects whereas Japanese detected more changes in the context and relationships between objects. These examples provide some evidence that at least some psychological processes differ between diverse cultural groups.

The mechanism of the differences in psychological processes between Westerns and East Asians including Mainland Chinese can be related to cultural differences (Nisbett, 2003; Chiu, 1972; Ji et al., 2004). People living in more complex, interdependent social world with many role prescriptions, have to attend to relationships and the context. On the contrary, people living in more independent, individualistic social circumstances, need to attend more to objects and refrain from being constrained by demands, needs, and expectations of others. In summary, the difference of psychological processes can be at least partly explained by cultural preferences and values. It follows, therefore, that variation in metacognition, if one exists, might be at least partly explained by cultural preferences and differences.

2.2.4.6 How and why culture might influence metacognition?

As previously outlined, there is evidence that cognition is culturally influenced (Miller, 1999). Interests in culturally bound cognition are shared by researchers around the world. Because metacognition is a form of higher order cognition and cognition is culturally influenced, we might infer that metacognition too is culturally influenced. However, up to now, there has been little if any study regarding cultural influences on metacognition. This study will significantly contribute to cultural psychology and education research if the study can find evidence of a connection between metacognition and culture. Examining cultural influences on metacognition would mean examining cultural influences on metacognitive knowledge, control and awareness of learning processes, and metacognitive experiences.

2.2.4.6.1 Cultural influences on metacognitive knowledge

As previously noted, metacognitive knowledge is an individual's knowledge about his/her learning processes, including beliefs, values, and understanding about him/herself, the task, and strategies (Brown, 1987; Flavell, 1979; Thomas, 2002, 2006c; Veenman et al., 2006). Understanding cultural influences on metacognitive knowledge can be pursued via exploring the underlying connection between culture and learning as previously outlined. Culture can be regarded as a tradition of a specific configuration of learning and meta-learning (Balagangadhara, 1994). What and how students might learn will depend on their cultural orthodoxy. When individuals' thoughts, feelings and behaviors are consistent with the dominant cultural ideas and values, they are likely to be repeated, sustained, and eventually habitualized to form a relatively autonomous psychological structure (Heine et. al., 1999). In contrast, behaviors, thoughts, and feelings that do not fit well with cultural values are less likely to be recurred and thus less likely to become part of the person's habitualized repertoire. It is through this process of finding resonance with the cultural system that cultures come to shape how individuals think, feel, and perceive themselves and their social worlds (Heine, et al., 1999).

In the group's reservoir of values and knowledge, there must be knowledge of learning strategies regarding how to learn effectively, and it is proposed to form an element of a society's collective metacognitive knowledge. When values and knowledge are transferred from one generation to the next, procedural knowledge about using strategies and conditional knowledge about when to use these strategies are most likely taught, even if this more occur tacitly. Because cultural groups vary regarding their reservoirs of values and their collective metacognitive knowledge and also different means of transmitting the knowledge, we might infer that the metacognitive knowledge of individuals within different cultures will vary with that of individuals of other cultures.

As mentioned earlier, and to be detailed in the next section, Chinese culture is rich in learning principles that can be considered to vary from Western learning theories (Tweed & Lehman, 2002). Through socialization and cultivation, it is proposed that these learning principles are internalized and become part of Chinese students' metacognitive knowledge. For example, Mainland Chinese learners have been reported to hold the conception that true knowledge resides in classic written texts and authoritative figures such as teachers or parents (Wang & Mao, 1996). This traditional view of knowledge, which is distinct from the Western epistemology that knowledge is constructed individually by dynamic and active processes, may be closely associated with students' conceptions about how to conduct science learning effectively.

2.2.4.6.2 Cultural influences on metacognitive control

> "The greatest principle and foundation of all virtue and worth is placed in this; that a man is able to deny himself his own desires, cross his own inclinations, and purely follow what reason direct as best, although the appetite leans the other way" (Locke, 1693/1964, p. 40).

Metacognitive knowledge would not be enough and metacognitive skills of planning, monitoring and evaluation would not work well without the motivation and willpower that Locke refered to. Students must have willpower to control their learning processes as previously noted and as represented in Figure 2.1. They should be able to sustain and shift attention and to initiate and inhibit learning processes voluntarily. Willpower-related tendencies are a valued outcome of socialization.

Metacognitive control is probably the most important part of maturation in all cultures (Markus & Kitayama, 1991).

Metacognitive skills are learnt through interaction with social surroundings. Cultural differences in interaction between students, their peers, and their teachers will affect their metacognitive skills. For example, students from North America are reportedly more concerned about self-esteem and East Asian students are more concerned about face. Self-esteem and face are similar but differ in their vulnerability for loss (Hamamura & Heine, 2006). The consequence of this cultural difference in the orientation of metacognitive control is that North American students exhibit a greater tendency towards promotion focus while East Asian students exhibit greater prevention focus. An individual with promotion-focus is more concerned with higher level gains such as advancement and accomplishment, while the prevention-focus emphasizes security, safety, and responsibilities. These two foci of control influence how a person would be exposed to decision-making process, and determine the different ways they achieve their individual and social goals (Higgins et al., 2001).

Chinese culture might have an effect on students' metacognitive control over their learning processes. In Mainland China there is a deep reverence for science learning and the value position of education is so high that 万般皆下品唯有读书高 (everything is low, but education is high). The importance attached to education including science learning for Mainland Chinese people can be traced back to Confucianism. Confucius saw education as a means of turning an ordinary person into a superior one and a weak nation into a strong one (Gu, 2006; Watkins & Biggs, 1996). Besides the reward of inner satisfaction with full personal development, Confucius also saw a utilitarian function of education; that is, education can bring about social recognition and material rewards. The perceived functions and benefits of education including science learning provide Mainland Chinese students with powerful motivating forces to try to ensure their academic success.

In addition to the strong motivation to achieve academically, Mainland Chinese students might show more evidence of collective metacognitive skills due to Chinese education heavily emphasizing moral education across all subjects in accordance with the Confucian notion of educational cultivation. The moral virtues that Mainland Chinese students expect to have include loyalty, fidelity, altruism, modesty and, conformity, and these values encourage imitation of socially approved models and collective orientations, but they discourage individuality, fulfillment of personal needs, and self-expression (Paine, 1992; Hu, 2002). These values might manifest themselves in the processes of monitoring and controlling their science learning and communicating with their teachers and peers. However, no research seems to have explored this possibility yet. For example, Mainland Chinese students might be more self-conscious about their learning processes because they are especially concerned about how their teachers, parents, and peers may appraise them.

The literature of learning theories related to metacognition does not fully address the idea that metacognitive control is influenced by cultural factors. There is no research found to study how Chinese culture may or may not influence individuals' metacognitive control over their learning processes. By investigating how Chinese learners learn to learn science and their metacognition, it is speculated that some understanding regarding the possible influence of Chinese culture on learning processes and related metacognition might be forthcoming.

2.2.4.6.3 Cultural effects on metacognitive experience/s

A metacognitive experience arises when a person is engaging in a cognitive process and is aware of that engagement, the details, and outcomes of the cognitive process (Flavell, 1987; Veenman, 2006). When a goal-directed activity is blocked, frustration can occur that can generate goal-diverting emotional reactions. A person may become upset, angry or disappointed. Such a negative metacognitive experience may influence the person so that they give up on the task. A person with metacognitive knowledge about him/herself, available strategies, and strong metacognitive skills to control his/her learning processes might persist in the task and avoid further frustrations by sustaining attention toward the goal and inhibit unsuccessful behavior or initiate new goal-directed action voluntarily. When, at last, s/he completed her/his task successfully, s/he would enjoy positive metacognitive experience of satisfaction and possibly even happiness.

If we adopt the comprehensive conception of metacognition proposed by Flavell in 1987 that includes affective components such as disappointment, anxiety, anger, interest, satisfaction, happiness, etc., culture may have a voice in influencing metacognition. It is well known that Chinese people are more introverted than Westerners and that Chinese students are encouraged to keep peace and calmness whether in success or failure (in Chinese, 不以物喜不以己悲) (McCrae et al., 1996). Compared with Western culture that might encourage the expression of discontent or even anger as a strategy to assert oneself, Mainland Chinese culture discourages extremely the expression of anger. It is proposed in Chinese culture that everything that happens can be attributed to one's own behavior and should be accepted as the status quo without complaint (Zhou et al., 2010). Mainland Chinese culture highly lauds the social value of 'harmony' which may explain the abasement of expression of negative affect. Since negative metacognitive experiences may suspend action related to learning, and Chinese students are discouraged from those experiences, it might be inferred that Chinese learners may be less likely to stop engagement in learning tasks after failure. Thus the reported perseverance of Mainland Chinese learners in their science learning may be related to the Chinese cultural characteristics such as, for example, emphasis on effort, the social pressure on learning, and external motives.

Metacognitive affect plays an important role in keeping track of cognitive processing and triggering control decisions (Clore & Parrott, 1994; Efklides, 2001). Metacognitive affect may take the form of emotions such as interest or liking of the task, or feelings such as feelings of familiarity, of knowing, of difficulty, of uncertainty, of confidence, or of satisfaction (Efklides & Petkaki, 2005, Flavell, 1979). It is proposed that Chinese culture may shape students' metacognitive affect occurring during their experience of science learning. For example, Confucius talked about the joy of learning, 知之者不如好之者，好之者不如乐之者 (To know it [learning or the Way] is not as good as to love it, and to love it is not as good as to take delight in it). For Chinese students, learning means deep commitment and even sometimes hardship. But later, after they know how to learn within the context and have learnt what is expected, the learning process becomes an enjoyment. Thus internal interest for Chinese students is often regarded as developed and cultivated from positive learning experiences, instead of being generated merely from within or from nowhere.

Situations that have important consequences can stimulate strong metacognitive experiences (Flavell, 1987). If the outcome of the cognitive activity is taken to be very important, the individual is likely to monitor his/her judgments and decisions more carefully. The perceived importance of the cognitive activity may make the individual nervous or worried, and in response the individual may evoke all his/her metacognitive knowledge and skills and he/she may experience strong metacognitive affect, such as anxiety, satisfaction, and happiness. According to Hofstede (1980), Mainland Chinese culture has strong power distance and teachers have absolute authority over their students. The strong commitment of Chinese students to science learning comes from the outside authority coercing them to learn as well as the internal motivation of self-perfection. It is not uncommon to see Mainland Chinese students dropping tears in and out of classroom for reasons related to academic achievement to which they attach great importance.

In summary, the view proposed for this study is that science learning is not simply an individual endeavor that can stand away from social and cultural influences. There is strong evidence that psychological processes and cognitive structures are influenced by culture. It is proposed that metacognition may be culturally influenced and that Chinese culture may have some impact on the metacognitive knowledge, metacognitive control, and metacognitive experiences of Mainland Chinese learners.

2.3 The state of science education and science learning in Mainland China

In this section of this literature review, the state of science education in Mainland China is explained. The topics include the place of science in society, the place of science education in school curricula, curriculum reform in science education, the state of science learning, and the status of metacognition research in Mainland China.

2.3.1 The place of science in Chinese society

China has five thousand years of history and has made considerable contributions to the development of science and technology. Before 15th century, China was an influential empire who was not only a political and military power, but also advanced in science and technology when compared to other countries (Needham, 1986). But in traditional Chinese culture science and technology was sometimes not valued and was regarded as 奇技淫巧 (diabolic tricks and wicked craft) (Lin, 1995). In the late 19th century after China was defeated and humiliated by western powers, the Qing authorities began to realize the importance of science and technology. New schools were built and science courses translated from the West began to be taught in China. In the era of Public China before 1949, science and technology were given important positions. The slogan of 科学救国 (save the country by science) originated from the New Culture Movement and was respected and executed by the Kuomintang Government. Over thirty universities with majors in science and technology were established before 1949. The professors at that time were well paid and greatly respected. Since the foundation of People's Republic of China in 1949, science and technology have been put in high positions in society as well. Up to now there are over 1000 universities in China that have departments of science or engineering. The belief that science and technology will strengthen the country is strongly held by the contemporary leaders of the government and significantly influences policy making with regard to science and technology. The official position that 科学是第一生产力 (Science is the first productive force) as suggested by Deng Xiaoping and that 科教兴国 (Revitalizing China by Science & Education) reflects the belief that science and technology are driving forces behind economic development (Wu, 2009).

2.3.2 The importance of science education in the curriculum of Mainland Chinese schools

Science education has always been important in Mainland Chinese schools since the establishment of PRC in 1949. In the 1950s, for political reasons, China copied curriculum formats and standards from the former Soviet Union in which science courses were important parts of school curriculum. During the Great Cultural Revolution in around the 1970s science education was an important way for students to learn from workers and farmers. Since Deng Xiaoping began to be in charge of education issues in 1978, science education has become an important focus of education policy because science education was regarded as a way to train future scientists who could contribute directly to the prosperity of the country. School science such as physics and chemistry are compulsory courses from junior high to senior high schools. As mentioned previously, senior middle school students must pass the provincial test of these courses in order to be granted graduation.

2.3.3 Curriculum reforms in science education in PRC

Modern science was originally foreign to Chinese culture, and Chinese schools did not have science education until the end of 19th century. Under the huge influence of the Imperial Examination System ancient Chinese scholars had no interest in studying how nature works. The Opium Wars whacked the arrogance of the ruling class of Qing Dynasty and science education began to be imported as a tool to fight back against the 'barbarians'. In the 1920s, Dewey's progressive education movement stimulated the then educational authorities to reform the science curriculum by combining subjects and stressing the needs of students. It is worth noting that before 1949 most Chinese were illiterate and education was just for a very few rich people.

After the foundation of People's Republic of China in 1949, compulsory education was carried out and by 2005 about 214 million students were enrolled at primary and secondary schools learning science (MoE, 2008). Chinese education relies on mandatory national standards and curriculum that guide textbook content and teaching methods across the country. Education in China is closely related to politics and political movement always affects educational policies. The national standards change or are adjusted according to political and economic environments. Overall educational reform in PRC with regards to science education can be categorized into three waves of reform based on preferences of educational goals.

The first wave of reform happened in 1952 when the Ministry of Education issued the first secondary school curriculum standards after the foundation of PRC and enacted syllabi for physics, chemistry and other subjects with close reference to the contemporary syllabi of the former Soviet Union. The focus of science education was basic knowledge and basic skills. The 'double bases' of knowledge and skill produced a long lasting effect for Chinese science education (Su et al., 1994; Fang and Warschauer, 2004).

The second wave of reform started from 1963 and lasted until the end of 20th century. The syllabi made during this period, except during the period of Great Cultural Revolution, stressed the importance of fostering abilities of analyzing and solving problems as well as the importance of the double bases of knowledge and skills. The textbook content was designed to reflect the systematic knowledge of the science discipline. The science syllabus emphasized the goals of developing capabilities of scientific thinking, observation, and experiment.

The third wave of reforms began from the 1990s and reached its climax in 2001 when a new set of national standards were issued. The reform asked for great changes in educational goals and how science education should be conducted. Science education, it suggests, should focus on all students instead of a few elite. Science education should have a balance between systematic structure of scientific knowledge and a concern for students' life experiences. Science education should pay attention to scientific processes and scientific inquiry.

The MoE (Chinese Ministry of Education) were attempting to bring about a systemic change to the senior secondary education curriculum, emphasizing the following aspects (MoE, 2003): 1) replacement of the existing subject-based curriculum structure with an integrative, three level structure consisting of learning fields, subjects, and modules; 2) decentralization of the educational system and encouraging school-based curriculum development; 3) granting students the authority to choose courses, and adopting an elective course and credit system; 4) adoption of new approaches to teaching and learning, such as cooperative learning, self-regulated learning, and inquiry-based learning; 5) cultivation of students' generic skills, such as communication, problem solving, team spirit and creative thinking; 6) establishment of a formative student evaluation system and using growth portfolios to assess students' learning in schools (Yin et al., 2014, p.297-298).

2.3.4 The state of science learning in Mainland China

Science learning in China has made great leaps in theory and practice by exploring the rich traditions of Chinese education and making reference to the experiences of educational reform in other countries. Science education has produced millions of personnel specialized in science, engineering, and technology. But there are still problems with Chinese science education.

It has been argued that a utilitarian focus of science education in China submerged the ‘science spirit’ which is the essence of science that seeks for truth and innovation (Liu, 2006). In the 100 years since science education was imported to Chinese schools, science education has always shouldered the great responsibility of reviving or strengthening the country. For Mainland Chinese students, science learning becomes a tool or a bridge to enter a university. In one way, science learning can be considered to have a similar function to learning ancient classics as being the tool for ancient scholars to pass the Imperial Examinations and thus change their social status. Students aspired to pass the exams and thus just learnt what will appear in the exams. The consequence of the utilitarian and examination-focused science education is that students seldom learn more than what is examined and many of them lack inner interest to explore the world.

Further, it has been suggested that the over-emphasized preference on systematic structure of scientific knowledge has deprived students from living a real life (Li, 2003). Complex mathematic inference and justification of scientific theories and the huge amount of elaborate exercises to apply the scientific theories has made learning science difficult and time consuming. The tiresome work has little relevance with students’ real lives and the study process is a hardship for most Chinese students. As a consequence of the huge academic pressure, Mainland Chinese students are often deprived of the rights of enjoying leisure, undertaking athletic or recreational activities, or having even enough hours of sleep (Cui, 2007).

The Chinese educational reform needs theories originating from and developed by Chinese scholars (Gu, 2006; Wu, 2009). But the newly published national standards, such as the National High School Physics Syllabus (MoE, 2002), are heavily referenced on the U.S. national science standards and the underlying theories of constructivism are also from Western scholars (Liang and Yuan, 2008). Although there are thousands of people studying education, very few people study science education (Liu, 2007). Without instruction of theories developed from within the Chinese context, reform in science education may be superficial or distorted.

Theories of learning that guide teaching and learning are translated from the West and often lack localization (Wu, 2009). Confucian principles of learning may help students learn, but research that reports these principles being applied in learning science is sparse at best. Teachers would instruct their classes according to the recommendations of the curriculum. Although teaching experiences may help them know what works or not, learning theories specifically relevant for Chinese students need to come to the fore. Metacognition may be a valuable concept to employ to improve science learning in Mainland China. But before this is done, it is necessary to review the status of Metacognition research in Mainland China.

2.3.5 Metacognition research in Mainland China

Metacognition is the essential component of learning to learn. Metacognition research in China contributes to the theory and practice of learning science of Chinese students. Up to now some, but limited, research in metacognition has been conducted in the fields of psychology, English language learning, problem solving, and science education. As of date, 2137 articles with title containing ‘metacognition’ can be found in the China Academic Journals database. Only 7 out of the over 2000 articles deal with physics, 4 articles deal with chemistry, 2 articles deal with science, and none deals with biology. After briefly reading a sample of the 2000 articles, it is found that over 90% of these articles do not include empirical data and most of them are only reviews and discussions which are very similar in content. As Chinese educational research tries to integrate with the world, good papers with empirical data are only slowly beginning to emerge. Some examples are as follows.

Li and Zhang (2006) studied characteristics of on-line metacognitive regulating ability under two different cognitive tasks. On-line metacognitive processes include planning, strategies selecting, monitoring and debugging, while another two processes of prediction and evaluation are called off-line metacognitive regulation (Veenman et al., 2006). The two tasks were 'letter recall' and 'key strike' that require strategies to improve performance. They found that cognitive performance was enhanced through on-line metacognitive regulation and the on-line metacognitive regulation was both domain-general across different tasks and domain-specific in discovering the rules.

Wang and Chen (2007) studied the relationship between theory of mind and metacognition of preschool children. They used different instruments to measure the social perceptual and social cognitive components of theory of mind and the metacognitive knowledge, awareness, and control of 98 children from a kindergarten in Beijing. They found significant correlation between theory of mind and metacognition and that social cognitive component of theory of mind might predict the development of metacognition.

Tong and Zhang (2004) designed training materials to enhance students thinking skills and metacognitive awareness. They provided question sheets for students to improve their awareness of thinking processes. After comparing results with a control group, they concluded that metacognitive knowledge of strategies and metacognitive control could improve students' ability in solving mathematics problems. Jiang and Zhao (2009) shared their experience of training students with metacognitive skills in learning physics. Their suggestions of asking students to reflect on their relevant life experiences, think about their thinking processes in solving problems, and write diaries may have been effective to improve students' learning physics, but they did not provide any evidence that these measures were effective. Hou and Guo (2009) also gave similar suggestions on how to enhance metacognition in teaching and learning physics.

Metacognition research is conducted more extensively in the field of teaching and learning English as a second language in China, with more empirical research than in the field of science education. Shi (2005) used a qualitative methodology to study the contribution of 'diary of listening' to the development of metacognition. Cai (2006) designed a questionnaire to measure metacognition in listening and she concluded that listening comprehension is positively associated with metacognition. Some researchers (e.g., He, 2005; Zhu, 2009) intervened with metacognition training and found that listening comprehension is greatly improved after training.

Research on metacognition conducted by Mainland researchers is currently seldom seen in international academic journals. One reason is that not much research with empirical data has been done with appropriate methodology, and the other reason is that most researchers of metacognition have language barriers to publish their work in English. As I know, many professors in education were not trained to use any methodology except using classics, such as Marx or Mao's work to support their arguments. New generations of researchers will increasingly have learnt quantitative and/or qualitative methodologies, but mostly 'from the book' and not necessarily from their own graduate or past research practice. The key reason may be that the Chinese academics do not have a tradition to do empirical research. So there is a gap in the literature studying Chinese students' metacognition with appropriate methodology and with a consideration of cultural influence, and this research aims to partly fill in this gap.

2.4. Conceptions of learning

This section reviews the definition of conceptions of learning, the structure of conceptions, Western studies on conceptions of learning, research on conceptions of learning in Asia, and the relationship between metacognition and conceptions of learning.

2.4.1. Definition of conceptions of learning

The term "conception" is defined as "an idea of what something or someone is like, or a basic understanding of a situation or a principle" by the Cambridge Advanced Learner's Dictionary (n.d). Marton (1981a, 1981b, 1984, 1986, 2005) defined conceptions of learning as different ways of understanding of learning. Pratt (1992) defined conceptions of learning as specific meanings attached to the experience of learning which then mediate students' response to a given situation. Vermunt and Vermetten (2004) defined conceptions of learning as complex constructs that include many components, such as knowledge and beliefs about oneself as a learner, tasks, learning objectives, learning activities, and learning strategies:

> A conception of learning is a coherent system of knowledge and beliefs about learning and related phenomena (e.g., knowledge and beliefs about oneself as a learner, learning objectives, learning activities and strategies, learning tasks, learning and studying in general, and about the task division between students, teachers, and fellow students in learning processes). (p. 362)

The above definitions of conceptions of learning suggest that many components of conceptions of learning are also components of metacognitive knowledge which includes knowledge of the task, the self, and strategies (Flavell , 1979). Thus I propose that conceptions of learning are a congruent concept with metacognitive knowledge in the context of science learning, and this is discussed in section 2.4.5.

2.4.2 The structure of conceptions of learning

Marton (1988) developed a framework of conceptions of learning that contains two levels (see Figure 2.4.1). Later, Marton and Booth (1997) revised the framework to add a third level (see Figure 2.4.2). The first level includes 'what' and 'how' aspects. The 'what' aspect refers to what is learnt, and the 'how' aspect refers to how learning takes place. The second level contains referential and structural aspects. The referential aspect focuses on the overall meaning given to the experienced phenomenon, whilst the structural aspect focuses on how the referential aspect is understood (Watkins, 2000). Based on Marton and Pong (2005), the referential aspect refers to a particular meaning of anything that the subject has delimited and attended to; the structural aspect refers to the combination of features discerned and focused about the object. The third level includes direct object, indirect object, and act. The direct object is what to learn, the indirect object is the motives to learn, and act is the strategies applied.

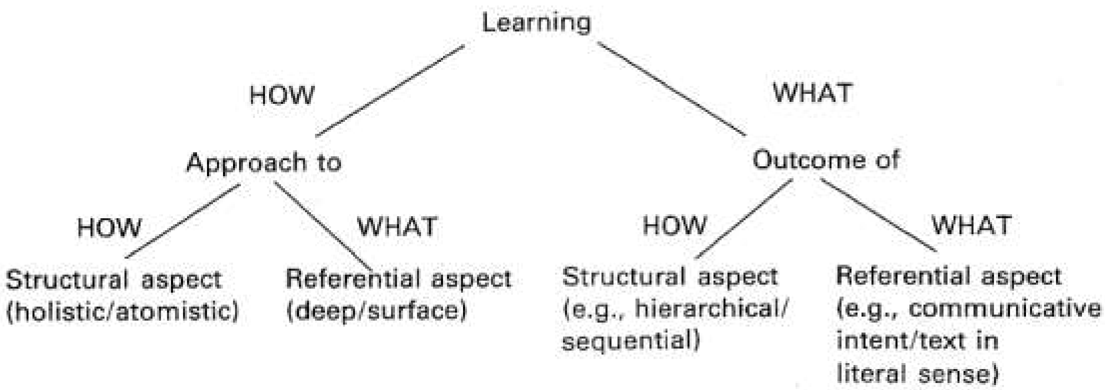

Figure 2.4.1: Diagram of the structure of categories describing learning from Marton (1988, p. 66).

Marton (1988) explained the meaning and relationship of these aspects of a conception in the following way:

> We could say that the outcome represents the “what” aspect of learning and the approach represents the “how” aspect. . . Qualitative differences in the outcome of learning have logically and dialectically related to structural and referential aspects. Structure refers to how the outcome is arranged, and reference refers to what the outcome is about (p. 60).

Marton stated that the ‘what’ aspect of learning also includes a ‘what’ and ‘how’ aspect, and the ‘how’ aspect of learning also includes a ‘what’ and ‘how’ aspect (see Figure 1). Marton developed the structure in order to provide some theoretical basis for phenomenography which originated from practical research. According to Marton and Booth (1997), the what/how framework is based on Brentano’s ideas about intentionality; “The what and the how aspects – is a special case of the notion of intentionality, the philosophical stance of Brentano enables us to picture the basic structure of learning” (p. 84). To provide theoretical grounding for the referential/structural framework, Marton and Booth (1997) drew on Gurwitsch’s (1964) layered model of awareness to define the referential (meaning) and structural (internal and external horizons) aspects.

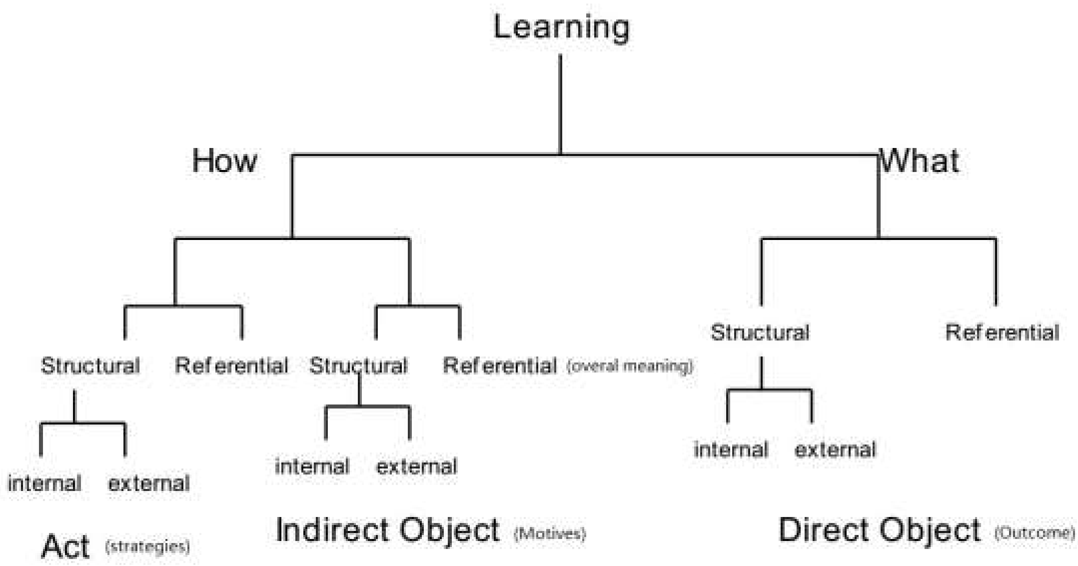

Figure 2.4.2: Diagram of conceptions of learning from Marton and Booth (1997, p. 91)

Marton’s (1988) definition of the ‘what’ aspect is different from many other researchers' definitions. Marton defined the 'what' aspect as "what is learned" (p. 278). Pramling and others (Irvin, 2006; Fyrenius, Silen, and Wirell, 2007) defined the "what" aspect as "what do you mean or understand learning is". For example, Fyrenius, Silen, and Wirell (2007) studied students' conceptions of medical physiology, and they defined the 'what' aspect as "how the students perceive of the actual content they are learning." (p. 365)

Harris (2011) reviewed 56 studies that studied conceptions of learning and used the frameworks Marton (1988) proposed. The review found heterogeneous definitions and usages of these frameworks. Most studies utilized the 'what' and 'how' aspects and ceased using the 'referential' and 'structural' aspects although they were "originally termed as a second level of what and how" (Harris, 2011, p.115). In addition, Harris pointed out that researchers of phenomenography and conceptions of learning did not report their results as being composed of the 'what' and 'how' aspects.

After reviewing the literature of conceptions of learning and analyzing the conceptions of learning of Chinese students in this study, this researcher considers that there should be a 'why' aspect in the structure of conceptions of learning, apart from the 'what' and 'how' aspect. In fact the 'structural' aspect proposed by Marton and Booth (1997) implies and overlaps with the 'why' aspect'. The structural aspect means "discernment of the whole from the context...and discernment of the parts and their relationship within the whole" (Marton & Booth, 1997, p. 87), and the former distinction was named as the phenomenon's external horizon and the latter as its internal horizon. The two horizons, i.e., the structural aspect, concern the constituent parts of the experience and their relationship to each other as well as to contextual factors. The discernment of the relationships implies that the learner understands why to learn (indirect object of learning) and why to learn in specific ways (act of learning). In other words, the 'why' aspect, i.e., why students learn as they do, is implied in and overlaps with the structural aspect in Marton's structure of conceptions of learning.

Some researchers of conceptions of learning studied the 'why' aspects apart from the 'what' and 'how' aspects. For example, Kruger (2003) investigated the perceptions of learners and educators regarding the efficacy of a therapy program by evaluating their content knowledge (what), procedures (how) and choices (why/when). She stated that "thinking about what you are doing, why you are doing it and how you are doing it" assist learners in reflecting and evaluating their learning experience (p. 196). Berglund (2005) studied university students' experience in learning computer systems by finding out students' perspective: the what, the why, the how and the where of their learning. McConnachie (2000) investigated grade 7 students' conception of what, why, and how they approached their learning processes. He argued that students who know what they are learning and why they learn as they do tend to learn metacognitively, creatively, and critically.

Thus the researcher of this study proposes that the structure of conceptions of learning contain 'what', 'how' and 'why' aspects. The 'what' aspect refers to what students think that learning is. The 'how' aspect refers to how students engage in their learning processes. The 'why' aspect refers to why students learn as they do.

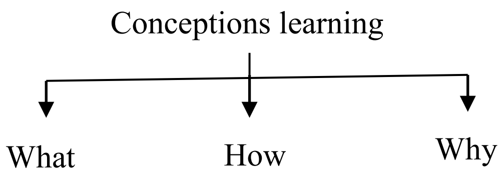

Figure 2.4.3: The structure of conceptions of learning

2.4.3 Western studies on conceptions of learning

The notion of conception of learning has been a research focus in education since the 1970s. The following is a review of the research to date. The purpose of reviewing literature is to find out what has become known about conceptions of learning in general, both in Western countries and Asian countries, so that a reference frame can be established, within which Mainland Chinese students' conceptions of learning might be positioned. At the same time, studying the rationale and frameworks emerging from the various existing studies aimed to assist with my data analysis and interpretation.

2.4.3.1 Early works: Saljo and Marton's conceptions of learning

Säljö (1979) interviewed 90 Swedish teenagers and adults with various level of education about their conceptions of learning. He asked them what they understood by learning and found five main categories of conceptions. 1) Learning as increasing the quantity of information; 2) Learning as memorizing, which is storing information that can be reproduced; 3) Learning as acquiring facts, skills, and methods which can be retained and used when necessary; 4) Learning as making sense or abstracting meaning; Learning involves relating parts of the subject matter to each other and to the real world; 5) Learning as interpreting and understanding reality in a different way; Learning involves comprehending the world by re-interpreting knowledge.

Saljo's categories are one dimensional, that is, all the categories center on knowledge acquisition. The first category states what learning is (Learning is to increase the quantity of information). The other four categories focus on the 'how' aspect, that is, how knowledge (or information) is acquired, memorized, applied, understood, and interpreted.

Marton et al. (1993) interviewed 29 students who enrolled in the Open University in Switzerland up to seven times about their learning experiences, and identified virtually the same five conceptions of learning as Saljo (1979) but also found a sixth conception of learning. The six conceptions of learning are stated as: (1) increasing one's knowledge; (2) memorizing and reproducing; (3) applying; (4) understanding; (5) seeing something in a different way and (6) changing as a person. Conceptions 1 to 3 reflect a surface understanding of learning, which primarily depicts learning as acquired and reproduced, while conceptions 4 to 6 reflect a deep understanding of learning, consistant with an interpretative/constructivist view of learning (Martin & Ramsden, 1987; Van Rossum & Schenk, 1984). For the first three conceptions, the notion of seeking meaning of what is being learnt is absent, and students with the three conceptions acquire, accumulate, store, and retrieve information with no attempt at interpretation of information. Whereas students with the latter three conceptions report wanting to gain a better understanding of reality by abstracting meaning from what is presented.

These six conceptions of learning have been described as a “nested hierarchy”, in which upper level conception of learning may also include elements of the lower levels, but not vice versa (Entwistle, 2000). In other words, the lower level conception of learning cannot contain any upper level conception of learning (see figure 2.4.4). For example, ‘understanding’ includes ‘memorizing and reproducing’, but ‘memorizing and reproducing’ does not include ‘understanding’.

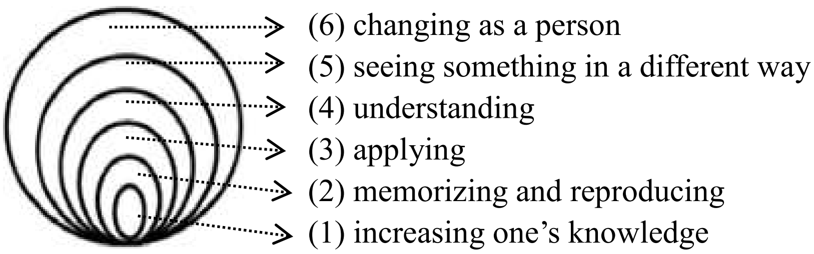

Figure 2.4.4 A nested hierarchy of Marton’s conceptions of learning

2.4.4.2 Studies on conceptions of learning in Western countries

Prosser, Trigwell, and Taylor (1994) interviewed 6 university teachers by asking them how they conceive of learning. They found five categories of conceptions of learning: (a) accumulating more information to satisfy external demands; (b) acquiring concepts to satisfy external demands; (c) acquiring concepts to satisfy internal demands; (d) conceptual development to satisfy internal demands; (e) conceptual change to satisfy internal demands. These categories consist of two dimensions. One dimension is knowledge, and learning is information accumulation and concept acquirement, development, and change. The other dimension is motivation, and learning is motivated either from internal or external demands.

Tynjala (1997) investigated 31 educational psychology students' conceptions of learning by analyzing their essays titled "my conceptions of learning." Seven categories of conceptions of learning emerged after their phenomenographic analysis: 1) learning as an externally determined event/process; 2) learning as a developmental process; 3) learning as student activity; 4) learning as strategies/styles/approaches; 5) learning as information processing; 6) learning as an interactive process; and 7) learning as a creative process. The first category, learning as externally determined event/process, described the conception of passive leaners with external motivations. The second category, learning as a developmental process, described internal motivation. The third category described learning as individual activity, whereas the sixth category describes learning as social interaction. The fifth category described learning as information processing, while the seventh category describes learning as creating process. The seven categories can be seen as hierarchically ordered from being oriented towards an examination-driven rote learning and surface approach to more of a constructivist learning and a deep approach (Tynjala, 1997).

Gustafson and Rowell (1995) studied the conceptions of learning science of 27 elementary pre-service teachers through questionnaires and semi-structured interviews at the beginning and end of two science education courses and obtained the same results. The ‘what’ aspect and ‘how’ aspects of conceptions were studied separately. The answer to the first question ‘what does it mean to learn science’ was: 1) gaining information; 2) problems solving; 3) assimilating new knowledge with existing knowledge; 4) charge; 5) reflection. The answer to the second questions ‘how do children learn science’ was: 1) learn through hands-on physical manipulation; 2) through peer interaction; 3) through connecting new information with old; 3) influenced by affective factors; 4) watching; 5) reflecting. In this study, the authors did not define conceptions of learning, nor did they attend to the structure of conceptions. They just used what and how questions and they did not merge the two into an integral structure. The answers to the questions are not hierarchically arranged either. The answers were arranged based on the frequency they appear on students.

2.4.4 Research on conceptions of learning in Asia

Chan et al. (2007) studied the conceptions of learning of 313 teacher education students in Singapore with questionnaire and identified two categories of conceptions, ‘traditional’ and ‘constructivist’. They found that students tended to hold a ‘constructivist’ conception about learning instead of the ‘traditional’ conception although both conceptions were prevailing. Students with ‘traditional’ conceptions perceived teachers to be the sole custodians of knowledge and equate learning to the reproduction of learned materials. On the other hand, students with ‘constructivist’ conception believed in the idea of learners constructing knowledge for themselves and of regarding learning as an interaction with their peers so as to fashion their own learning experiences with good understanding. Interestingly, Chan and his colleagues pointed out that the two contrasting notions coexist in students' minds and "the pre-service teachers were capable of embracing two seemingly contrasting notions of teaching and learning in chorus" (p. 192). Students who held more 'traditional' conception may also support 'constructivist' ideas and interact actively with their peers. Students with 'constructivist' conception may embrace the traditional classroom learning. The difference is the extent of embracement they gave to each conception. Chan and his colleagues did not further analyze the sub categories under the two conceptions.

Li (2001) examined conceptions of learning with a research method called "prototype" (p. 114). 83 Chinese adults with university degrees developed a repertoire of 225 learning- related terms, and 100 undergraduate students sorted these terms into similar groups. By studying the names given to the sorted groups of learning-related terms and the explanations of why the terms were grouped, Li found two categories, "Seeking Knowledge" and "Achievement". Under "seeking knowledge" there was a subcategory called hao xue xi (好学习, heart and mind for wanting to learn) that Li claimed to be an important quality for Chinese learners. The quality of heart and mind for wanting to learn, according to Li, is the quartet of diligence, endurance of hardship, steadfastness, and concentration. Li argued that the quality of heart and mind for wanting to learn was the core attitude toward learning and essence for lifelong pursuit of knowledge.

Pratt (1992) employed phenomenography and found four qualitatively different conceptions of learning by interviewing about 60 Chinese scholars. Learning was understood as (l) the acquisition of knowledge or skill from others, (2) a fulfillment of responsibility to society, (3) a change in understanding of something external to self, and (4) a change in understanding one's self. The categories were acquired by "moving back and forth between the data and emergent categories of meaning, which ultimately resulted in conceptions of learning" (page 310).

Tsai (2004) studied Taiwan high school students' conceptions of learning science and argued for 7 categories after using phenomenographic analysis. The seven categories were, learning science as memorizing, preparing for tests, calculating and practicing tutorial problems, the increase of knowledge, applying, understanding, seeing in a new way. The questions Tsai asked are "what do you understand by learning science?" and "how do you learn science?" Memorizing, practicing, applying, understanding were directly related to knowledge and skills, while preparing for tests and seeing in a new way were motivation and results separately. Compared with earlier findings, Tsai (2004) identified two distinct conceptions of learning science, 'preparing for tests' and 'calculating and practicing tutorial problems'. Tsai (2004) suggested that the 'Memorizing', 'Testing', and 'Calculating and Practicing' are a lower-level group, and 'Increasing one's knowledge', 'Applying', 'Understanding', and 'Seeing in a new way' are the higher-level group.

In summary, studies about conceptions of learning have been conducted using phenomenography. Most studies conclude that conceptions of learning are hierarchically structured, and usually further divided into two higher-order categories:

Table 2.4. Summary of key findings of conceptions of learning

<table>
<tr><th>Authors</th><th colspan="2">Conceptions of learning</th></tr>
<tr><td>Säljö (1979)</td><td colspan="2">1) Increasing the quantity of information;
2) Memorizing,
3) Acquiring facts, skills, and methods
4) Making sense or abstracting meaning.
5) Interpreting and understanding reality</td></tr>
<tr><td>Marton et al. (1993)</td><td colspan="2">1) Increasing one's knowledge
2) Memorizing and reproducing
3) Applying
4) Understanding
5) Seeing something in a different way
6) Changing as a person</td></tr>
<tr><td>Prosser Trigwell, and Taylor (1994)</td><td colspan="2">1) Accumulating more information to satisfy external demands
2) Acquiring concepts to satisfy external demands
3) Acquiring concepts to satisfy internal demands
4) Conceptual development to satisfy internal demands
5) Conceptual change to satisfy internal demands.</td></tr>
<tr><td>Tynjala (1997)</td><td colspan="2">1) An externally determined event/process
2) A developmental process
3) Student activity
4) Strategies/styles/approaches
5) Information processing
6) An interactive process
7) A creative process.</td></tr>
<tr><td rowspan="2">Gustafson and Rowell (1995)</td><td>What does it mean to learn science</td><td>How to learn science</td></tr>
<tr><td>1) gaining information
2) problems solving
3) assimilating new knowledge with existing knowledge
4) charge
5) reflection.</td><td>1) hands-on physical manipulation
2) peer interaction
3) connecting new with old
4) influenced by affective factor
5) watching
6) reflecting.</td></tr>
<tr><td>Chan et al. (2007)</td><td colspan="2">1) surface (traditional)
2) deep (constructive).</td></tr>
<tr><td>Li (2001)</td><td colspan="2">1) Seeking Knowledge
2) Achievement</td></tr>
<tr><td>Pratt (1992)</td><td colspan="2">1) the acquisition of knowledge or skill from others
2) a fulfillment of responsibility to society
3) a change in understanding of something external to self
4) a change in understanding one's self</td></tr>
<tr><td>Tsai (2004)</td><td colspan="2">1) memorizing
2) preparing for tests
3) calculating and practicing tutorial problems
4) increase of knowledge
5) applying
6) understanding
7) seeing in a new way</td></tr>
</table>

lower-level conceptions and higher-level conceptions, or surface approaches and deep approaches, or traditional orientations and constructivist orientations. The key findings of literature of conceptions of learning are listed in table 2.4.

2.4.5 Relationship between metacognition and conceptions of learning

Researchers, such as Cano and Cardelle-Elawar (2004), Thomas (1999a, 1999b, 2002, 2006b, 2006c), and Vermunt and Vermetten (2004), have stated the implicit innate connections between metacognition and conceptions of learning. Vermunt and Vermetten (2004) demonstrated that students' use of regulation strategies was consistently associated with students' conceptions of learning. Students' use of regulation strategies is a natural result of their metacognitive awareness and control, thus Vermunt and Vermetten's statement of the connection between conceptions of learning and metacognition is coherent with the previously described working model of metacognition (Thomas, 1999b) in that metacognitive knowledge is the basis of metacognitive awareness and control.

Cano and Cardelle-Elawar (2004) stated that conceptions of learning were studied by two lines of research: phenomenographic and metacognitive. They claimed that metacognitive research on conceptions of learning was quantatitive, while the phenomenographic research was qualitative. They used both qualitative and quantitative methods to study students' learning conceptions as well as their epistemological beliefs. Cano and Cardelle-Elawar intentionally integrated conceptions of learning and metacognitive knowledge in one study. In other words, these authors regarded the conceptions of learning and metacognitive knowledge the same construct.

As discussed earlier, the definitions of conceptions of learning and that of metacognitive knowledge overlap and are interrelated. Conceptions of learning refer to students' ideas, knowledge, and beliefs about learning (Pratt, 1992; Vermunt and Vermetten, 2004). Metacognitive knowledge is the knowledge of cognition, which includes the mental processes such as attention, memory, reasoning and thinking. In the context of education, cognition means "to know," and metacognition can be described as knowledge and control of learning. In this sense, metacognitive knowledge is the knowledge of learning, that is, students' conceptions of learning. To think the other way around, conceptions of learning are metacognitive in nature, since these ideas are about the cognitive activities, i.e., learning activities. With these ideas about learning, students can evaluate, regulate, and control their learning activities (Purdie et.al., 1996).

Based on the literature of metacognition and conceptions of learning, this researcher considers that metacognitive knowledge and conceptions of learning are two congruent constructs in the context of learning science. Metacognitive knowledge consists of three different kinds of metacognitive awareness: declarative, procedural, and conditional knowledge (Brown, 1987; Jacobs & Paris, 1987; Schraw & Moshman, 1995). Declarative knowledge refers to knowing about learning science. Procedural knowledge refers to knowing how to learn science. Conditional knowledge refers to knowing why and when to learn science as one does. A Conception of learning contains three aspects: the 'what' aspect, 'how' aspect and 'why' aspect. The 'what' aspect refers to the understanding of what learning science is, the ‘how’ aspect refers to the understanding of how science is learnt, and the ‘why’ aspect refers to why a person learns science as he/she does (see section 2.4.2). Thus metacognitive knowledge and conceptions of learning are very similar constructs, and they are used interchangeably in this study. The relationship of the two similar constructs is illustrated in figure 2.4.2.

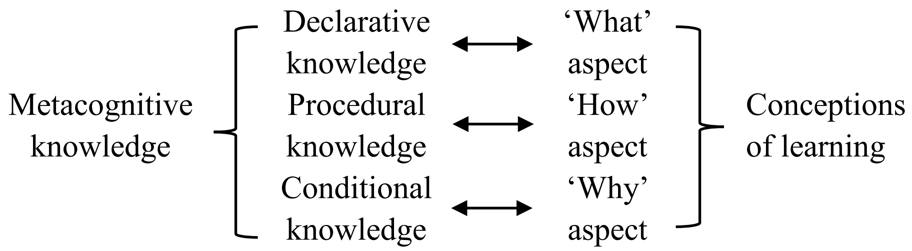

Figure 2.4.5: Diagram of the relationship between the two similar constructs (adapted from Thomas 1999b)

2.4.6 The relationship between conceptions of learning and their learning experiences.

Thomas (1999a, b) explored teaching students about learning, engaging them in metacognition, and altering their conceptions of learning. The researcher worked with his students to build a social constructivist classroom where students planned, monitored, and evaluated their science learning. By introducing this constructivist learning experience, the researcher designed to change his students’ conceptions of learning from that of transmissionist to constructivist. The students understood the rationale of the metaphor “learning is constructing” and reported improvements in their learning in the constructivist classroom, that is to say, they agreed that the constructivist's conception was "intelligible, plausible and fruitful" (p. 239). However, 12 out of 24 students reported that their conceptions of learning were unaltered, and for those who reported changes to their conceptions of learning, their pragmatic and utilitarian learning orientation remained the same. Thomas explained that their former experiences of learning science plus the societal belief systems are the major barriers to the conceptual change.

> Their beliefs and practices, constructions composed from experiences that have been filtered and sorted from their earliest experiences of schooling, are reflective of the larger social identity of the school population. Asking students to investigate and interrogate their beliefs about learning and their roles as learners might require that they question societal belief systems including those of their peer group, their parents, their teachers, their school and the education system within which they must conform in order to matriculate and continue to further study (Thomas, 1999a, p. 16).

Thomas' statement (1999a) that students' conceptions of learning are based on their learning experiences is consistent with the views of situated learning theorists (e.g., Billett, 1996; Lave & Wenger, 1991) and Vygotsky's social development theory. Vygotsky (1978) stressed the fundamental role of social interaction in the development of cognition and argued that "learning is a necessary and universal aspect of the process of developing culturally organized, specifically human psychological function" (1978, p. 90). According to Vygotsky (1978), much important learning occurs through social interaction with a skillful tutor within the zone of proximal development. The interventional constructivist conception contradicts with students' transmissionist conception and thus falls far outside the zone of proximal development. But as Thomas (2002) pointed out, students' metacognition, including their conceptions of learning, will be enhanced and developed if each stakeholder — the child himself, his parents and family, his teachers, the community, as well as the school advisory/management committee — can see the real and relevant value of the types of learning processes that the constructivist conception entails.

Thomas (2002) highlighted the influence on experiences of learning by the pedagogical hegemony, which was a product of habitus, i.e., people's internalized dispositions and values that guide their behaviors. When students enter the classroom, they bring in their conceptions of learning developed from early learning experiences that were shaped by the dominant societal values and beliefs. Their conceptions of learning are constantly enforced or modified by "their classroom learning environments that themselves are not divorced from the social milieu that envelopes and pervades them" (Thomas, 2006b, p. 87). Saljo (1987) made a similar statement that conceptions of learning are socially, historically, and culturally constructed: "To learn is to act within man made institutions and to adapt to the particular definitions of learning that are valid in the educational environment in which one finds oneself" (p. 106).

Students' conceptions of learning that are drawn and reflect their learning experiences are commonly studied within the methodology of phenomenography, which describes students' ideas and experiences of learning. The aim of phenomenography is to explore the different ways in which students experience, interpret, perceive or conceptualize learning. Phenomenography is reviewed in detail in Sections 3.1 and 3.2.

2.5 A caveat: variations in Chinese culture

This section reviews English language literature on Chinese students' learning processes and shows that Chinese culture is not homogeneous but different across the regions, namely Mainland China, Hong Kong, Taiwang, and Singapore. The purpose of clarifying the difference is twofold: to question the tendency of treating these regions as an identical group in cultural studies and to highlight the importance of this research since it is difficult to find literature about Mainland Chinese students' metacognition and conceptions of learning science while some literature of them exists in Hongkong and Taiwan.

2.5.1 Variations of culture between Hong Kong, Taiwan, Mainland China, and other large Chinese communities.

Current cultural analyses have a tendency to lump Hong Kong, Taiwan, Mainland China into one group, probably because of their near identical racial root as well as common Confucian heritage. One or two centuries ago there would be less difference than now since many historical incidents have happened that would influence cultural values. Hong Kong was a colonial territory of Great Britain for over 100 years and the colonial system will have influenced the Hong Kong culture. Taiwan was a colony of Holland in the fifteenth century and an occupied land of Japan for 50 years in the early twentieth century. It is supposed that the colonial history of Taiwan may add special characteristics to its culture. In addition, Taiwan, Hong Kong and other large Chinese communities practice capitalism, but Mainland

China endorses socialism with a market orientation. The political system and its ideology will likely affect the shared values and social axioms.

Although empirical observation strongly suggests that, regardless of the environmental factors, Confucianism has persisted in Chinese societies for over 2000 years (Li et al., 2004), researchers who employ a static definition of Confucian cultural values may find it difficult to explain important cultural differences that continue to emerge within and across different Chinese societies. Li et al. studied the differences in leadership behaviours among managers in Taiwan, Singapore, Hong Kong and Mainland China. They found Hong Kong leaders ranked very high on 'autonomous' and 'autocratic', but low in 'modesty', 'integrity', and 'face-saving'. 'Conflict inducer' is ranked very high by Taiwan leaders but very low by Mainland Chinese leaders. Mainland Chinese communities gave low scores to 'being diplomatic', 'being decisive', and 'being self-sacrificial' (Li et al., 2004). The differences in leadership behaviour that societal cultures legitimize indicate there are at least some, and likely more, distinct cultural differences among the four Chinese societies.

Hofstede (1991) studied the cultural differences across various regions including Mainland China, Hongkong, Taiwan and Singapore. Hofstede's work suggests that there is heterogeneity in these regions, and there is no evidence today to refute these findings. As mentioned earlier, Hofstede defined five dimensions of culture: individualism–collectivism, power distance, uncertainty avoidance, masculinity–femininity, and long-term orientation. Hofstede analyzed a large data base of values scores covering more than 70 countries including the four Chinese societies (Hofstede, 1991), as shown in table 2.5.

Table 2.5 *Index of Cultural Dimensions*

Country	PDI	IDV	MAS	UAI	LTO
Arab World	80	38	52	68	
Australia	36	90	61	51	31
Canada	39	80	52	48	**23**
China	**80**	20	66	30	**118**
Denmark	18	74	16	23	
France	68	71	43	86	
Germany	35	67	66	65	31
Hong Kong	68	25	57	29	96
India	77	48	56	40	61
Israel	**13**	54	47	81	
Italy	50	76	70	75	
Japan	54	46	**95**	**92**	80
New Zealand	22	79	58	49	30
Singapore	74	20	48	**8**	48
Sweden	31	71	**5**	29	33
Taiwan	58	**17**	45	69	87
United Kingdom	35	89	66	35	25
United States	40	**91**	62	46	29

Note: PDI: Power Distance Index; IDV: Individualism; MAS: Masculinity; UAI: Uncertainty Avoidance Index; LTO: Long-Term Orientation

Graph adapted from Hofstede, 1991. Source from:
http://www.geert-hofstede.com/hofstede_dimensions.php

Hofstede's Power distance Index assesses the extent to which the less powerful members of a society accept and expect that power is distributed unequally. If the score is high, it suggests that this society's inequality is endorsed by its members, and vice versa. Hong Kong has a 68 on the cultural scale of Hofstede's analysis (Hofstede, 1980). Compared to Mainland China where the power distance is very high (80) and Taiwan is comparatively low (58), Hong Kong is somewhat in the middle. This can be understood as democracy is still a taboo in Mainland China, but in Taiwan democratic reform has occurred for over thirty years. In Hong Kong, the Great Qing Legal Code based on Confucian social hierarchy remained in force until the Marriage Act of 1971. Singapore scored 74 of the power distance index that is lower than Mainland China and higher than Hong Kong and Taiwan, indicating that Singaporeans are rather comfortable with their hierarchical society in which people are unequal in rank and standing. The reason for high power distance in Singapore may be that most Singaporeans are Chinese and Confucian teaching is very strong (Craig, 1994).

Individualism measures the degree to which individuals are integrated into groups. In individualist societies the ties between individuals are loose, but in the collectivist societies people are integrated into strong, cohesive in-groups, and extended families. Mainland China, Hong Kong, Taiwan, and Singapore score 20, 25, 17, and 20 respectively on the cultural scale, whereas the United states has a very high score (91). This suggests that although Mainland China, Hong Kong, Taiwan and Singapore are slightly different in their degrees of individualism, the four societies are very similar in collectivism when compared to the United States (Hofstede, 1980).

Masculinity measures the distribution of roles between the genders in a society. Masculinity refers to the values of being assertive and competitive, and femininity refers to the values of being modest and caring. Mainland China, Hong Kong, Taiwan, and Singapore scored 66, 57, 45, and 48 respectively. The Uncertainty avoidance Index measures a society's tolerance for uncertainty and ambiguity. A high score from a society suggests its members are uncomfortable in unstructured situations and that they try to minimize the possibility of such situations by developing and enforcing strict laws and security procedures. Mainland China, Hong Kong, Taiwan, and Singapore have scores of 40, 29, 69, and 8. Compared to Japan (92), the four societies are fairly comfortable with uncertainty, with Singapore being rated the lowest. Hofstede and Bond (1988) defined a fifth characteristic, long-term orientation or "Confucian dynamism," which was found to be particularly relevant to Asian culture. Long-term orientation cultures value virtues oriented toward future rewards, in particular perseverance and thrift. Short-term orientation stands for the fostering of virtues related to the past and present, in particular, respect for tradition, preservation of face, and fulfilling social obligations. Mainland China scores the highest (118), Singapore scores the lowest (48), and Hong Kong and Taiwan are in the middle (96; 87). The differences of cultural index scores indicate that the four societies have distinct cultural characteristics despite their common racial root and shared Confucian heritage. Therefore they cannot be considered as exactly the same culture.

Leung and colleagues (2002) proposed another perspective to measure culture and their result of measurement is consistent with Hofstede's survey results that the four Chinese societies are not culturally identical. Leung et al suggested the use of general beliefs, or social axioms as cultural indicators and defined a five-dimensional structure of social axioms including cynicism, social complexity, reward for application, spirituality, and fate control. Cynicism refers to a negative view of life and a mistrust of social institutions. Social Complexity refers to the belief that human behavior is variable across situations. Reward for Application refers to a belief that effort, knowledge, and careful planning will lead to positive results. Spirituality refers to a belief in the reality of a supreme being and the positive functions of religious practice. Finally, Fate Control refers to a belief that life events are predetermined. Bond et al. (2004) adopted the social axioms theory and administered the social axioms survey to 7,672 college students in 41 cultural groups. Their result showed significant cultural differences among the Chinese societies including Mainland China, Hong Kong, and Taiwan.

Overall, for the reasons suggested above which are historical, economical and political, Chinese societies including Mainland China, Hong Kong, Taiwan, and Singapore are not a single homogeneous cultural group, even although these societies are similar in several ways and share same languages, race, and Confucian heritage. Therefore, it is important to be cautious and to state clearly which Chinese community is referred to. The assumption that there is ‘only one’ Chinese culture needs to be treated with caution and researchers should be careful to elaborate the characteristics of that/those Chinese culture/s they seek to explore. This study seeks to explore the nature and origins (cultural roots) of learning processes and metacognition of Mainland Chinese science learners.

2.5.2 A brief review of the English language literature on Chinese students’ learning processes

Not only anthropologists have an interest in Chinese culture. Researchers in psychology and education show an interest in Chinese culture. An etic account of

Chinese culture by a non-Chinese observer can be culturally neutral, but not necessarily true to fact, since the average values cannot be directly observed and accurately reported. One example is the perception of Chinese as rote learners (Murphy, 1987; Samuelowicz, 1987). Rote learners use the technique of repetition to memorize knowledge while trying to avoid deep understanding. Later researchers such as Biggs (1994, 1996), Kember and Gow (1990), and Marton et al (1993) questioned this stereotype and recognized that in Asian cultures understanding may come through memorization. Biggs (2003) points out that Western countries teach and assess in a way that encourages rote learning more than many Asian countries do.

Another example of an etic account of Chinese culture of learning is the paradox of Chinese learners that Biggs (1996) proposed when he was surprised to find that Chinese students can have high academic achievement in a rather harsh classroom environment.

> The types of teaching context prevailing in many Asian countries is typically characterized as unvarying and expository, taking place in what seems to be highly authoritarian classrooms, where the main thrust of teaching and learning is focused on preparation for external examinations, which tend to address lower level cognitive goals, and to exert excessive pressure on teachers and exam stress on students (Biggs, 1996; page 147).

The observations that Chinese classrooms are authoritarian, expository, and examination-oriented reflect the real situations in Chinese classrooms. But Chinese teachers and students do not only address lower level cognitive goals. While there are differences regarding the extent of classroom democracy and deluge examinations between Western schools and Chinese schools, it might be ethnocentric to assert that

Western ways of teaching and learning might be superior to Chinese ways of teaching and learning, and to think that Chinese teaching and learning only address lower level cognitive goals. The values that determine why Chinese learners learn (science in this case) in a certain way are profound and need to be explored.

2.6 Summary

Science education in Mainland China has been afforded a strategic status in Mainland China because science education is believed to have a utilitarian function of strengthening and revitalizing the country. As a result, the school curriculum highly prioritizes science courses including physics, chemistry, and biology. Students may have to spend as many as thirty hours a week on average including homework time in studying science. Although students make greats effort in studying science, and some students may achieve academic successes according to Chinese standards, science education in China is less satisfactory overall in some aspects. One problem is that the real enjoyable life of students is sacrificed for the heavy burden of school work. Another problem is that the utilitarian and examination-focused science education may have submerged the 'science spirit' of science learners to seek for innovation and a deep, personal understanding of the natural world.

It is generally reported that Chinese students excel at recalling factual knowledge and solving algorithmic content-based problems, but that their scientific reasoning and higher-order thinking are reportedly relatively underdeveloped. However, recent PISA results (PISA, 2010) suggest that the ability of 15 year old

Chinese science learners from Mainland China (Shanghai) and the two Special Administrative Regions of China adjoining the southern part of Mainland China (Hong Kong and Macau) to use their knowledge and skills to meet real-life challenges is quite well developed. Therefore the general perception of Chinese science learners may need to be challenged as more findings become available. Still, the general consensus is that an over-emphasized preference on the systematic structure of scientific knowledge, the still-prevailing teacher-centered didactic classroom instruction, and the tactics of excessive assignments of problems to be solved may have attributed to the low capability of Mainland Chinese learners in relation to some elements of learning science such as higher-order thinking and metacognitive skills.

The key element to enhance science education is to teach students to learn how to learn science and the core of learning how to learn is metacognition. Metacognition refers to learners' knowledge, awareness, and control of their learning processes. Metacognition plays essential roles in science learning, specifically in conceptual change, learning the nature of science, engaging in scientific inquiry, and nurturing problem-solving abilities and higher-order thinking skills. A working model of metacognition is necessary and has been proposed to conceptualize student's metacognition in relation to their science learning. According to this working model, metacognition is a hierarchy of four components: knowledge of the thinking and learning, awareness of one's own use of thinking and learning processes, purposeful control of thinking and learning processes, and the willingness to exercise control of those processes. Conceptions of learning belong to metacognitive knowledge, and in the context of students' learning science, conceptions of learning and metacognitive knowledge are two interchangeable terms.

One big challenge for the improvement of science education in Mainland China, and worldwide, is that metacognition, the key element of a successful science learning, is not emphasized and may be almost totally ignored in the Mainland Chinese context. This research will explore Chinese learners' conceptions of learning science and their metacognitive knowledge, control, and awareness of their science learning processes. The literature suggests that all students are metacognitive to some extent, even without formal instruction, on account of their own learning experiences and their everyday interaction with teachers, parents and peers. The underlying reason is that learning is culturally influenced and culture molds a person regarding how they learn to learn. Chinese culture abounds in learning principles that may have shaped the metacognitive knowledge, awareness, and control of Mainland Chinese learners in learning science. However, no evidence to support or refute such a notion is available in the literature. There exists rich evidence that culture influences psychological processes, but little research is found that examines if and how culture influences metacognitive knowledge (including conceptions of learning), metacognitive control, and metacognitive experiences of science learning. This research seeks to begin to fill this gap in the field of metacognition research and contribute to a deeper understanding of how Mainland Chinese learners learn science.

In summary, the research seeks to understand and describe Mainland Chinese students' metacognition including their conceptions of learning science and the origins of these conceptions and learning processes. More specifically, answers to the following three questions will be explored:

1). What do Mainland Chinese students report as their metacognition including their conceptions of learning science?

2). What do Mainland Chinese students report as the origins of their conceptions of learning and science learning processes?

3) How do Mainland Chinese students report, if at all, that culture influences their metacognition including their conceptions of learning?

Chapter 3 Methodology

This chapter describes the methodology that was employed to investigate Mainland Chinese learners' metacognition, that is, their metacognitive knowledge, including their conceptions of what it means to learn science, and their metacognitive awareness, and metacognitive control of their science learning processes. It also seeks to explore how Chinese culture may or not influence Mainland Chinese learners' metacognition, its development and origins. The methodology used in this research is phenomenography. There has been rapid growth in the number of journal papers and dissertations that employ phenomenography to investigate or explore various phenomena. Interest in the approach has spread from Sweden to Asia, North America and South Africa (Bruce and Gerber, 1997; Dahlin, 2007).

The first section of the chapter discusses what phenomenography is and its history of development. The second section discusses the theoretical foundation and philosophical considerations with respect to the methodology. The third section includes a justification for the selection of phenomenography as the research methodology. The fourth section describes data collection procedures of phenomenography and ethical considerations related to the participants and the context. The fifth section describes the process of data analysis. The sixth section describes quality, validity, and reliability issues related to the research.

3.1 phenomenography and its history

Phenomenography is an empirical research tradition that aims to answer questions about thinking and learning, especially in the context of educational research (Marton, 1986). The word ‘phenomenography’ is derived from Greek words “phainonmenon” meaning appearance and “graphein” meaning description. Thus literally, phenomenography is a “description of appearances” of a phenomenon (Hasselgren & Beach, 1997, p.192).

Marton (1981b) suggested that there exist two approaches to understand learning. One approach is to make statements about learning. Another approach is to study peoples’ ideas or experiences of learning. Phenomenography is consistent with the latter approach to explore how people experience a given phenomenon. Different people may, and tend not, to experience any given phenomenon in the same way. Rather, there will be a variety of ways in which people experience or understand a phenomenon. The aim of phenomenography is to explore the different ways in which people experience, interpret, understand, perceive or conceptualize a phenomenon, or a certain aspect of their reality. In this study, I seek to identify the multiple conceptions or meanings that Mainland Chinese learners have for learning science and how they learn science. This is related to the research questions because as discussed earlier, metacognitive knowledge in the context of learning is present as conceptions of learning, and metacognition is a Western construct that is used in this study to study how Mainland Chinese students learn to learn science as a temporary placeholder concept.

Phenomenography provides a way of looking at collective human experience of phenomena holistically despite the fact that such phenomena may be perceived differently by different people and under different circumstances (Åkerlind, 2005). Trigwell (2000) gave an overview of how phenomenography is distinguished from other research approaches:

> The key aspects of a phenomenographic research approach … are that it takes a relational (or non-dualist) qualitative, second-order perspective, that it aims to describe the key aspects of the variation of the experience of a phenomenon rather than the richness of individual experiences, and that it yields a limited number of internally related, hierarchical categories of description of the variation." (Trigwell, 2000, p77)

Historically, phenomenography was originally developed by a research group consisting of Marton (1981a, 1981b, 1976), Säljö (1979, 1981, 1987), Svensson (1977) and Dahlgren (1984) in the Department of Education, at the University of Gothenburg, Sweden in the mid-70s. They conducted a set of studies investigating students' conceptions of learning as a departure from the view that some people are better at learning than others. The studies were implemented by giving university students an academic article to read and then asking them to reflect on their learning approaches. The analysis of students' descriptions of how they treated the task produced the distinction between 'surface' and 'deep' approaches to learning (Marton and Säljö 1976). Their studies suggested that students who described using a deep approach were more likely to finish the task successfully (Säljö, 1981).

A large number of studies have been conducted to study students' conceptions of learning, an aforementioned element of metacognition, using phenomenography. Phenomenographic research can be classified into three categories (Marton, 1984). A considerable amount of research continues with the original research tradition that focuses on the qualitative differences in general learning processes (e.g., Berry & Sahlberg, 1996; Dahlin, 2007; Linder & Marshall, 2003; Svensson, 1997). Other research focuses on learning within a disciplinary context and on student conceptions of subject matter (e.g., Bruce, 1994; Crawford et al., 1994; Linder & Erickson, 1989; Lybeck et al., 1988; Ornek, 2008). Finally, some research is concerned with how individuals conceive of various aspects of life in their everyday contexts (e.g., Brookfield, 1994; Dahlgren, 1980; Hazel et al., 1997). Each of these groups of phenomenographic research offers an insider's perspective and helps develop a substantive understanding of the phenomenon itself. The research in this thesis explores the metacognition of Mainland Chinese students regarding their learning of science and thus fits in the second category.

3.2 Theoretical foundations of phenomenography

Phenomenography has developed as an empirical approach in educational research which does not emphasize the metaphysical beliefs about the nature of reality and the nature of knowledge (Uljens, 1996). Different phenomenographic researchers may have different metaphysical and epistemological positions. As Svensson (1997) explained, when new researchers enter the tradition and new investigations are made, the theoretical foundation may be modified to varying degrees on account of their own ontological and epistemological beliefs. Nevertheless, there are some common assumptions among phenomenographic researchers.

Ontology in the social sciences is concerned with the social nature of reality and how it can be studied. From the interpretivist paradigm, social reality is a product of meaningful interactions between participants and their social settings. Phenomenography shares the ontological assumptions of interpretivism which proposes that different people construe and experience the existing world in many different ways (Bowden, 2005; Marton & Booth, 1997). Phenomenographers do not claim that their research results represent truth; however, they do claim that their results are useful (Ornek, 2008).

Epistemology is concerned with the nature and scope of knowledge. The epistemological position of phenomenography supports a constructivist view that knowledge is created and sustained by social relations and interactions. The emphasis of phenomenography is on description of phenomena, such as learning and learning processes, which are both the product and foundation of human activity (Svensson, 1997). Conceptions of phenomena of individuals are the product of an interaction between them and their experiences with their external world/s. A person usually comprehends and conceives a phenomenon individually, irrespective of any concern for objectivity and/or intersubjectivity. Thus, epistemologically, knowledge for phenomenographers is more “subjectivistic and relative” to an individual’s social and cultural context rather than being objectivistic and intersubjectivistic (Svensson, 1997, p. 163).

Phenomenography aims to describe the world as experienced by the experiencer and study the variations of an aspect of the world that has been experienced (Marton and Booth 1997). Experience for phenomenographers is relational, not purely objective or independent of individuals, nor purely subjective or independent of the world (Bowden 2005). Phenomenography takes a non-dualistic ontological perspective and claims that object and subject are not separate and/or independent of each other. For instance, a textbook and its reader's constructions regarding the textbook are not independent from each other because of the meaning attached to the textbook by the reader (Walker, 1998). As Marton and Booth (1997) explained, there is not a real world 'out there' and a subjective world 'in here'. This non-dualist ontology of phenomenography can be illustrated in figure 3.2.1.

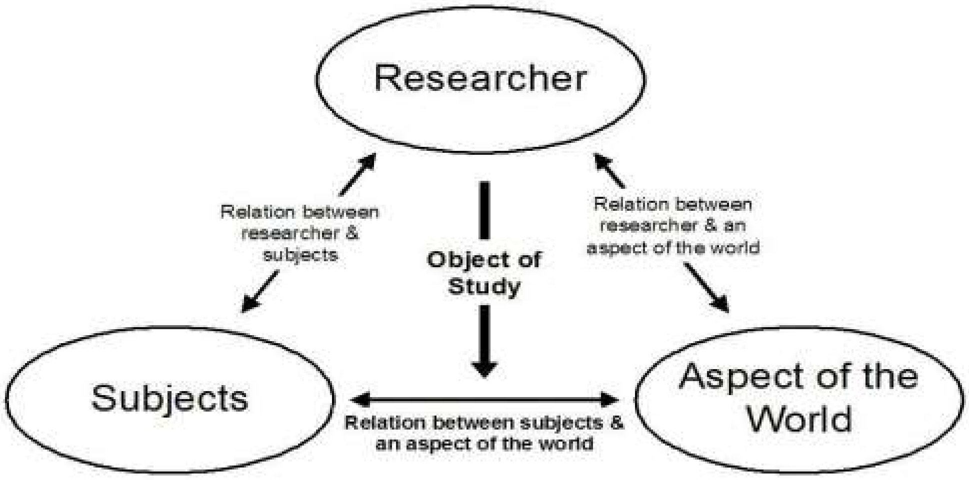

Figure 3.2.1. Non-dualist ontology of Phenomenographic Research (adapted from Bowden 2005)

Figure 3.2.1 depicts the relations among the researcher, subjects and an 'unspecified' aspect of the world. The relation between subjects and an aspect of the world reflects the non-dualist ontology of phenomenography. The relationship between the researcher and the aspect of the world under investigation is important for the researcher to carry out the research, since an understanding of the aspect of the world is a prerequisite to be able to interpret the statements made and to keep the research focused. However, any preconceptions or theories about the aspect of the world that the researcher has from their own experiences must be held back during the research (Sandberg, 1997). Withholding from one's preconceptions allows the researcher to be open to other ways of experiencing the phenomenon, and be able to present these other experiences as genuinely as possible.

3.3 Justification of the selection of phenomenography

There were three reasons this researcher chose phenomenography as the methodology for this research. The first was the result of comparison with two other qualitative research traditions, that is, grounded theory and phenomenology. The second was that the examination of my personal identity suggested that phenomenography fitted well with my ontological and epistemological positions and phenomenography helped me understand my lingering questions regarding possible cultural effect on science learning and metacognition. Phenomenography is an effective method to reveal the range, patterns, trends and complexity of students' metacognition including their conceptions of learning (Boulton-Lewis et al. 2004). Phenomenography is a way of learning about the different ways that learners think about and experience learning processes. The third reason to choose phenomenography is due to its educational function to enhance students' science learning. Phenomenography provides a way of asking each person to describe his or her learning experience, and so it is also educative in nature (Bowden, 2005; Marton, 1985).

3.3.1 Grounded theory, phenomenology, and phenomenography: a brief comparison

Grounded theory and phenomenology are two other research traditions that seek to analyze qualitative data. Grounded theory is often used to generate theory from gathered data, while phenomenology is often used when studying the participants' understanding of some phenomena (Creswell, 1998; 2003). Grounded theory tends to consider multiple views of the collected data, while phenomenology tries to identify themes and their structure. In contrast to grounded theory and phenomenology, phenomenographic analysis is comparative and uses multiple iterations of sorting and resorting to examine participant responses in search of emergent categories and diversity (Akerlind, 2005).

Richardson (1999) reviewed the concepts and methods of phenomenographic research and stated that the approaches that Marton and other researchers of phenomenography used to analyze data were very similar to those suggested by Glaser and Strauss (1967) for grounded theory. First of all, phenomenography is an empirical research tradition that underpins post hoc rationales and lacks detailed guidance on the analytic procedures, and thus some researchers seemed to have simply adopted the techniques of grounded theory in order to analyze transcripts of interviews (Richardson, 1999). Secondly, the idea that categories should emerge from data instead of being imposed on the data in advance was also found in grounded theory.

Grounded theory attempted to make qualitative research scientifically respectable by discovering theoretical concepts from the participants' accounts (Denzin,1988). When Glaser and Strauss (1967) talked about discovering theory from data, they implied that a set of social or psychological relationships existed objectively in the world, and were reflected in qualitative data. As discussed in section 3.2, phenomenography is based on an interpretivist paradigm which considers social reality as a product of meaningful interactions between participants and their social settings. Phenomenographers do not claim their categories to be a theory discovered, rather, their research results help understand how a group of people describe their experiences.

Phenomenography is often mistakenly considered as a variant of phenomenology. Phenomenography and phenomenology are two distinct research traditions. Although both phenomenology and phenomenography embrace the concept of life world and take experience as their objects, according to Marton and Booth (1997), phenomenology was a philosophical method that was "directed towards the pre-reflective level of consciousness" (Marton & Booth, 1997, pp. 116-117); whereas phenomenographers adopt an empirical orientation and study the experiences of others. Phenomenological research allows studying the experience of one individual; but phenomenography investigates and describes the experiences of a group of people who experience a particular phenomenon in qualitatively different ways (Barnard et al., 1999). In phenomenology an important dividing line is drawn between the pre-reflective experience and conceptual thought; but in phenomenography the structure and meaning of a phenomenon as experienced can be found both in pre-reflective experience and conceptual thought. Phenomenologists are more concerned with the richness of experience, the fullness of all the ways in which a person experiences and describes the phenomenon of interest, while phenomenographers are more interested to know the logical hierarchy of the outcome space (see section 3.5 for details) or efficient ways of experiencing the world (Svensson, 1997). A phenomenographic approach is chosen due to my interest in identifying and categorizing the variation and diversity of conceptions that may emerge from the responses of Mainland Chinese learners.

Larsson and Holmastrom (2007) conducted a study on anesthesiologists' understanding of work for the purpose of showing the differences between the phenomenographic and phenomenological approach. In their study, they used both approaches to analyze the same transcripts. The result of the phenomenographic study was four ways of understanding work: (a) monitoring and controlling the patient's vital functions; (b) guiding the patient safely through the operation; (c) serving patients, other doctors and nurses; (d) leading the operating theatre and team. The phenomenological analysis portrayed the essence of being an anesthesiologist: Carrying the responsibility for the patient's vital functions; always being alert, watching carefully over the patient's body, ready to act whenever the patient's life is in danger, however difficult the circumstances. Larsson and Holmastrom (2007) discussed the differences between the two approaches as illustrated in table 3.3.

Table 3.3 The Differences between Phenomenography and Phenomenology (adapted from Larsson and Holmastrom, 2007).

Phenomenography	Phenomenology
The aim is to describe variation in different ways of experiencing a phenomenon.	The aim is to clarify experiential foundations in the form of a singular essence.
The structure and meaning of a phenomenon as experienced can be found in pre-reflective and conceptual thought.	A division is claimed between pre-reflective experience and conceptual thought.
An emphasis on collective meaning.	An emphasis on individual experience.
A second-order perspective.	A first-order perspective.
Analysis leads to the identification of conceptions and outcome space.	Analysis leads to the identification of meaning units

Therefore, there are distinctions that can be made between phenomenography and phenomenology and the choice to employ phenomenography is made as it is most suitable option for this research.

3.3.2 Identity self-examination

Webb (1997) critiques the assumption of some researchers who employ phenomenography that they can be 'neutral foils' while analyzing their research data. He argues that researchers' certain experiences and certain theoretical beliefs might influence their data analysis and categorization. Webb calls for researchers to make their backgrounds and beliefs explicit so that readers know about the variables that may have potentially affected the study and its results. In addition, such self-examination may lead to additional insights into the data and may be more informative about the justification of the methodology. The identity of the researcher that may influence methodology and data analysis can be revealed by the answers to the questions of “who am I, and how am I?” The following is a brief reflection of this researcher in relation to these two questions.

I grew up in rural China where many old traditions and cultural values were well maintained and children were disciplined by their parents. I had an opinion that those of my university classmates who were brought up in cities were more selfish, less considerate, and less hardworking. My prejudice against city students did not fade, even though I worked and lived in big cities, until my city-born daughter gradually grew up with many merits. Although it is educationally wrong to polarize students based on their origins of birth, and my personal bias was solely from my personal experience, there exists strong evidence that in Mainland China urban and rural areas are culturally very different (e.g. Fuligni & Zhang, 2004; Sicular et al, 2007,; Zhao, 1999). I had another chance to experience differences of culture after I came to Canada as a Ph.D. student. The cultural differences I experienced were huge and sometimes things are considered quite the opposite to how they are viewed in China. The cultural shock and cultural difficulties I experienced enhanced my belief that ‘culture matters’. I came to consider and speculate on the idea that culture does not only mold our everyday lives, but also influences how science is learnt and how metacognition is involved and evident in science learning processes.

Before coming to Canada pursuing my PhD, my ontological belief was dialectic materialism, which is the core theory of Marxism and states that the world is both material and dialectic. With this philosophical thinking in my mind, it would be impossible for me to conduct this study that proposes that culture may influence metacognition and science learning. Dialectic materialism suggests that there is only one eternal and unconditional truth. In other words, science learning and metacognition should be the same all across the world. As a result of the political practice of one party and one-ism that permeates Chinese education, I always thought, as many people still think, that science is the objective reflection of how the material world works. My obstinate world view began to change after many rounds of clashes and conflicts when reading the work of Husserl, Heidegger, Kuhn, Latour, etc. Now I am comfortable with conceptions of relativism, multiple truths, multicultural science, and indigenous science. My ontological belief is consistent with the theoretical foundation of phenomenography; that a real world exists outside our minds but is experienced and conceived differently because of historical and cultural factors.

I was a student of science and then a science teacher for ten years in China where science classrooms were traditionally teacher-centered. I was a ‘good’ student who had no objection to the cramming format of teaching until I read about its issues. As a science teacher, I would try to avoid lecturing for the entire class and if I had to, I would try an alternate model of teaching called 启发教学(enlightening instruction), which originates from Confucius and focus on inspiring reasoning and understanding through questioning and discussion. In Mainland China where science education is mainly examination-driven, the teacher-centered format of instruction is effective in the sense of instructing students to obtain good scores. But I believe that reform of science education must be executed involving more autonomy and participation of students in the activities of inquiry and argumentation.

I had been a successful student of science from when I attended middle school to when I finished my undergraduate study of physical science. I did not know of the concept of metacognition, nor did I think that I had better strategies of learning science before I became a teacher. I guess that at that time I did not care how I learnt science because I did not have either the motivation or necessity to consciously consider it. I might think that my weak classmates were either not intelligent or diligent enough.

When I was a teacher of science I gradually realized that it was too narrow-minded to attribute failure of science learning to only factors of effort and intelligence. Many students simply did not know how to learn science. In other words, they were lost into 'nowhere' while being asked by me to border cross into the world and culture of school science. A second-year student of physics (grade 9) felt despair after his first year's failure and asked me for help. After three times of tutoring after class, he grasped the methods of learning physics and did well after that. Although I did not know the word of metacognition until I went back to graduate school majoring in general education in 2000, I taught my students the strategies to consciously control their study. Now I strongly believe that the key factors for successful science learning are metacognitive knowledge and metacognitive skills for controlling the learning processes.

3.3.3 The Educational function of the phenomenographic approach

Bowden (2005) explained that phenomenographic research mirrors what good teachers do in trying to understand what their students are doing in the process of learning. Teachers should know the multiple conceptions their students hold for a particular phenomenon in order to better instruct their students to develop conceptions that are consistent with those of experts. Marton (1986) maintained that a careful account of the different ways people think about phenomena may help uncover conditions that facilitate the transition from one way of thinking to a qualitatively better way of thinking. One possible benefit of phenomenographical research is that students may become conscious of contradictions in their own reasoning and become more open to alternative ideas as they reflect on their perceptions and understandings of their world experiences (Marton, 1986).

When I was interviewing the students in this study, they showed great willingness and readiness in participating in the interviews because they expected getting suggestions or help from a 'specialist' in education. After about one hour's conversation, all the participants showed satisfaction and delight. The students were happy to share their successful or bewildering experiences with me. By talking and reflecting their learning experiences, it was hoped that these students were more aware of the optimal ways of learning science.

In summary, after comparing phenomenography with other research traditions, examining my personal identity, and acknowledging the educational benefits of phenomenography, phenomenography was chosen to explore the answers to the research questions of this study. Phenomenography can reveal the metacognition of Mainland Chinese students, including their different conceptions and processes of science learning, and help understand the why and how such metacognition develops.

3.4 Data collection procedures

In this section, guidelines and procedures of collecting data are discussed. Firstly, the general data collection guidelines for phenomenography were reviewed, and then the detailed procedures, including the research setting, participation information, interview questions, and research ethics were discussed.

3.4.1 General data collection procedures of phenomenographic research

Phenomenographic studies attempt to discover the different ways in which people understand or experience certain phenomena. Data gathering in phenomenographic research is a process of discovery which concentrates on each individual as a separate case and a possibly unique world. Open and deep interviews are usually the best method to explore an individual's life-world and reveal his/her understanding or conception of a particular phenomenon (Marton & Booth, 1997). Open interviews have no definite structure and few, if any predetermined questions. Researchers should be prepared to expect to follow any 'unexpected' lines of reasoning as some of departures may lead to fruitful reflections (Marton, 1994).

The research subjects should be identified in the planning stage of the research due to their relationship with the specific aspect of the world under consideration and also be selected to obtain as much variation in their experiences as possible (Bowden

2000). In this study, the research subjects consisted of junior and senior middle school science students, the details of which are outlined in the next section.

In the interviews, both the initial and follow up questions should function for interviewees to reflect, elaborate and reveal their ways of experiencing learning, the processes, strategies and skills they employ and their origins. The follow up questions are extracted from what the interviewee has revealed, and not formed through predetermined ideas from the interviewer. Understanding of participants' views of their experience/s is achieved through a hermeneutic circle, in which the researcher moves back and forth from initial questions to follow-up questions and vice versa. The hermeneutic circle is the circular form of interpretation shared between persons in their interactions (Guba and Lincoln, 1989; Heidegger, 1927/1962). The hermeneutic circle continues and spirals until the prejudices (or preconceptions) are filtered out through the interplay of the whole and the parts of the research questions.

The experiences and understandings are jointly constituted by interviewer and interviewee (Marton, 1994). These experiences and understandings are not necessarily there prior to the interview, ready to be read off. They are the subjects' awareness from being un-reflected to being reflected, that is, from being implicit and 'unthematized' to being explicit and 'thematized' (Marton, 1994). A 'good' interview is considered to be the mixture of the process of reflection of the participant on his or her experiences and the interviewer's interpretations of the account of the experiences. For the interview to be an authentic dialogue or conversation that encourages the interviewees to fully reflect on their experiences of learning science, judgmental comments should never be made in the interview since they may interfere with that which is to be reflected (Bowden 2005).

An important aspect of the phenomenographic interview is the use of empathy to ensure acute sensitivity to the individuality of conceptions of the world (Ashworth and Lucas 2000). Being empathetic requires ‘bracketing’ the interviewer’s own assumptions, beliefs, theories, personal knowledge, and earlier research findings. Although the interviewer’s own life-world experiences enable him/her to interpret what is said, he/she should focus on the experiences of the participant. The temptation to marginalize the ‘erroneous’ views and factual claims of the interviewees should be restrained. On the contrary, researchers who adopt an attitude of empathy would find such views and factual claims of immense interest (Bowden 2005).

The researcher employed the method of a semi-structured interview that allowed the participants to bring up new ideas while attending to their conceptions of learning science. The suggestions of Marton (1994) and Bowden (2005) were adopted in taking the interviews. Specifically, the researcher was empathic and non-judgmental so that the participants could freely reflect and describe their learning experiences.

3.4.2 Research setting, participants and interviews

3.4.2.1 Research Locale

This study focuses on Mainland Chinese learners’ metacognition, of which their conceptions of learning science form part, and how they came to such understandings. Hence the research locale is Mainland Chinese junior and senior middle schools. The ages of students in these schools would range from 13 to 19 years. This is the equivalent of junior and senior high schools in Canada. As mentioned earlier, Taiwan, Hong Kong, Singapore, and overseas Chinese communities are at least in some ways, historically, politically, and economically different from Mainland China. It is possible that Mainland Chinese learners' views of science learning processes, their conceptions of learning, and their origins of these varies from those from that of ethnic Chinese in other countries or territories due to cultural differences. As previously explained (section 2.2), studies of Mainland Chinese learners' metacognition, including their conceptions and processes of learning science have not been found in the literature. This study sets a foundation for future research in this area.

3.4.2.2 Sampling methods

Purposeful sampling was employed in this study. Purposeful sampling is a type of non-probability sampling in which one selects the units to be observed on the basis of one's own judgment about which individuals will be the most useful or representative (Babbie, 2005). Purposeful sampling is not designed to achieve population validity, but the intent is to achieve in-depth understanding of selected individuals (Gall et al., 2003). Although purposeful sampling is used mainly to seek maximum information, the selected group should represent the character of the population in a meaningful way (Wiseman, 1999).

In order for the samples to be representative, the author went to different schools in different cities of two provinces in China. In Shijiazhuang, four different sorts of schools were chosen. One school was a top elite senior middle school and one school was a top elite junior middle school. The other two schools were common junior and senior middle schools. Apart from choosing city schools, three middle schools in the countryside were chosen. To ensure that the selected participants represent the character of Mainland Chinese students, a broad cross-section of students were chosen, including both male and female students, and academically strong and weak students.

3.4.2.3 Participants

The literature suggests that different groups of learners may have different conceptions of learning (Eklund-Myrskog, 2004; Purdie et al., 1996; Tynjälä, 1997). In order to develop a comprehensive and credible view of how Mainland Chinese learners consider they learn science and how Chinese culture may influence their learning and metacognition, the participants included Mainland Chinese learners who were learning science in secondary schools. Specifically, the research participants consisted of junior middle school students and senior middle school students. Although elementary students in Mainland China learn science, both the content and class hours are very limited (Lin, 2010). Gao and Zheng (2015) showed that elementary students have conceptions of science learning, but the variability in the amount of instruction across the PRC makes it potentially more likely that the conceptions will be affected by the amount of instruction. The potential of this problem declines in the upper levels when high stakes exams often compel that schools spend time on science instruction. Thus elementary school students were not included for this research. College students, science teachers, science researchers, and professors of science education would be good participation groups for a systematic study of Chinese learners, but due to time constraints and workloads they were excluded from this research. Furthermore, focusing on participants from middle schools may make it easier to reveal and make sense of students' metacognition and the deep and potentially diverse meanings and unique conceptions of learning science they may report.

The number of participants engaged in phenomenographical research studies is determined by when what is referred to as the theme saturation is achieved. Sample size in phenomenographic research is most often small due to the intensive nature of analyzing the responses. A sample with 15 to 20 participants is often considered to be large enough to reveal most of the possible viewpoints and allow a defensible interpretation (Trigwell, 2000). Some phenomenographic studies have smaller sample sizes of between 10 to 15 (Bowden, 2005). The sample sizes reflected in phenomenographic studies are consistent with other qualitative studies which involve much smaller sample sizes than in quantitative research (Strauss and Corbin, 1998).

The author conducted 96 interviews from May 2011 to July 2011 in 11 schools of 7 cities in Heibei and Shandong provinces of China. The locale, school, grade, and gender of the participants are listed in table 3.4. To protect the privacy of the participants, pseudonyms were used both for the participants and their schools.

Table 3.4. Information of participants

Province	City/county	School	Grade	Male	Female
Hebei	Shijiazhuang	Middle School A	11 & 12	6	6
		Middle School B	8 & 9	6	6
		Middle School C	11	3	3
		Middle School D	10	3	3
	Xinji	Middle School E	12	3	3
		Middle School F	8 & 9	6	6
	Xingtai	Middle School G	9	2	2
	Boye	Middle School H	10 &11	4	4
Shandong	Liaocheng	Middle School I	10, 11 & 12	9	10
	Qingdao	Middle School J	10 & 11	6	5

3.4.2.4 Interview procedures

Interviews were conducted openly, deeply, and thoroughly as previously suggested. Interview questions were adopted from Thomas and McRobbie (2001) and from Thomas (2003, 2006b). These questions provided a structure and framework that focused on the two main research questions: what Mainland Chinese learners report as their metacognition, including their conceptions of learning science and how Mainland Chinese science learners report that Chinese culture influences their conceptions of science learning. The questions asked included:

- Tell me about how you think you learn science.
  请讲讲你认为你自己是如何学习科学的。
- Do you consider yourself as a successful science learner? Why or why not?
  你觉得自己学习科学成功吗？为什么这么认为？
- What procedures and/or strategies do you use to learn science?
  你学习科学采取那些步骤？
- What happens inside your head when you learn science?

你在学习科学的时候脑子里面在想什么

- Can you remember learning science in any way different than this previously?
  你记得过去学习科学的时候有什么和现在不一样吗？
- Can you remember if there was/were one or more experiences in which people spoke to you about how you might or should learn science?
  你记得有什么人给你讲过如何学习科学吗？
- What sort of qualities do you think it is necessary to possess to be a good science learner?
  你认为要学好科学需要具备什么样的品质？
- Why do you think these qualities are necessary?
  你为什么认为这些品质是学好科学所必须的？
- How did you come to learn about or consider these qualities?
  你是如何知道这些品质的？
- Can you remember specific people or events that made you aware that these qualities are necessary?
  你记得有什么人或者什么事件让你觉察出这些品质的重要性？

Answers to such interview questions revealed how Chinese learners perceived science learning, how they described, felt, and experienced science learning, and how Chinese culture may or may not have influenced their learning processes and metacognition. The questions about the sources of the conceptions, and the follow-up questions that could not necessarily be predicted as they were contingent on answers to these ‘foundation’ questions, provided data for the aim of analyzing how the conceptions of science and metacognition might be shaped by cultural factors. Such questions have been used successfully before to garner information from students regarding their learning processes and metacognition (e.g. Thomas, 2006, 2003, 2012; Thomas & McRobbie, 2001). As noted above, it was not feasible to specify all research questions in a predetermined manner. Some flexibility was applied in interviews to be able to explore previously unconsidered details and ideas that emerged as interviews proceeded. Some of the above questions were elaborated on as the research proceeded. For example, some students used idioms, proverbs, and sayings when they talked about why and how they learnt science. I realized that these idioms, proverbs, and sayings contained traditional values that the speaker believed in. Thus I intentionally asked for the information with the questions like: do you have motto, or a saying that you used to inspire your learning?

3.4.2.5 Research Ethics

Research thesis proposals including information of participants, research question, and research procedures were submitted to and approved by the university's committee of research ethics to ensure that the research was valuable and educational.

Prior to any questioning, participants were given the opportunity to read instructions regarding their informed consent. All forms were originally written in English and then translated to Chinese (see Appendix 1). Participants were advised that transcripts from their interviews would not be disclosed and they had the right to withdraw without penalty. Informed consent was gained before an interview started.

To facilitate thorough and honest responses, questioning was done in a relaxed, conversational manner in their native Chinese language in places that were convenient for the participants. The commonly used place was rooms provided by the schools, in which there were no observers or disruptions. Audio recording was used for the purpose of uninterrupted interview and transcription.

3.5 Data analysis

3.5.1 Transcripts

Phenomenographers believe that different people may experience a concept or phenomenon quite differently (Marton, 1994; Åkerlind, 2005). It is proposed that great variation exists among science learners regarding their experiences and conceptions of learning science. A limited number of categories may be possible to represent the variation of Chinese learners' metacognition including their conceptions of learning science and the origins of their self-knowledge and conceptions, but prior to this study, little of any research has been done in this area. The variation can be ascertained by analyzing the transcriptions of the interviews which is the focus of phenomenographic analysis (Åkerlind, 2005). The set of transcripts represent a 'snapshot' of a selection of the experiences of Chinese learners' view of their science learning processes and metacognition and the origins of those phenomena.

In this study both the participants and the researcher speak, read, and write Chinese. Research questions and research protocols were translated into Chinese. To ensure the English and Chinese versions conceptually equivalent, a series of translations and back translations as outlined in Thomas (2003) and Larkin et al. (2007) were undertaken. The translation of the interview questions were verified by colleagues who know both languages well. The interviews were conducted in Chinese to provide an atmosphere of ease and ensure smooth communication. After each interview, the recorded conversation was translated into English by the researcher. A translator with knowledge of Chinese and English proofread and confirmed the translated transcripts. In order for the transcripts to fully reflect the conceptions of participants, the transcripts were translated back into Chinese and be presented to the interviewees by email for accuracy examination, i.e. member-checking. The results of data analysis were in English and Chinese as well. Two bilingual peers with expertise in education and Chinese culture, one PhD student in education and one PhD student in business, reviewed the outcome space obtained from the transcripts, and their feedback assisted the quality of the data analysis.

3.5.2 The goals of data analysis

Marton (1981) stated that the goal of phenomenography is to describe, analyze and understand experience. Marton stated:

> The kind of research we wish to argue for is complementary to other kinds of research. It is research which aims at description, analysis, and understanding of experiences; that is, research which is directed towards experiential description. Such an approach points to a relatively distinct field of inquiry which we would like to label phenomenography. (Marton, 1981, p. 185)

Phenomenographic studies are qualitative, describing variation in ways of experiencing aspects of the world. Phenomenographic studies take a second order perspective, that is, they investigate and make statements about other people's experiences of the world. Data analysis is explorative in nature, which is brought on by the need to delimit the various ways the population experiences the phenomenon. Phenomenographic data analysis is variously considered as a process of discovery, construction or constitution, or in some cases, for instance Bruce (1997), a combination of discovery and construction.

The focus of a phenomenographic study is on the variety of conceptions within a group. Phenomenographers describe the variation in conceptions across the group and do not focus specifically on the commonalities in group members' conceptions. They focus on the variation in the conceptions of a particular group and not on individuals' conceptions. As such, detailed descriptions of the individuals in the group are not typically included in phenomenographic studies. In effect, the overall outcome space of the study represents a continuum of the description of the learning experience. It is important to note that not any one individual's conceptions constitutes the outcome space in this phenomenographic study, but rather, it is an amalgam of conceptions across the entire group studied (Richardson, 1999).

The process is an explorative dialogue between participants and interviewer. The experiences and understandings are jointly constituted by interviewer and interviewees. These experiences and understandings are neither there prior to the interview, ready to be "read off," nor are they only situational social constructions. They are aspects of the subject's awareness that change from being un-reflected to being reflected (Marton 1994, p. 4427).

The phenomenographic data analysis is both a process of discovery and a process of construction from transcripts (Bruce 2002, Hasselgren & Beach, 1997). In this sense, phenomenographic analysis is an inductive bottom-up way of obtaining results from data, rather than a top-down way of constructing then testing an hypothesis (Green 2005). The analysis process started by the researcher's reading and re-reading all the transcripts searching for similarities and differences (Green 2005). Transcripts with similar meanings were grouped, and a description of each category was written with illustrative quotations from the transcripts. These descriptions formed the preliminary categories for the set of transcripts. In order for the categories to be sufficiently descriptive and indicative of the interview data, iterative modification, addition, or deletion of the category descriptions were performed. This process of modification and data review continued until the modified categories were consistent with the interview data and the whole system of meanings was stabilized.

3.5.3 The outcome space of a phenomenographic study

This section reviews the literature of phenomenographic study with regards to the definition of the outcome space and the structure of the outcome space.

1) The definition of the outcome space

Once a system of categories had been defined, the researcher attempted to discover how if at all the individual categories related to each other. Marton and Booth (1997) described the set of related categories of description of the phenomenon as the outcome space of the phenomenographic study. The categories of description represent the researcher's analysis and description of variation in a group of individual's accounts of ways of experiencing the phenomenon. The outcome space documents the relationship between the categories of description. The relationship between the individual categories could not be found unless a deep and full understanding of what has been meant is obtained (Marton, 1994). A set of categories of description needs to satisfy three criteria according to Marton and Booth (1997).

> 1). Each category of description should denote a distinctly different aspect of the experience of the phenomenon.
> 2). A logical relationship, commonly hierarchical, should exist between the different categories.
> 3). The outcome space should consist of the minimum number of different categories required to describe the critical variation in experience in the population of interest.

2) The outcome space should be hierarchical

Samuelowicz and Bain (1992) claimed that studies that do not focus on producing conceptions that are hierarchically related cannot be described as phenomenographic. Reed (2006) argued that it was not enough simply to determine a set of qualitatively different categories to have a phenomenographic result.

> In fact, it is not so much the categories per se that are important, but rather the differences and similarities that serve to link and differentiate one category from another, i.e. the structure and meaning related to the categories. (Reed, 2006, p 6)

Alsop and Tompsett (2006) argued that phenomenography distinguishes itself from other approaches (e.g. action research, discourse analysis, ethnomethodology, grounded theory, etc.) that share the same interest in describing the ways in which individuals can understand their experience of a phenomenon through the structure of the outcome space as a hierarchy. In other words, Alsop and Tompsett (2006) claimed that a hierarchical structure of the outcome space separated phenomenography from other research approaches.

Richardson (1999) summarized the key findings of phenomenographic studies in educational settings, and maintained that the different conceptions of learning represented a developmental hierarchy:

1) When different students engage with an academic text, their attempts to recall the gist of the text define a hierarchy of different learning outcomes.
2) Students exhibit qualitatively different approaches to studying that depend upon their perceptions of the learning task and their conceptions of themselves as learners.
3) Different students exhibit a number of different conceptions of learning that appear to represent a developmental hierarchy partially mediated by participation in higher education.

Central to the outcome space is the typical hierarchy in which each successive category being a more complex way of experiencing the phenomenon under investigation (Marton and Booth, 1997). In other words, the hierarchy in the categories of description is based on the complexity of way of experiencing the phenomenon. Akerlind (2002) used the term ‘comprehensive’ to define a hierarchy in which a lower category is less comprehensive than a higher category. Similar to Marton and Booth’s ‘inclusive hierarchy’ (1997), Ashwin (2005) applied the term ‘nested hierarchy’ to describe the inclusiveness of higher categories over the lower ones. To be specific, the more complex category includes the simpler category, the more complex category is ordered hierarchically above the simpler.

Saljo’s and also Marton’s first three categories are often regarded as being quantitative or reproductive, while Saljo’s last and Marton’s last three categories are often regarded as being qualitative or transformative. Marton (1981) claimed that more complex experiences reflect a higher level, or a more ‘authorized’ view of the world, or more advanced cultural development (p. 184).

Mann (2009) maintained that a strong emphasis on looking for structure in the phenomenographic analysis process is vital because the focus on structure is an epistemological underpinning of phenomenography, increases the potential for practical applications from the research, and provides a simultaneous focus on variation and commonality.

As for when to analyze the structural relationship, some researchers (e.g., Ashworth and Lucas 2000, Bowden 2005) emphasize not analyzing the structural relationships between the categories until the categories themselves are finalized, as it may introduce the researcher's relationship with the phenomenon into the categories. Others (e.g., Åkerlind 2005) argue that focusing on the structure of the categories and outcome space too late could lead to the meaning and structure not being adequately co-constituted in the final outcome space.

3) The outcome space is NOT necessarily hierarchical

Following Säljö's study, over two decades of research has led to the now commonly accepted view that there exists a hierarchical set of conceptions of learning that show a developmental trend (in the sense that conceptions at the upper levels reflect an interpretative/constructivist view of learning as opposed to one in which learning is acquired and reproduced). In other words, these researchers posited a 'stage' theory of intellectual development (cf. Piaget, 1977). However, some researchers have contended that the outcome space is not necessarily hierarchical.

In Nepalese students, Watkins and Regmi (1992) found that (in some cases, at least) a conception of learning as changing as a person had been induced by local cultural and religious traditions and did not represent the most sophisticated level in a developmental hierarchy (also discussed by Dahlin & Regmi, 1997).

Marton, Dall'Alba, and Tse (1996) found that memorization and understanding were intertwined for Chinese participants and concluded that memorization was not necessarily lower than understanding in the Chinese culture. In addition, for some participants, understanding was taken to be the sum of all the pieces of knowledge that are remembered or memorized (p. 4). In other words, understanding was interpreted as the sum of the first three of the six conceptions for the Chinese participants (Marton et.al., 1993).

Marton, Watkins, and Tang (1997) introduced an additional perspective to the initial six categories. When individuals are asked about their conceptions of learning they tend to alternate between different temporal facets. For example in a narrow sense, learning is seen as acquiring skills and capabilities; on the other hand, the notion of acquiring knowledge at times focuses on application of knowledge to further refine one's understanding, which is considered a deep approach. Thus it would be inadequate to order 'acquiring' in a lower level than 'applying'. Marton et al. proposed a form of learning called "knowing." Knowing is when individuals know they have acquired the necessary knowledge and also can successfully apply the knowledge.

Tynjala (1997) studied Finnish students' conception of learning and identified seven different conceptions. Tynjala observed that these conceptions did not define a clear hierarchy. Moreover, many of the students described more than one conception. Other researchers (e.g., Purdie and Hattie, 2002) also claimed that many students endorsed more than one conception.

In summary, as Akerlind (2005) pointed out, “the structure of an outcome space need not always take the form of a linear hierarchy of inclusiveness; branching structures or hierarchies are also a possibility”. This research did not find a hierarchical structure, and the outcome space appeared as a holistic structure, which is discussed in section 4.3.

3.5.4 Examples of analysis for past studies

One example of phenomenographic data analysis is provided by Brown et al. (2006) who studied 19 college science professors for their views of inquiry in college science classrooms. The professors were asked a series of questions for an hour about their beliefs and practices in laboratory instruction, including their best and worst experiences as a laboratory instructor and their experiences with and meanings for inquiry. The researchers applied an iterative data analysis process to determine the phenomenographic categories of description and their internal consistency. First, they analyzed a subset of interviews and obtained a set of analysis codes. Then they applied the codes to a set of interviews using some qualitative research analysis software. The researchers created profiles for each participant in order to provide context in which to understand the views of individual faculty members. After the coding and profiles were complete, they met to determine the patterns and themes across the data set and generated a set of tentative assertions. Finally, they returned to the data to test the claims and find supporting and/or non-supporting evidence. Based on the data set, Brown et al. (2006) generated four assertions that described the major themes common among the participants' views of inquiry. They did not discuss the relationship between these themes, i.e., they did not propose the outcome space of their study.

Ebenezer and Fraser (2001) also illustrated the process of data analysis of phenomenographic research. They interviewed twenty-one first-year chemical engineering students for their conceptions of the energy changes taking place in dissolution. The analysis of the transcripts was conducted in four steps. First, a matrix is used to organize each student's conceptions for each task. Then descriptive categories of energy in solution processes for each task were generated from the matrix of students' conceptions. Next, students' conceptions were slotted into each descriptive category. Finally, a matrix was made to show the consistency and/or the variations of each student's conception across tasks and within a task.

3.5.5 Procedures of data analysis of this study

In this study, multiple iterations of analysis were performed to understand and describe Mainland Chinese students' conceptions of learning and their origins. The first iteration of analysis focused on the common themes across the participants. Data from the notes, interviews, and transcriptions were repetitively reviewed, coded, categorized, and studied for content and meaning until patterns emerged. For example, by reviewing the notes and transcribes, ‘reviewing the notebook of wrongly-solved problems’ was repeatedly mentioned when students talked about how they learnt science. Then the researcher intentionally checked other transcripts and examined that if most students would regard ‘reviewing the wrongly solved problems’ as an effective way to learn science. After finding out that most students talked about ‘reviewing wrongly solved problems’, it became a theme of this study.

Then the themes were organized into different categories of metacognitive knowledge, that is, their conceptions of what learning science is and how they learn science. For example, ‘reviewing wrongly solved problems,’ along with other themes such as ‘improving abilities’ and ‘persevering in solving problems’, was organized into the category of ‘doing problems’.

The origins of Mainland Chinese students’ metacognitive knowledge are conceptions of how they learnt to learn science. The themes of origins were analyzed into different categories according to the influences of parents, teachers, peers and traditional values.

6 pieces of A0 size paper were used as part of the process to integrate the themes (see Appendix 2 for pictures). 30 students were coded as Student plus numbers, such as Student 1 or Student 2. For each student, their ideas were coded into short sentence or phrases such as “I need to remember the formulas” or “patterns of problems” under different preliminary headings such as “strategies” or “control”.

The second iteration of analysis was carried out by using Nvivo, a qualitative data analysis computer software package. NVivo is intended to help organize and analyze non-numerical or unstructured data, instead of trying to quantify the data. More specifically, Nvivo does not quantify students' conceptions of learning. Rather, Nvivo provided a way to ensure the qualitative analysis to be comprehensive and complete. Nvivo helped to look for patterns and themes of the 96 interviews by creating nodes (coded themes), which were followed by collections of references (quotes). The nodes were organized hierarchically into a tree structure, in which general categories represented by parent nodes were on top and specific ideas/themes represented by child and sub-child nodes were underneath (see Appendix 3).

The third iteration of data analysis organized and interpreted the data by individual students, who may be representative and exemplar as some different groups of Mainland Chinese students with different understanding of science learning. Each student's learning experience is a unique world worthy to be appreciated. Describing and analyzing their lived experiences in learning science helps to develop a better idea how and why Chinese students learn science in the way as it is.

The third iteration of data analysis can be categorized as case study, although "there is little consensus on what constitutes a case study or how this type of research is done" (Merriam, 1998, p. 26). Gerring (2004) defined case study as "an intensive study of a single unit for the purpose of understanding a larger class of (similar) units" (p. 341). Thomas (2011) defined case study as "analyses of persons, events, decisions, periods, projects, policies, institutions, or other systems that are studied holistically by one or more method. The case that is the subject of the inquiry will be an instance of a class of phenomena that provides an analytical frame - an object - within which the study is conducted and which the case illuminates and explicates" (p.513).

The purpose of a case study can be explanatory or exploratory (Yin, 2003), intrinsic or instrumental (Stake, 2005). Case study is "the preferred strategy when 'how' or 'why' questions are being posed" (Yin, 2009, p. 1) and it improves our understanding of the world of education by "bringing to life what goes on" (Yin, 2005, p.xiv). Merriam (1998) stated that the case study "focuses on holistic description and explanation" (p. 29) and is a way to gain understanding and in-depth insights into participants' lived experiences.

Stake (2005) stated that "case study is not a methodological choice but a choice of what is to be studied" (p. 443). Stake proposed that researchers of case study should concentrate on a case or cases and study it/them by whatever methods they choose, either analytically or holistically, entirely by repeated measures or hermeneutically, organically or culturally, or by mixed methods.

In this research, case study is applied as a supplementary approach that helps with the main methodology, phenomenography, to understand and describe Mainland Chinese students' conceptions of learning and their origins. The practice of using case study as a supplementary approach is common in the literature of educational research. For example, Thomas (1999b) applied classroom intervention, participant observation, constructivism metaphor, and case study to investigate students' change in metacognition including their conceptions of learning. Some researchers of phenomenography, such as Trigwell (2000), also utilized case study in their research as a supplementary approach.

The researcher of this study hopes to reach two goals by employing the case study approach. One goal is to increase understanding and appreciation of individual students' unique experiences of learning science. The case study describes comprehensively the 'what' aspect, 'how' aspect, and 'why' aspects of each individual student's conceptions of learning science in a 'longitudinal' way, i.e., to report all the categories of conceptions of learning of one student, compared with the 'transverse' analysis that focused on common themes across all the participants. The other goal of applying case study in this research is to create an effective triangulation process in the analysis and interpretation of data (Mills, 2000). The categories obtained from the 'transverse' analysis across all the participants and the relationship of the categories, the outcome space, are to be triangulated, verified, and illustrated by the intense scrutiny of the conceptions of learning of individual students.

3.6 Credibility of the research

The traditional criteria of quality in quantitative research, that is, validity and reliability, are not applicable for judging the credibility of qualitative research since the two bipolar research paradigms have different objectives and approaches (Glaser and Strauss, 1967; Thomas, 1999b, 2003, 2006a). Quantitative researchers seek causal determination, prediction, and generalization of findings by means of experimentation and quantitative measurement; while qualitative researchers aspire for illumination, understanding, and extrapolation to similar situations by using a naturalistic approach in context-specific settings. The criteria of judgment of qualitative research should be based on the detailed elements of the actual strategies used for collecting, coding, analyzing, and presenting data (Glaser and Strauss, 1967).

For phenomenographic research, the justification for presenting the outcome space and other findings as credible and trustworthy lies in a full and open account of the study's method and results (Cope, 2004). Specifically, the following requirements are expected for the credibility of a phenomenographic study:

- The researcher's background and the characteristics of the participants should be clearly stated so that readers of the study will know the context within which the analysis took place.
- The design of interview questions should be consistent with research questions and help establish critical variation in a group of participants' ways of experiencing a phenomenon.
- The strategies taken to collect unbiased data should be included and the data analysis method be detailed.
- Categories of description should be fully described, entirely supported by transcripts, and adequately illustrated with quotes (Cope, 2004).

The main issue of credibility of a phenomenographic study is making explicit the relationship between the data obtained from interviews and the categories for describing the ways in which people experience a certain phenomenon (Ornek, 2008). The relationship will determine the quality of the developed categories. Marton and Booth (1997) put forward three criteria for judging the quality of the categories of description developed in a phenomenographic study: 1). The individual categories should tell something distinct about a particular way of experiencing the aspect of the world under investigation; 2). The categories have to stand in a logical relationship with one another; 3). The system should be parsimonious for capturing the critical variation/s in the data. This study attended to these criteria, as will be explained in the result section.

In quantitative research reliability refers to the replicability of results. It might be difficult for different researchers of phenomenography to report the same outcome space for the same study in the same context, since the open and explorative nature of data collection and the interpretative nature of data analysis might cause the method applied by different researchers to possibly vary (Booth, 1997). To ensure the rigor of phenomenographic research approaches, 'interjudge reliability' or 'interjudge communicability' was proposed by Martin et al., (1992) and Trigwell (2000) as a test of the reliability of the description of an outcome space. Interjudge reliability is tested by multiple researchers within or outside the study classifying independently the interview transcripts against the categories of description (Guba & Linconln, 1989). The objective of the reliability check is to test whether other researchers can obtain the categories of description in the data (Cope, 2004). The reliability of an outcome space is claimed if an agreement of 80 to 90% can be reached among the researchers' classifications (Saljo, 1987). Although there are voices of criticism of any 'reliability' in qualitative research (e.g. Guba & Linconln, 1989; Sandberg, 1997), interjudge reliability provides one way of triangulating against interpretation bias.

In this study, peer debriefing was used as a way to increase inter-judge reliability (Guba and Lincoln, 1989). Peer researchers, science teachers, and friends were invited into extended and extensive discussions about findings, conclusions, tentative analyses. Two PhD students in the faculty of education, and one PhD student in business administration helped me to verify translations of transcripts and discussed the findings. The varied interpretations on same data from people with different backgrounds helped the researcher triangulate against his prejudice and preconceptions so that the categories developed met the criteria of phenomenographic research.

3.7 Summary

In this chapter the methodology employed in this research, that is, phenomenography, including its history, its theoretical foundations, and the justification of using this approach to explore the answers to the research questions has been outlined and discussed. The research procedures have been outlined with a description of the research setting, the information of participants, interview methods, and specific interview questions. Data analysis protocols and precautions have been addressed to ensure credibility, trustworthiness, and quality of the research.

Chapter 4 Results

4.1 Introduction

The goal of this study is to understand and describe Chinese students' metacognition including their conceptions of learning science and the origins of their conceptions and science learning processes. As discussed in the literature review (see section 2.5.4), metacognitive knowledge and conceptions of learning are two overlapping constructs and, in the context of learning science, the two constructs are congruent and thus used interchangeably in this study.

Phenomenography requires the researcher to bracket his/her assumptions, beliefs, theories and earlier research findings from the literature. All categories of the outcome space should come from the data instead of being imposed with reference to existing theories and constructs. It would be against the essence and spirit of the methodology if the framework of metacognition or conceptions was used in such a way as to dominate the data analysis. The focus of phenomenography is to find out the themes and categories that reflect the various ways of experiencing a phenomenon, in this study, experiencing science learning, rather than to fit a ready-found category into some framework. In other words, the existing frameworks of metacognition and phenomenography play the function of facilitating the analysis process and development of categories. As pointed out in section 2.4.2, researchers of phenomenography do not report their results being composed of the 'what' and 'how' aspects, or 'referential' and 'structural' aspects, since these aspects are intertwined closely in their conceptions of learning and difficult to separate. What they report are the categories of the conceptions of learning and the outcome space, i.e., the logical relationship between these categories.

After multiple iterations of data analysis (see section 3.5), seven categories of conceptions of learning were developed, and are discussed in detail in section 4.2. Usually the outcome space of phenomenographic research is hierarchical, but this study proposes a holistic structure, in which each category has an equivalent status with the others. In other words, no category is dominant over another. The structure being holistic also implies that a student has a holistic view about learning science, i.e., the student may perceive of science learning as consisting of all the seven categories. When students report their views about learning science, they may mention all the categories, or just some of the categories. Thus readers may expect to see a particular name appear frequently in all sections of these results.

This chapter consists of four sections. The first section, 4.1, introduces the contents of this chapter. The second section, 4.2, presents the seven categories of Mainland Chinese students' conceptions of learning science. The third section, 4.3, presents the outcome space, i.e., the relationship among the seven categories. The fourth section, 4.4, presents a case study in which two students' conceptions of learning science are scrutinized. The origins of students' conceptions of learning are discussed in chapter 5.

4.2. Mainland Chinese students' conceptions of learning science

Mainland Chinese students perceive and experience science learning in different ways. They possess varying knowledge about what science learning is, how and why they should engage in science learning. Seven categories of conceptions of learning, and subcategories under each category, emerged from the phenomenographic analysis. The students in this study suggested that learning science in mainland China is regarded as: 1) listening to teacher; 2) attending to exams; 3) memorizing; 4) understanding; 5) doing problems; 6) engaging in hard work; 7) improving oneself.

A conception of learning is a structure composed of 'what', 'how' and 'why' aspects. Each category of conceptions of learning is a statement about what learning science is, how and why science learning should be engaged. When students in this study made a statement about their understanding of what learning science is, they usually also shared their views about how they engaged in science learning and why they did so in the way they suggested. Thus each category of conception of learning is a system of the 'what', 'how' and 'why' aspects, which are integrated together and difficult to separate. The intertwinement of the three aspects can be observed from the quotes from the participants, which are exemplars illustrating one particular conception of a group of students within the cohort of Mainland Chinese students.

In the following, the seven categories of conceptions of learning, with their subcategories respectively, are discussed in detail. Under the category and subcategories, a brief introduction of the category is provided. After the introduction of every category, a diagram of the structure of the category is presented, illustrating the sophisticated meaning of the conception, and providing the rich variety of how students in this study perceived and engaged science learning as reported.

4.2.1 Category one: Listening to the teacher

Listening to the teacher was found to carry two interrelated meanings. One was that students should be attentive to the explanations and detail of the science content that the teacher was presenting. The other was that students should obey their teacher in all aspects of their learning processes, such as what to learn, how to learn, when and where to learn. Listening to the teacher (上课认真听讲) was the predominate statement about science learning for the participants in this study. However their understandings of why they should listen to teacher, how they should listen to teacher, and when they should listen to teacher varied. Three subcategories were identified: following the teacher unquestioningly, actively thinking while listening, and taking initiatives while listening to the teacher. Figure 4.1 offers a visual representation of the structure of the category.

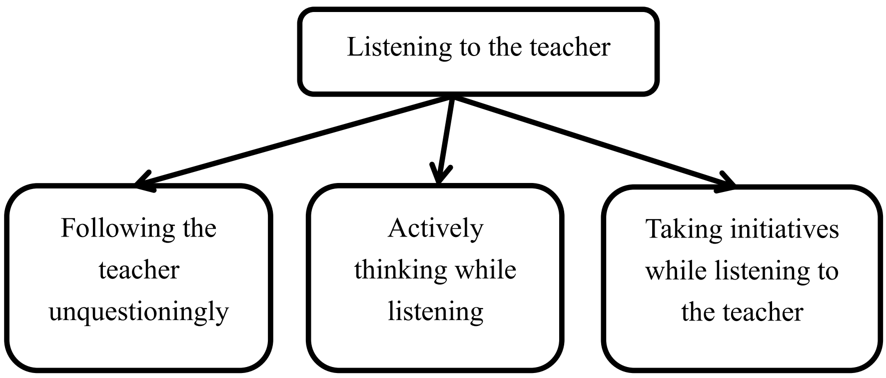

Figure 4.1 Structure of ‘Listening to teacher’

4.2.1.1 Listening to the teacher as following the teacher unquestioningly

To follow the teacher unquestioningly meant to be attentive, obedient, and respectful to the teacher without reservation. It was a common statement of the students in this study that they paid attention to listen to their teacher attentively, and noted down important content and examples. Shi was such a student who attributed his good scores to being obedient.

> I am obedient to my teacher. I will [try to] remember what my teacher emphasizes... I mainly follow my teacher. I do the problems only assigned by my teacher...I do well in understanding the basic knowledge that my teacher emphasized.

Another student, Shuo, expressed similar ideas. When asked how he learnt science, he claimed: "I mainly learn by following the prescribed order (按部就班). I usually follow my teachers and do my homework as required." Shuo's statement suggests he believed that to learn science he needed to obey his teachers and do what was required.

As for the reason why students considered that they should follow their teachers unquestioningly, student Cai's statement is typical; "In class you are certain to listen to the teacher attentively (it means that Cai thought it was unquestioning that students would listen to their teachers)." These students suggested that there was no need to question why they should listen to teacher. In a way, to follow their teacher is like abiding to natural laws. Listening to teacher had become an automatic behavior and an essential part of what learning is. For example, Wen claimed:

> To listen to teacher is my utmost priority. No matter what happened, no

> matter how well I have known the knowledge, no matter if I want to or I do not want to, I have to listen to my teacher, with my heart and soul.

Students provided reasons to explain why listening to teacher was a priority for them. The first reason was the institutional authority of teachers and the corresponding respect and awe they draw from students. Student Hui said: "Generally, I listen to the teacher from below the platform while my teacher is lecturing up on the platform." The second reason they provided was that it helped them to learn how to solve problems. Student Wei said: "You may not know how to use the knowledge or how to use it correctly if not listening to the teacher. But when you listen well at class, you can solve problems correctly." The third reason was that listening to teacher was an efficient way to learn science. Student Cai said:

> Listening to the teacher is an important way for better understanding. To listen to the teacher attentively at class is equivalent to saving time after class. With a good understanding of the class content, I would have less difficulty in finishing my homework, and my scores in exams will be high too.

It was noteworthy that some students stated it was necessary to listen to teacher attentively even if they thought they had understood or knew the content. Two reasons were reported for this statement. One reason was that the teacher's "method may be different from mine" (Guo). The other reason was that "not listening to the teacher at class is a bad and disastrous habit" (Feng).

In summary, these students are examples of those who reported that they should listen to their teacher unquestioningly. The reasons students provided to support their claim were related to teacher authority, learning to solve problems, and improving learning efficiency.

4.2.1.2 Listening to the teacher as actively thinking

The second subcategory identified was actively thinking while listening to the teacher. The students with this subcategory of the conception of learning stated their strong belief in the obligation of listening to their teacher attentively and actively. They reported that the essential element of listening to teacher was to think actively. By saying ‘to think actively’ they meant to focus on and comprehend what the teacher was explaining with various active mental and emotional processes. For example, Wei said:

> I am thinking actively when I am listening to my teacher, instead of listening passively. I would try my best to understand every word of my teacher. My principle is to ensure my train of thinking is complete and correct. I can naturally remember what the teacher taught in class.

Student Meng reported a similar view of listening to his teacher actively.

> At class I pay attention to and think over my teacher’s words. I try to comprehend all the details. When my teacher emphasizes something, I note it down. My teacher of physics has a good blackboard display, which is the summary of the lesson. I usually note it down. As a result of my being attentive and active at class, I can vividly remember what my teacher said in class, like a movie playing in my mind.

Student Yong reported that he was very active at class. Yong’s being active is distinctive in that he was both mentally and physically active at class. He said,

> I am a person who can bring up the mood of enthusiasm of the whole class. My method is to shout out the answers. For example, when my teacher asked a question, like what is A plus B, I would yell out C. I would have deeper impressions if I yell at class.

In summary, students reported that they were mentally, physically, and verbally active in listening to their teacher. As a result of this active engagement in class, students considered that they developed good understanding and deep impressions/memory of scientific knowledge.

4.2.1.3 Listening to teacher as taking learning initiatives

The third subcategory identified was to take initiatives in listening to teacher. Students holding this belief reported their autonomy in deciding what to learn, when to learn and how to learn. As a result of this autonomy, these students reported that they might not listen to their teachers all the time.

One typical scenario reflecting this sub-category is that a student needs to continue his/her thinking on one question while his/her teacher has moved on. Wei said:

> I follow the teacher attentively. I would note anything that I do not understand. Sometimes when my train of thinking is different from that of my teacher, I may keep on thinking about it without listening to the teacher. After class I would communicate with my classmates, to see what the teacher's reasoning is. My principle is to ensure my train of thinking is complete and correct.

Some students reported engaging in self-regulatory behaviors of self-assessing what the teacher was explaining. They testified to not listening to their teacher if they understood the content or knew the solution. For example, Liu said: "I would study other content instead of listening to my teacher when I have understood the question". Some other students reported that they would keep on listening to their teacher although they knew the solution, but might not listen to their teacher in other cases. For example, Shuo said:

> I do not listen to him when he is explaining a problem that I did not try before class. I would do the problem instead of listening to him. If I did the problem and I did not do well, I would concentrate on listening to the point where I was stranded. I listened to him as well when I know how to do the problem, since there are other things to learn, like format, procedures, etc. You would lose unnecessary points if you do not know the detailed requirements of the format.

Shuo’s above statement suggests that he considered that he should take the initiative in what to listen and what to pass on at certain times. Shuo professed his intention of listening to his teacher attentively although he knew the solution, that is, to learn the format of doing problems so as to earn full marks in exams.

Some students stated the need to explore new learning approaches and the necessity to search for new knowledge or deeper understanding of the knowledge after listening to the teacher. Hao said:

> My way of learning may be called formularization plus imagination. First of all you must have a formula/model to learn, then you should have creative imagination. If you only use the formula that teachers taught for learning, your learning is like old China, only with convention, but with no innovation. But if you add imagination to the model, your learning is like China’s reforming and opening up. When you first learn new knowledge, you have no clue and you have to follow the teachers’ model. For example, when you learn a new element, you have to know its simple substance, its chemical compounds, the acid, base, salt, and their various reactions and qualities. After knowing this, if you stop here and do not go forward (How), what you learnt is the knowledge given by the teacher. You have to imagine and explore some unknowns.

Hao maintained that listening to teacher was the first step in order to learn to learn. He explained that the information learnt by listening to teacher had to be personalized and adapted. Hao also argued for the need to explore and envisage the just learnt knowledge so as to develop new knowledge and new understanding.

To sum up, these students who reported taking initiatives while listening to teacher considered that they were in charge of their own learning processes and thus could decide to listen to their teacher or not. After assessing their understanding of the content they reported regulating their learning behavior in class, engaging in their own thinking, studying other content, focusing on details, or exploring new knowledge. Although these students advocated not to listening to their teacher all the time, they did not depreciate the importance of listening to teacher. As Hao pointed out, they could only afford not to listen to the teacher after they had listened to him/her.

Summary

To summarize the description of the first category of conception of learning, Mainland Chinese students in this study all communicated the significance of listening to teacher, but their understanding of the 'what', 'how' and 'why' aspects of listening to teacher varied. Some students insisted on listening to teacher in any situation and without any question, some other students suggested active engagement in class, while some students saw value in and argued for some flexibility in how they cooperated what they learnt from listening to teacher into their overall learning processes.

4.2.2 Category Two: Learning science as attending to exams

The students in the study reported that exams were important and that they had to attend to exams. However, variations existed in students' understandings of why exams were important and how to prepare for and take exams. Three subcategories of ‘attending to exams’ were constructed from the data: avoiding distress, competing with peers, and assessing learning. Figure 4.2 gives a visual representation of the structure of the category.

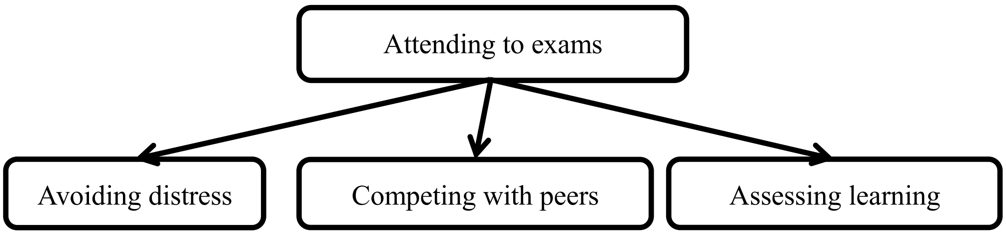

Figure 4.2 Structure of ‘attending to exams’

4.2.2.1 Attending to exams as to avoid distress

Students with the subcategory of ‘avoid distress’ understood the importance of exams, and they wanted to pass exams, but often failed after a lot of struggling efforts. These students reported misery in disappointing their parents, teachers, and themselves. They also reported few strategies for making any change to their miserable situations. For example, Yan wanted nothing but to avoid the distress caused by failing in exams. He stated:

> My physics is not good. Sometimes my scores are too low. It is shameful to fail in exams. My teacher scolded me for my low marks several times. My parents once beat me. For me to pass exams is what I wish the most.

Students with the conception of ‘avoiding distress’ reported that they did not want to disappoint their parents, their teachers or themselves and thus experienced negative emotions when they performed badly in exams. For example:

> Once I did poorly in an exam of science. At that time I had a flashing impulse to open the window and jump down of the high building. (Shuo).

> When I saw my test paper, my tears burst out. I could not believe that my score was that low. I knew I did not learn that part well, but I did not expect to fail in that test. I wept for the whole class. My desk-mate comforted me, but I just could not help weeping. I thought I was too useless and I had disappointed my parents. (Xiaoli)

Students' failing in exams might be related to their limited report of knowledge in how to prepare for and take exams. Yan was one of the students who could not say much about how they could pass exams. When Yan said that he often failed in physics, I asked him if he had any means to realize his wish, that is, to pass exams. He said that he needed to work harder. I asked him how to work harder, he said to allocate more time in physics. I went on to ask him to how he would spend the extra time on physics, and he said nothing more than reviewing. Yan's reporting less strategies than other participants might suggest that he does not have detailed procedural knowledge that would help him realize his wish to evade the miseries.

In summary, students who struggled to pass exams understood the importance of exams and wanted to avoid distress, but often did poorly and suffered miserably due to their limited knowledge of how to prepare for exams.

4.2.2.2 Attending to exams as to competing with peers

Students who had the conception of 'competing' reported that their motivation to learn science was to compete and excel in exams. The reported reason why they enjoyed competition was that high rankings would satisfy their self-esteem and make them happy. These students reported a good understanding of how they should learn to prepare for exams and demonstrated a good knowledge of why these strategies worked.

'Competing' students reported their appreciation for ranking, and to learn science was a way to get a higher ranking in class. For example, Cai talked about his experience of choosing a classmate to compete with. He said:

> Every time before a new semester, our teacher would let us make a plan chart... At the last of the chart, we are required to state our goals, such as nominating some classmate to exceed. It is a reasonable competition. I would choose a classmate who is always ahead of me in ranking.

Ranking high would satisfy these students' self-esteem, and they reported being happy when compliments and admiration came from parents, teachers, and peers. Hao was one of these students who claimed always being ranked high in his class.

> I study for praises and compliments. I feel I have a better face and feel good about myself if I learn well and get praises. I have always been No. 1 student since I was in elementary school.

'Competing' students reported a good understanding of how they should learn to prepare for exams and a good knowledge of why these strategies worked. For example, Cai stated:

> We have chapter exams and term exams. The burden of review is big at these occasions. I have to attend classes and do homework. At the same time I need to review for the exam. Every night I would review my materials into deep nights, since learning is a process of accumulation.

Cai reported studying into the nights since he understood that learning was a process of accumulation. He described his feeling of being burdensome but he persisted in studying hard.

'Competing' students reported strategies in helping them to get high marks such as reading the intentions of examiners. For example, Dong said:

> You have to recognize the intentions of the examiner. It helps you to get a good score. You can answer the question to the right point if you know what the examiner wants from you. And you will avoid a twisting course. So it is necessary to see through the surface and see the essence. I analyze the intentions of the examiner in solving complicated problems, not the simple ones, which are solved easily with basic knowledge.

Students with 'competing' conception cared for the outcome of exams, and thus tended to worry about what would happen if they could not do well in exams. For example, Juan explained:

> My teachers often say that tests are to expose my shortcomings, and I can make them up once I know where my weaknesses are. But it is unavoidable for me think how my result would be and how I would be ranked in class, and other consequences of a bad performance. A set of consequences would appear in my mind.

To sum up, students with 'competing' conception reported enjoyment in outperforming their peers and appreciation of compliments from their parents and teachers. These students were usually highly motived and would like to work hard, but some reported worrying about exams.

4.2.2.3 Attending to exams as to assessing learning

In this subcategory of 'attending to exams', exams were viewed as one way of assessing learning process and results. These students valued exams because they regarded them as an essential component of their science learning, not necessarily because of the consequence or the outcome of the exams. Students with this view reported peace of mind towards low scores in exams because they thought it a good thing to have problems exposed. For example, Cai stated:

> My mother told me, and my perception also is, that examination is a test of what I learnt. It would be not bad a thing, but rather good if I did not do well in an exam. It completely exposed my problems. These problems will be corrected in my later learning.

Students who reported an ‘assessing’ conception did not endorse the idea of learning to compete. They argued against the idea of competition because they thought it departed from the nature of learning. For example, Yu maintained:

> … But the underlying reason to compete may be that the person wants to show how good he is in front of others. To compete departs from the learning itself. I do not think one should seek for ranking… I think a good score, a good ranking, and going to a good school are the results of good learning, and they are not the reasons to learn.

Another student Wang expressed a similar understanding of why exams were important. Wang stated:

> Many people think learning is to get great scores, go to university, and find a good job. But my grandfather told me that learning was not for fame or wealth. Learning is fun for itself. Exams are a way to assess my learning and help me to learn.

In summary, students who reported an ‘assessing’ conception valued exams not because of what status exams might bring to them; they valued exams because of the assessing function of exams. With ‘assessing’ conception, students reported peace of mind with regards to high or low scores.

To summarize the description of the second category of conception of learning, Mainland Chinese students in this study all highly valued exams, but their reported understandings of how and why they valued exams are different. The 'avoiding distress' students wished to escape the ordeals caused by failing in exams, but their limited knowledge of how to prepare for exams impeded them from doing so. The 'competing' students attached great importance to exams and found great enjoyment in outperforming their peers. The 'assessing' students valued exams because exams could assess their learning and help them learn.

4.2.3 Category three: Learning science as memorization

The Mainland Chinese students in this study reported that they highly valued and engaged in memorization as the indispensable process of science learning. They reported that they needed to memorize diverse information when they were learning science. Two different views of how and why they should memorize the information were identified in the interview data: rote memorization and memorization through understanding. The two categories were mutually exclusive in meaning, but one particular student, for example, Fei, might have reported rote learning and memorization through understanding for different tasks, or at different times. Thus the same pseudonym, Fei, may appear in the both categories.

In the following section, the varying declarative knowledge of what to remember, the procedural knowledge of how to remember, and the conditional knowledge when and why to remember are outlined and discussed. Figure 4.3 describes the structure of the category.

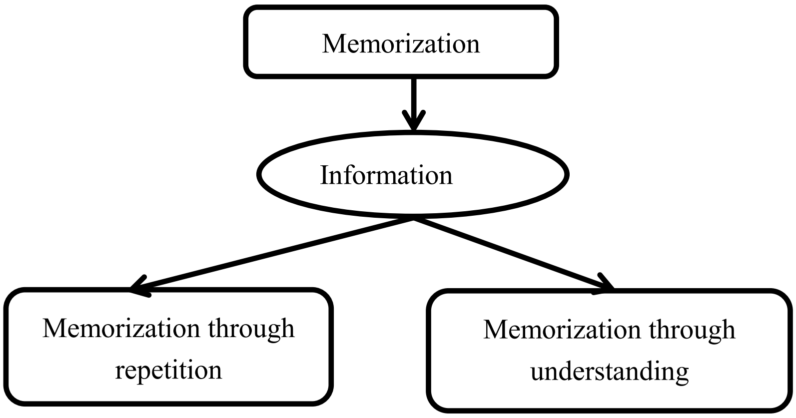

Figure 4.3 Structure of 'Memorization'

The varying information to memorize

Mainland Chinese students in this study reported that they had to memorize a range of information when they were learning science. The information could be divided to four categories: scientific facts, procedural knowledge to solve problems, deducted conclusions, and experiments.

Scientific facts, which refers to formulas, concepts, and laws, were the most common category of information students reported that they had to memorize. Participants said that they were never given formula sheets in exams, and thus they had to memorize all the formulas before applying them in solving problems. The rationale of memorizing formulas, as Li stated, is that "remembering the formulas helps understand the laws they represent". Apart from formulas, students often were required to memorize concepts and laws word for word. By memorizing the wordings, students reported that they could learn the language of science and improve their understanding. Wei said:

> Concepts and laws in my textbooks are expressed by the most concise and accurate words. I think the words are beautiful and worthy to put into my memory. In the process of memorizing the wordings, I also make connections, and my understanding of the concepts or laws improves.

Students reported that they needed to know and remember the steps of how to attack a problem. Fei articulated the process of solving a physics problem.

> Knowing the procedures does not guarantee you to solve a problem, but you must know the steps of solving problems. Firstly you understand the problem statement. Then you draw a diagram, not only mentally, but a must [sic] on the paper. After that you analyze the process and figure out how to solve the problem, and this is most challenging part. If you find out the way to the solution, it is easy to compute and write it out.

Many students expressed the importance of remembering model problems. The model problems could be sample problems, or typical problems students found. For example, Cai enunciated his understanding of why and how to employ model problems.

> I will have a model of solving problems in my mind. Once I see a problem, my mind would respond with the right model at once… Some problems look like that they do not belong to a pattern, but in fact they do. So these problems are the so-called difficult problems…It is a difficult process of transforming the problem into a recognized pattern of problems.

Not only was it model problems that students reported having to remember, they also reported that it was very helpful for them to remember the problems they had done. For example, Wei explained:

> Good memory is important. You should remember the problems that you did before. Otherwise you would have wasted your time by doing problems.

Apart from concepts, laws, and formulas, some students interviewed mentioned the importance of remembering deducted conclusions, that is, results of typical scenarios or the deductions from basic laws. Chao explained why they need to memorize these conclusions.

> I think one need to memorize more, and see more. The secondary conclusions need be put into memory. Then it may help to think more comprehensively. Take a very simple instance. If an object slides on a level surface, the acceleration must be ug (a=f/m=umg/m=ug). Thus memorizing the conclusion saves time in manipulating formulas, and increases your speed of doing problems.

Hao talked about the rationales why the secondary conclusions had to be remembered.

> You have to remember some deductions. During the exams you have no time to deduce them. If you are uncertain about the deduction, you may have to deduce it to ensure its correctness and you will have not enough time to finish the problems in the exams.

Students reported that they needed to memorize the procedures to do experiments, the principals tested in the experiments, and the strategies applied in the experiments. For example, Hao explained:

> The procedures and strategies must be remembered. Many exams ask which strategy an experiment applies. So remembering the strategies will help a lot in analyzing the experiments… The strategies shared by physics and chemistry experiments are comparison, control of a variable, and modeling...

In summary, students reported that they needed to memorize diverse information in learning science. To be specific, students needed to memorize scientific facts, procedural knowledge to solve problems, deducted conclusions, and experimental procedures, principles and strategies.

4.2.3.1 Memorization through repetition

Students reported that they sometimes memorized information by repetition without much understanding. They thought mechanical memorization would apply to learning science, but they realized that mechanical memorization did not help them achieve success all the time. For instance, students explained:

> I am good at art subjects such as Chinese, history and social studies... So I learnt science subjects with the methods of learning art subjects. For example, I memorized formulas mechanically. I put values into the formulas and many times I did it wrong. (Tian).
>
> At the beginning since physics was simple, it is ok to depend on memorization, as with other subjects. Sounds, lights, and change of state are easy. I can get 95% right in an exam only depending on memorization. The second term I started to learn electronics and I found it very difficult for me. It depends on understanding. At that time, my scores were always low. I felt so disgraced... (Fei)

Students reported disadvantages with rote memorization, such as that it was time consuming, difficult to retain, almost impossible to apply the information. For instance, two students stated:

> I did not learn chemistry and biology well, since the two subjects required a lot of memorization. I can put the knowledge in my memory by repetition, but I forgot it soon. I may have not understood the knowledge well. (Bo).
>
> It would be easier to remember the knowledge if I had a thorough understanding. If I remember the knowledge mechanically, I am likely to forget it in exams, and [it would be] difficult to apply it. (Dong)

Students reported two reasons of using rote memorization although they understood that it was not the best way to learn science. One reason was that they did not have the time or resources to understand the information and simply remembering the information might satisfy the requirements of their teacher and exams. The other reason was that the repetition process to remember may help reach understanding.

For example, Fei talked about her living environment that might hinder her from understanding plants and animals.

> I was born and grew up in the city. Plants and animals are far from me… My life is either to study or to play computers, not like my classmates from the countryside. So biology is far from me and I do not quite understand what I have to remember.

Chang talked about time constraint for understanding and his belief that rote memorization is a preparation for further study.

> …My teacher asked us to remember something and he will let us recite it next day at class. So I had to manage to remember it, usually by repeating it for many times. I did not have much time to think about and comprehend it. My 'face' would be lost if I could not recite it…Remembering the information is useful for further study, and I will have chance later for a better understanding.

Quan believed that mechanical memorization improved her understanding.

> Many things in chemistry need to remember. Many of them are very abstract, and I cannot see and touch them, like the ion concentration. But after remembering them, I feel my understanding improved. In fact it made more sense to me after I have memorized the information and reflected it in my mind.

In summary, students reported knowing the disadvantages of rote memorization, such as it being time-consuming to memorize the knowledge and difficult to apply the knowledge, but that they had to use it for the purpose of meeting the requirements of their teachers and passing exams. At the same time, some students thought rote memorization as a preparatory step for a better understanding.

4.2.3.2 Memorization through understanding

Students stated the importance of developing an understanding in memorization. ‘Understanding’ based on these students’ views refers to knowing the logic, the relationship, and the origins of the scientific concepts and laws. Students reported that after having developed an understanding of the knowledge, it was easy for them to remember the knowledge, sometimes with little effort. For example, some students explained:

> I naturally remember what the teacher taught at class, since he is always meticulous in explaining the knowledge. Usually I read the textbook and compare my understanding with what my teacher taught. This process of comparison would allow me to have a deeper understanding and a more solid memorization. (Wei).
>
> My physics teacher told us that the electronics unit was difficult to learn because 死记硬背 (memorization without understanding) would not work. We had to understand the rules and laws before putting them into memorization. (Fei)
>
> The important thing is to understand what you have to remember. In fact after you understand it, you will naturally remember it. I would not be able to hold it for long in my memory if I did not understand it. (Hui)

Apart from requiring little effort to remember the understood information, the advantages reported also consisted of retaining information for a longer time and the memorized information being applicable. For example, Student Liu claimed that “you cannot remember the knowledge well if you did not understand it.” Another student Dong expressed similar views:

> It is easier to remember if you have a thorough understanding. If you remember the knowledge mechanically, you are likely to forget it in exams, and difficult to apply it.

Students who emphasized understanding in memorization demonstrated a wide range of knowledge with regards to when and how to remember the information with understanding. The following are three examples.

> I do not hurry to do the homework after class. I would arrange the knowledge in my brain with proper order first. Every night before going to sleep, I would recall what teachers taught at class. (Li)
>
> I have to memorize them from time to time. If I did not review, I would forget it. (Shan)
>
> The most important thing is to review in time. You have to review the knowledge after class, before going to bed, and before exams. Otherwise you may forget it. Reviewing not only improves memory, but also helps understanding. (Bo)

Students reported that the time after getting up and before going to bed were the best moment to memorize things.

> Sometimes I want to get up early to memorize something. In the mornings it is easy to memorize things, isn't it? (Hui)
>
> He (her father) advised me to memorize important knowledge points every night before going to bed. He said one's memory is good before bedtime, and my knowledge would accumulate over a long period. (Li)

In summary, students reported that they could remember information with little effort but retain it for a longer time when they memorized it through understanding. Students reported strategies to help them in memorization through understanding.

Summary

Memorization through repetition and memorization thorough understanding were reported as two ways to memorize the diverse information that includes scientific facts, deducted conclusions, experimental procedures, and model problems. Memorization through repetition was regarded as being time-consuming and inefficient but was still used to meet learning requirements and to prepare for further study. Memorization with understanding was stated as being optimal because of effortless and extended retainment and high efficiency for application.

4.2.4 Category four: Learning science as developing understanding

Although a few students did not reference or talk about understanding, and they seemed to be submerged in various learning activities, most students in this study stressed the importance of 'developing understanding' in activities such as attending class, doing problems, and preparing for exams. Apart from the aforementioned learning activities that are discussed in Category 1, 2, 3, and 5, three salient themes emerged to develop their understanding, i.e., preview, review and summarization. In the following the 'what', 'how' and 'why' aspects of the three themes are deliberated. Some students reported one subcategory, while some other students reported two or three subcategories, thus the same student's statements may be used as exemplars of the three subcategories.

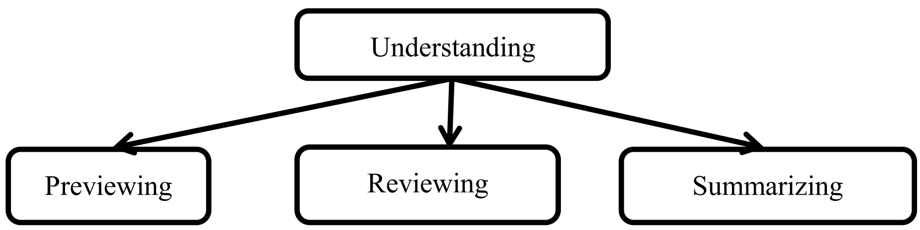

Figure 4.4 Structure of 'Understanding'

4.2.4.1 Developing understanding by previewing

The referential meaning of the strategy is to pre-study the material before class. Preview is a strategy that students reported to use the most to enhance their understanding of scientific knowledge. The structural aspect of this strategy includes the reasons why they previewed, the processes how they previewed, and the conditions for them to be able preview.

1) Why to preview

The main reason students reported to preview was to help them to follow the teacher well and to develop a good understanding. For example, Dong stated: “If you did not preview what the teacher is to teach, you would be in a haze while listening to the teacher.” Dong’s argument for the absolute necessity of pre-class learning may not be representative of for all students, because about half of the students in this study reported they were doing ok by not to pre-learning the materials. Nevertheless, Dong and some other students reported that if they did not preview the content, they would have difficulty understanding it at class.

Cheng expressed a similar idea in the importance of pre-class learning, especially at high school.

> At junior middle school I was ok not to preview, but at senior middle school, I would feel difficult to follow the teacher if I did not preview the content. I can feel the big difference that pre-class learning makes…Although my teachers would give us some minutes to read the textbook before giving the lecture, the time is usually too short.

Some students regarded pre-class learning as an essential procedure to gain understanding. These students reported having formed the habit of pre-class learning. Attending class becomes the step to review and consolidate their pre-learnt content. Bo reported that he usually spent 30 to 40 minutes for every new lesson, and his pre-class learning did not make him less interested in class.

> I usually spend 30 to 40 minutes to preview... For me I often take classes in the summer time to study the subjects in advance. Having already understood the content would not interfere with my listening to my teacher attentively in class…Listening to the teacher makes my pre-class learning more complete and sufficient, and decreases my burden of review.

2) How to preview

Preview is a process of self-learning, in which students reported mainly using their textbooks to comprehend the scientific knowledge. For example, Chang stated:

> I would preview the textbook and mark the places that I do not understand. At class I could ask my teacher about the difficult point in my pre-class learning.

Reading the textbooks carefully was the main principle in previewing. For example Lin highly valued textbooks and recommended reading them for many times so as to understand the content and the logic of the authors.

> The textbooks are the marrow of the subjects. They should be read for many times. The intentions of the authors should be fathomed.

Another principle suggested by students in previewing was to make connections. For instance, Bo would “reflect on old knowledge and connect it with new knowledge”. Yu would “connect the abstract concepts with everyday life”.

3) Why not preview?

Interview data suggests that about half of the students did not preview although they reported knowing that preview would be helpful for understanding. Qun's explanation was that she did not have the time. "I am weak in this aspect. I did not preview much. The reason is that I do not have the time. I do not have much time left after finishing homework." Qun reported being good in science, but still she did not have much time left after finishing homework.

Another reason reported by students of not previewing was that 'preview' was not required by their teachers and they seemed ok not doing it. For example, Liu said: "I pre-study a section if my teacher asks us to do so, otherwise I do not preview… I can understand what my teacher teaches at class (although I did not preview the materials)".

In summary, preview was reported as an effective way to enhance their understanding, but the data suggests that less than half of the students interviewed engaged in this learning activity due to time constraint or because it was not a compulsory requirement.

4.2.4.2 Developing understanding by reviewing

Review is an after-class learning process to go over and study the scientific knowledge. Almost every student interviewed expressed the idea that review was very important in learning science, but students reported different perspectives on why, how and when to review.

1) Why to review

Students reported many reasons to review. Apart from the previously reported reasons of memorization and preparation for exams, the main reason of after-class learning was to improve understanding. In many cases students had to re-study the scientific knowledge because they did not fully understand their teacher at class. For example, Dong said:

> I may not completely understand what my teacher teaches at class. I go over them after class... I ask myself what I do not understand, and then I review it.

Students may have superficial or little understanding of some concepts and laws when they first learnt them, but later when they reviewed them, they reported that their understanding greatly improved. For instance, Shuo said:

> ...But I would have trouble when the problem needed a good understanding of concepts... Later when I learnt other chapters, I had to use the concepts, and thus I reviewed them. Suddenly the formerly incomprehensible concepts became easy to understand. I think it is an interesting phenomenon. For example, the electric field was too abstract and very difficult for me to understand at the beginning, but later when I reviewed it, I found it not difficult at all.

Some other students reported that they might have followed their teachers very well at class, but they still went over the scientific knowledge after class, because they wanted a deeper and better understanding. For example, Wei quoted Confucius' learning principle to support his conception that "reviewing the known leads to know the unknown"(温故而知新). In other words, to review cannot only enhance the known and facilitate knowledge application, but can also create new understandings of the knowledge. Wei claimed:

> To learn physics well, one has to connect all the knowledge points. But you may not be able to do so, thus the teacher can help you think it out. Then you should often review the connected knowledge. In addition, to review is to know the unknown through the known (温故而知新). The more you review the knowledge, the more you will be able to apply it, and at the same time you may have a new understanding of the knowledge.

2) How to review

Students reported three ways to review: re-studying, recollecting, and teaching others.

Re-studying was the most common practice students reported regarding reviewing. Students reported that they would go over the content after class. For example, Meng said: “When I feel that I do not have a good grasp on the content, I would study my notes, or re-study the textbook”.

Recollecting is a way to reflect on what is learnt. Students would think back and remember what the teacher taught at class. By reflecting on the scientific concepts, laws, and their applications, students reported that they would have a better understanding. For example, Fei said:

> I would recollect what the teacher taught at class and his train of thought. I learn physics, chemistry, and biology in this way, for every lesson… I do not hurry to do the homework after class. I would arrange the knowledge in my brain with proper order first. Every night before going to sleep, I would recall what teachers taught at class.

Generally speaking, students reported that they reviewed by themselves, but it is interesting to note that some students reported reviewing by helping others to learn. Dai thought it was a great way to review the knowledge by helping his classmates. “It is important to keep a good relationship with my classmates. We help each other. In fact I am reviewing the knowledge when I explain it to my classmates." Another participant Li said that his school required students to help each other.

> Our seats were arranged in a way that strong and weak students sat together so that strong students can conveniently help weak students. The strong student had to review the knowledge before teaching the weak student. Both the reviewing and teaching helped the strong student in gaining further understanding of the knowledge.

3) When to review

To know when to go over the concepts and laws was reported as being essential to develop a good understanding. Some students stated that they went over the content before exams, but some other students pointed out that they must review the materials every day, instead of until the last minute. For example, Cai was told by his teacher and parents to review regularly, but the idea was not absorbed deeply. Only after he failed in an exam, he realized that he should review every day. Cai recounted:

> When I began to learn science, my mother told me how to learn science. At that time my impression was not deep. Thus I did not do well in the exam for the first month… In fact my teacher once said that I should review in my ordinary routine of learning. I did not have a clear and deep understanding of it [when to review] until after failing in the exam.

Students reported that it was a good strategy to withhold the impetus to do homework before a thorough review. For example, Guan stated:

> Before doing my homework, I often read my textbook or notes. I do not think it good to do problems without reviewing the content just learnt. My

comprehension may not be good enough to apply the knowledge.

In summary, students reported that review was an essential way to enhance their understanding of scientific knowledge. By going over the textbook regularly, reflecting what was learnt in time, and helping peers to learn, students claimed that they not only developed a good understanding of the old knowledge, but also created new knowledge.

4.2.4.3 Developing understanding by summarizing

Summarization was reported by students in this study as an effective way to develop their understanding. The focus of summarization was on systemizing the concepts and laws. In the following the rationale why they made summaries and the ways how they made summaries are discussed.

1) Reasons for summarization

The first reason reported for summarization was to pass exams. If a subject or a part of subject was not tested, students would not bother to make summaries. For example, Fei admitted that she did not make summaries in learning biology at junior middle school since biology was not tested in the high school examinations. I asked how she would learn biology if it was included in the **entrance** examinations, she answered very assuredly: “Absolutely I would summarize the knowledge and make it more systematic, just like what I did to chemistry.”

The second reason reported for summarization was to build a system of knowledge. For example, Shi stated that to learn science one should build a knowledge house in his/her brain. Shi explained:

> You should ensure you have an outline of what you learnt. I have an analogy between knowledge and a house. There are stories, rooms, and storages in a house to keep things. Your brain should be like a house holding the knowledge in an orderly and systematic way. When this house is built in your brain, it means you have learnt science well.

The third reason reported to make summaries was to assess understanding so as to improve where it was necessary. For example, Li clarified:

> I draw a knowledge tree. I list the title and subtitles. By looking at the knowledge tree, I can see which part I am not very familiar with. I will put more time into this part of knowledge.

The fourth reason reported was to stand high with a bird's-eye view of the detailed knowledge, i.e., to have a panorama or a whole picture of the knowledge in a unit. As a result of this remarkable understanding, students can apply the concepts and laws in complex situations. For example, Lin elaborated:

> It is common for my classmates to fail to see the wood for the trees (只见树木不见森林). They do not know how to apply the knowledge in complex situations. But if I systematize my knowledge, I know what I have learnt. Although this process may be time consuming, my scores increase a lot and I feel confident that I have learnt science well.

In short, students reported that they systematized their knowledge for the purpose of gaining high scores in exams, building a systematic framework of knowledge, assessing their understanding of some specific knowledge, and constructing a panorama of knowledge in a whole unit.

2) How to summarize information

The interview data suggested that students systematized their knowledge by listing outlines, abstracting the framework of the textbook, and making deductions.

'Listing outlines' means that students organized their scattered knowledge points into a system. For example, Tian reported that her high school biology would test the junior biology which she did not have a good understanding, and she had to find a way to make up. "…I learnt to list outlines. By listing all the knowledge points, I can have a more systematic knowledge."

'Abstracting the framework of textbooks' means that students analyzed the structure of the systematic knowledge of their textbook and built a similar construct in their mind. For example, Fei stated:

> The textbook is different from other books because it is very systematic... After learning a chapter or a section, I build a [mental] knowledge framework as the textbook does.

'Making deductions' means that students connected the concepts and laws by mathematical derivation. Students reported that making deductions helped them to reach a deep understanding, gain a firm memorization, and apply easily and confidently. For example, Yihao elaborated:

> When a student learns something new, at the beginning he does not know much about it. He must start from the most basic knowledge. He must slowly, step by step, deeply understand the knowledge. For example, to understand the production of alternating current, the student should be able to deduce it from the basic Lorenz Force. If the student was just told about the formula or concept, he could not remember it deeply and firmly, and he could not apply confidently the formula or concept.

Summary

The data analysis suggested that although some students seemed to misplace their focus on doing a sea of problems and did not report on the importance of ‘understanding’ in learning science, most students reported that they believed ‘understanding’ was the fundamental element of learning science. Apart from the learning activities discussed in other sections, three salient themes of strategies emerged, with which students developed their understanding of scientific concepts and laws. ‘Previewing’ was reported as an effective way to develop their understanding, but less than half of the students interviewed executed preview in their science learning. ‘Reviewing’ was reported almost by all the students as an indispensable way to improve their understanding. Summarization was reported as an essential way to gain a supreme understanding by constructing a systematic framework of knowledge in their minds.

4.2.5 Category Five: Doing problems.

The interview data suggested that students in this study regarded doing problems as the dominant part of their science learning processes. When describing how they learnt science, most interviewees would talk about doing problems, and on average they reported spending two or three hours a day after class in doing science problems. More than 10 themes emerged about the ‘what’, ‘how’ and ‘why’ aspects of ‘doing problems’. The themes could be simply put into subcategories titled by ‘how’ and ‘why’, but it makes more sense and the result is more informative to classify these themes into two subcategories: ‘practicing’ and ‘applying’.

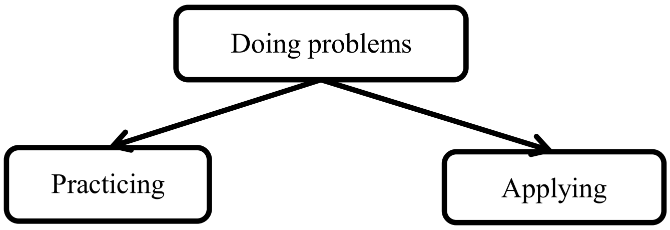

Figure 4.5 Structure of ‘Doing problems’

The above classification is based upon the differences between the two subcategories about the students’ reported views of doing problems. More specifically, the students reported different views about the amount of problems they should do; about whether doing problems is for understanding or based on understanding; about persisting in doing as many problems, or in delving into one problem; about focusing on improving skills of solving problems, or on applying knowledge in solving problems; and about whether accumulating the wrongly-solved problems to notebooks, or draw inferences based on one problem. The differences of the two subcategories of ‘doing problems’ are listed in table 4.1 and discussed in the following sections.

4.2.5.1 Doing problems as practicing

The students with the view of ‘practicing’ considered that they needed to practice doing as many problems as possible. The reasons for these students wishing

Table 4.1 Differences of ‘practicing’ and ‘applying’

Practicing	Applying
Do a sea of problems	Do some typical problems
Do problems for understanding	Do problems based on understanding
Focus on improving skills of doing problems	Focus on applying knowledge in solving problems
Persist in doing many problems	Persist in solving one problem
Review wrongly-solved problems	Draw inferences based on one problem

to practice this much were reported to be that they might develop understanding of concepts and laws and improve their skills and abilities to solve problems. The approaches they reported in doing problems consist of persisting in doing a ‘sea’ of problems and reviewing wrongly-solved problems.

1) Do a ‘sea’ of problems

Some students in this study considered that they should do as many problems as possible, although they reported that they might not have the time and energy to do a ‘sea’ of problems. The first reason reported to do as many problems as possible was that their teachers expected them to do a lot of problems. For example, Yi stated that in their third year of high school all their focus was to do problems, which implied that their teachers’ teaching plans focused on having them practice doing problems. For another example, Hui stated that their teachers asked them to do a lot of problems from workbooks: “In my opinion, In China you are given a lot of workbooks, and you have to do a lot of problems. Any time after class is devoted to do problems.”

The second reason reported to do a sea of problems was to become good at solving problems. “Practice makes perfect” was the most quoted proverb to support their notion that they should do as many problems as possible. For example, Yi claimed:

> I strongly believe that practice makes perfect and second best is not good enough (精益求精). I have to do as many problems as possible…

As for why ‘practice makes perfect’, apart from being able to facilitate understanding of concepts and laws, which will be discussed afterwards, doing as many problems as possible was reported to help students to encounter and acquaint all types of problems. For example, Dai explained:

> The more problems I do, the more types of problems I will see. When I see a problem of the same kind, although perhaps being asked in different ways, I know how to solve it.

2) Do problems for understanding

Students with the view of ‘practicing doing problems’ reported that they wanted to develop understanding of concepts and laws by doing problems, and they reported that they really achieved this goal by practicing doing problems. For example, Shan stated that she had difficulty in understanding some concepts, and doing problem increased her understanding of these concepts.

> I did not understand some concepts, nor did my classmate [she assumed or found out after she asked them]. Then I began to do problems. Gradually I understood a little… A problem must be testing

> some knowledge. By doing the problem, I can study this knowledge and thus have a better understanding of it.

These students reported that it took them much time and many processes, including doing problems, to fully understand some concepts and laws. For example, Hui said: "doing problems will help to consolidate the knowledge points (concepts)." Yi expressed the same idea that he must do a lot of problems in order to understand some concepts: "It is important to do problems. Without doing problems, it is difficult to comprehend the concepts and principles."

These students reported that a real understanding of concepts and laws came from practice, that is, by doing problems. For example, Shi argued that the knowledge would be 'fake' or futile without practice, and he claimed that knowledge came from practice:

> To practice is very important, because as the old sayings go, it is the fake expert who only talks without action（光说不练假把式）, and a student who does not practice is like an armchair strategist（纸上谈兵）. In a way practice is more important than knowledge, because knowledge comes from practice.

3) Focus on improving skills of doing problems

The students with the view of 'practicing doing problems' considered that they needed to be skillful in doing problems, and they reported that practice made them skillful in doing problems. For example, Xiong explained that he could become fast and accurate in doing problems after a lot of practice:

> At the beginning I think to do problem is to help understand the concepts. In the last year since I have understood all the concepts and principles, the purpose of doing problems is to become more skillful

> in solving problems. More specifically, it is to improve the speed of attacking problems and increase the rate of accurateness.

These students considered that being skillful at solving problems required certain abilities and practicing doing problems was a way to improve their abilities. For example, Yi said that "learning is a process of forging a person's abilities". Dan articulated why practicing doing problems can improve a person's abilities, and become skillful in doing problems:

> Being smart means his brain runs faster. Not being smart means his brain runs slower. But practice makes perfect. After you see much and practice much, you will be quick and skillful… A person's inborn ability may be different from others'. But cultivation is more important. The inborn ability won't develop without cultivation. A man's ability can improve greatly by practice.

4) Persist in doing many problems

The students with the conception of 'practicing doing problems' wanted to do as many problems as possible, but due to the fact that they had to deal with seven subjects, quite often they did not have the time and energy to do the amount of problems that they wished to do. Thus these students would try to sacrifice their rest time or very limited leisure time to do problems.

For example, Hui wanted to practice doing problems, but she said that she "did not have enough time to work on problems after class." The reason was "due to time constraint." Then she planned to "make use of the ten minute breaks during classes to do a problem", and to "get up early, like 5 AM in the mornings". Although Hui reported that she did not persist in executing her plans as she wished, she thought that she should persist in doing as many problems as possible.

These students reported that they considered it wrong to spend too much time in trying to solve one problem because they would not have time to do other problems. For example, Liao did not think it a good idea to spend too much time in attacking a difficult problem:

> If I have already spent 3 or 5 minutes to attack a problem but it is not solved yet, I would pass it. Otherwise I would feel disappointed and low if I spent too much time on it without a solution. I always have too many problems to do, so there is not really much time to spend on attacking difficult problems.

Hui considered it wrong and not wise to use too much time in digging into difficult problems:

> It is wrong to use too much time in solving difficult problems, because you would have no time to do the simple problems, and no time to check them. Spending too much time in difficult problems was not wise.

5) Review wrongly-solved problems

Students with the view of 'practice doing problems' reported that copying the wrongly-solved problems to a notebook and then reviewing them afterwards was a great way to become good at doing problems, because they could avoid similar mistakes next time when they encountered a similar problem. For example, Shan reported being poor at physics for the first two years of senior middle school, but for the third year she made a progress by reviewing the wrongly solved problems. She stated:

> I thought I worked hard enough in the past, but you may not necessarily learn physics well if you simply work hard. The methods I used were not right, so I walked too many detours. The method I found very effective is to have the notebook of wrong problems, and to review it from time to time.

Hao explained that reviewing the wrongly-solved problems was very effective because the notebook was full of the problems she used not to do right. Hao stated:

> When my learning was not good, I tried the method of using a wrongly-solved notebook and found it make my learning easier. I think reviewing the notebook of wrong problems has a better effect than simply doing more problems. My aunt said that I might meet two or three problems out of ten that I cannot solve; but by reviewing the notebook of wrongly-solved problems, I will see all the problems that I could not solve.

In summary, the students with the view of 'practicing doing problems' reported that they should do as many problems as possible because they considered that they were expected to do a lot of problems, and importantly, they reported that practicing doing problems facilitated their understanding of concepts and laws and improved their skills and abilities in doing problems. They reported that reviewing the wrongly-solved problems was an effect way of becoming good at doing problems because they could avoid similar mistakes in the future.

4.2.5.2 Doing problems as applying

The students with the view of 'applying' considered that doing problems was a way to apply the scientific concepts and laws they already knew and understood. These students considered that doing some typical problems was enough, and there was no need to do too many problems. The reason for them to do problems was to apply the already well understood concepts and laws to various situations. The approaches they reported in doing problems consist of persisting in solving one problem and drawing inferences about other problems based on the one problem.

1) Do some typical problems

Students with the view of applying concepts and laws in doing problems considered it was not necessary to do a sea of problems. For example, Li thought it was wrong to do a sea of problems, because doing problems was not the main part of learning science. Li argued:

> Doing problems takes most of my study time. I think this is not right. I think understanding is the most important. The intentions of the authors of the textbooks should be fathomed out. Doing problems cannot reach these effects... I think doing problems is necessary, but not the main part of learning physics and chemistry.

These students considered that the objectives of doing problems were to apply the concepts and to learn how to think, and thus there was no need to do too many problems after having reached these goals. For example, Wei stated the purpose of doing problems and argued against doing a sea of problems:

> I do not think doing a sea of problems is a good strategy. Problems vary, but they cannot depart from their origin: concepts (万变不离其宗)... When you do enough problems, not too many, you should be able to know how to think, where to think. This is the goal of doing enough problems... So the important thing is to analyze the reasoning of a problem, not the absolute amount of problems.

2) Do problems based on understanding

The students with the view of applying concepts and laws in doing problems reported that they did problems after having a good understanding of the concepts and laws, in contrast to the students who reported that they did problems for understanding of the concepts and laws. For example, Guan stated that he often withheld the impetus to do problems before a thorough understanding of the concepts and laws:

> Before doing my homework, I often read my textbook and notes. I do not think it is good to do problems without reviewing the content just learnt. My comprehension may not be well enough to apply the knowledge.

These students reported that a sound grasp of concepts and laws was essential to be proficient of solving problems. For example, Ze stated that a good understanding of the concepts and laws always came first before doing problems.

> First of all the content of the textbook must be well understood. The second is to do problems. Any problem is to test a concept and law from the textbook. When I was doing problems, I have a habit to ask two questions: 'why is the problem given?' and 'What concept does this problem test?' By reflecting on the problem, I know the essence of the problem.

3) Focus on applying knowledge in solving problems

The students with the view of applying concepts and laws in doing problems reported that they focused on how to apply their knowledge in solving problems. In contrast to the students who focused on practicing doing a sea of problems to improve their skills, these students focused on applying the well understood concepts and laws to diverse situations. For example, Wei quoted Confucius' maxim, "apply what one has learnt" (学以致用), to support this focus.

These students stressed the importance of connecting concepts and laws to real life situations, and they regarded doing problems as one way to make it happen. In most cases, problems would present a real life situation that needed to be analyzed with the scientific concepts and laws they had learnt. For example, Zheng gave an example to illustrate how a problem could be solved with a scientific concept:

> In the university entrance examinations there was a problem asking for the electricity field between two layers of clouds. The clouds can be regarded as a capacitor.

The strategy the students reported to apply knowledge to solve problems was to mentally form a picture of the real life situation, and in many cases to draw the diagram on a piece of scratch paper. For example, Shi stated that being able to imagine the scenes of physical process that the problem presented was the key to solve the problem:

> I remember what the teacher said when he tutored me: 'the truth about many students not being able to solve physical problems is that they do not have a clear picture, or live scene of the physical processes'. If the student could have this clear live scene of the abstract process, he would have no problems not to be solved.

Juan used her experience to testify the importance of imagining the scenes of the physical processes that the problem presented. Juan recounted her experience in solving a problem:

> At the beginning I had no clue, I had to think hard. After thinking about the problem for a while, I gradually knew the process the problem described. After knowing the physical process of the problem, I could try different ways with different formulas, at last I would be able to find the breaking point and solve the problem.

4) Persist in solving one problem

In contrast with the students who thought it unwise to persist in solving difficult problems, the students with the view of ‘applying’ considered that persisting in digging in problems was a quality students should possess in learning science. For example, Hui said: “The best quality a student should possess to learn science is to be able to persist in digging into problems.” Xue believed that persisting in solving problems was the quality for a student to win a fierce competition in university entrance exams.

> In this fierce environment of competition, the current university entrance examinations test one’s confidence, carefulness, and one’s persistence in solving difficult problems.

Students reported enjoyment of the enlightenment and success that solving a difficult problem brought to them. The enjoyment could become an incentive for them to try on other difficult problems apart from an enhanced self-esteem. For example, Shuo reported sudden enlightenment and happiness in solving a problem after a long time of thinking:

> It may take ten to twenty minutes to attack a difficult problem. Sometimes it may take longer… Anyway it takes time before some divine light shines and the solution is found... I was happy because I was the only student who solved the problem.

Students reported that the process of persisting in solving a problem helped to improve their thinking skills. For example, Liang described how he solved a problem and stated the significance of this process:

> Because I had pondered on the problem for a while, I gradually formed a picture of the physical situation. Then I tried different ways with different formulas, at last I would be able to find the breakpoint (突破点) and get the problem solved… My thoughts became wider and my knowledge became solid after pondering on problems.

Shuo expressed a similar idea that his persistence in solving problems helped expand his mind and thinking skills.

> I mainly depend on my own efforts to solve problems. I have had a habit of thinking out myself since I was young. It is very helpful to expand my thinking and help my thinking leap forward if I can solve a difficult problem myself. It is quite different from just listening to how this problem should be solved.

5) Draw inferences about other problems based on one problem

Drawing inferences based on one problem meant that students could infer how to do a set of problems based on one solved problem. The students with the view of 'applying' considered that drawing inferences based on one problem as a more effective approach than practicing doing problems. For example, Fei quoted Confucius' maxims to support her argument:

> Sometimes I want to do as many problems as possible, but in fact it is not as meaningful as to stop and think over a problem just done. There is a saying called 'learning without thinking is a waste of time' （学而不思则罔思而不学则殆）. To do more problems in order to see more problems is

> an act of seeking quick success. The best approach to do problems is to draw inferences about others based on one instance (举一反三).

The crux of drawing inferences based on one problem was reflection, or "thinking over" in Fei's vocabulary. Similarly, Wei reported that she would explore how one problem could be changed to other forms and how the concepts involved could be applied in other situations:

> There is a concept involved in this problem, and you can ponder how this concept can be used in other situations…the more you think over the problem and make associations by thinking about the concept, the more understandings you will have.

In summary, students with the view of applying concepts and laws in doing problems did not agree to the idea that they should do a sea of problems, because they thought that the goals of doing problems were to apply what they learnt to diverse situations and improve their thinking skills. These students reported that they persisted in solving difficult problems and they inferred how to do a set of problems based on one solved problem.

Summary

The students in this study reported that doing problems was a major part of their process of learning science. Two contrasting views emerged as to why and how they should do problems. The students with the view of 'practicing' considered that practicing a great amount of problems was necessary, because it could develop their understanding of the concepts and laws, and improved their skills and abilities in doing problems. The students with the view of 'applying' considered that they needed not to do a sea of problems because doing problems was a way to apply what they learnt to diverse situations and develop their thinking skills. The students with the view of ‘practicing’ stressed reviewing wrongly-solved problems, while the students with the view of ‘applying’ focused on drawing inferences based on one solved problem.

4.2.6 Category Six: Learning science as working hard

The students in this study reported that learning science required hard work. In their views, a student cannot succeed in learning science without working hard. Two subcategories were developed in understanding their notion of working hard in learning science: working hard as investing time and working hard as being wholehearted.

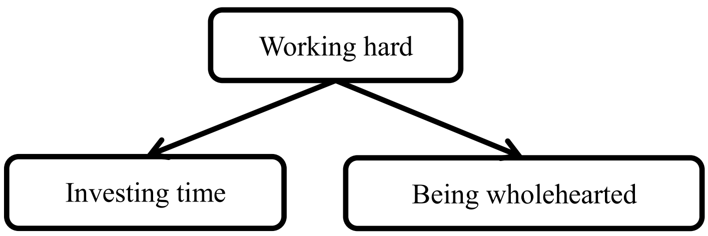

Figure 4.6 Structure of ‘Requiring hard work’

This researcher noticed that some students have a holistic view on working hard, i.e. they do not tell the difference between investing a lot of time and being wholehearted. But for the cohort of students being studied, the data suggested that they have different inclinations whether regarding working hard as investing time, or regarding working hard as being wholehearted. The students with a view of working hard as investing time tended to consider that learning was hardship, i.e., hardship was an indispensable part of learning science, while some other students tended to consider high efficiency was the key component of learning science. The former group of students tended to plan quantitatively, while the latter group of students tended to plan qualitatively. The former group of students emphasizing the function of willpower in investing a long time in learning science; while the latter group of students stressed the importance of awareness and control in retaining the high efficiency.

Table 4.2 Investing time versus being wholehearted

	Investing time	Being wholehearted
What	Inclining to invest time	Believing in wholeheartedness
Why	Approving of hardship	Seeking for high efficiency
How	Planning quantitatively	Planning qualitatively
	Emphasizing willpower	Emphasizing awareness and control

4.2.6.1 Working hard as investing time

The students who reported working hard as investing time considered that enduring hardship was a quality to learn science. These students emphasized the importance of applying willpower in enduring the hardship. Some of these students reported that they did not make plans because plans had been made for them, and some of these students made quantitative plans as how much time to invest or how many problems to do.

1) Being inclined to invest time

Xiong was one of the many students who reported that they spent many hours in learning science. Xiong indicated that the time he spent by his desk every day was about 15 hours, and he persevered in his studies in spite of mental and physical fatigue. Xiong stated:

> From 5: 30 am to 9:30 pm, every hour is packed with classes, except three half hours for three meals. I only have some time to play basketball on Sunday afternoons. Sitting over 12 hours a day makes my legs and waist uncomfortable sometimes...

The students with the view of working hard as investing time reported that they got up very early or stayed up very late so that they had more time on their study. These students showed great perseverance in challenging their biological craving for rest. For example, Shuo reported that he worked into the early mornings and slept only for three hours a day. Shuo stated:

> I was dreaming to enter the provincial team for science Olympics. I worked very hard during that time. I worked into 2 am every day, and I sometimes got up at 5 am.

The reason reported that they had to persevere with their studies in spite of their biological need to sleep was that they always felt that their study time was not enough. For example, Cai explained:

> The time is often not enough. After finishing my homework, it would be 10:30 pm. If I went to bed at that time, I would not have the time for review. Thus I did not go to bed and persevered with my reviewing.

2) Accepting hardship

The students reported that working hard was bitter and painful but they must endure it. For example, Xu talked about the physical fatigue and the psychological pressure in learning science, but he asserted that one should not be afraid of it. Xu explained his understanding of working hard.

> Learning science is not only physically demanding, that is, you have to get up very early and stay up until very late, but also the psychological pressure is bitterer than physical labor. You cannot go to sleep, like when your teacher criticized you or people close to you said something (negative about your study). Thus to learn science is to eat bitterness and you should not be afraid of that.

These students reported that they may not feel bitter in the process of learning, but after that they may feel tired and bitter. For example, Zheng described how hard he worked in learning science:

> If you are immersed in your learning, you will not feel bitter. But after you reflect and see back, you do feel painful. Every day you get up at 5:30 am and got to bed at 11 pm or 12 am. At noon you have a 15 minute nap by putting your head on the desk in the classroom. It is a painful process when looking back, but you do not feel it painful when you are in the process, except for that you feel sleepy or troublesome sometimes.

These students reported that they believed that hardship was a necessary experience before they can succeed. For example, Li quoted her teacher's motto to support her belief:

> I like what my teacher said: A beautiful butterfly cannot come alive unless the pupa has experienced a long darkness (只有经受蛹的黑暗，才有破茧成蝶的美丽). One has to experience the hardship of working hard before success.

3) Planning quantitatively

The students with a view of working hard as investing time reported that they made quantitative plans. Some of these students made zero plans because plans had been made for them by their teachers and parents. Some other students reported that they made plans, such as how much time to invest in learning science or how many problems to do. For example, Xiong stated that he followed his teachers' plans, and when he made plans his focus was the amount of problems done. Xiong explained:

> I follow my teacher's plans. I will ensure the amount of problems that I do every day. Otherwise my hand will be out of practice. My speed of doing a problem would be reduced significantly.

For another example, Shi reported that he did not make plans, but his mother forced him to do so, and the plan was about investing how much time in learning.

> I do not plan much. My mother forced me to write a holiday plan and put it on the door. The plan is to tell what to do at what time... For example the plan says to watch TV at 9, study at 10, I would watch TV at 9 and 10.

For the third example, Hui made plans, and her plans were mainly to invest more time in learning science. Hui planned to get up too early in the morning or she planned to make use of the break time between classes:

> I planned to make use of the ten-minute break to read or do a problem... Sometimes I wanted to get up early to memorize something…

4) Emphasizing willpower

The students with a view of working hard as investing time reported that willpower was required for them to work hard. They stated that they must have the willpower and be willing to control their focus on their work. Being distracted and obsessed with novels, internet surfing, and computer games were major obstacles reported for students from working hard. For example Tian confessed that she did not have the will power to work hard and she wished she did:

> Will power is very important, but my will power is very weak. That is why my grades are not good…I planned to do homework, but because I like reading novels, watching videos and listening to music, I may indulge in one of these activities and submerge... I said to myself that I will work after this chapter, but after one chapter I am still talking to myself that I will begin to work a chapter later. So the time passed along without learning at all...

Some other students reported that they possessed strong willpower to work hard. With the willpower, they could fight against the biological needs for rest. For example, Shuo talked about how he used his willpower and according measures to invest time in learning:

> I worked into 2 am every day, and I sometimes got up at 5 am. It was in winter. When I got up, I would immerse my head into the cold water to keep me awake.

These students reported that having strong willpower was more important than having an interest in learning science. They would force themselves to invest a lot of time in learning science. For example, Shan believed that a student could learn well if he or she was obligated to learn. Shan claimed:

> If he is obligated to learn, he can apply his willpower to invest more time and still learn well, even when he is not interested in learning science.

In summary, the students with a view of working hard as investing time considered hardship as an indispensable part of learning science, and they reported that they must possess strong willpower so that they can execute their plans of investing a long time and doing many problems.

4.2.6.2 Working hard as being wholehearted.

The students with the view of working hard as being wholehearted reported that they sought for high efficiency of learning instead of the absolute quantity of time invested in learning. They also reported the tendency of planning qualitatively, and emphasized the important role of awareness and control in retaining the high efficiency.

1) Being wholehearted in learning science.

When students talked about working hard, many of them meant being wholehearted. The Chinese word they used, 认真, can be translated as ‘serious’ or ‘earnest’, and the essence of the seriousness and earnestness was to put all their heart in learning. For example, Tian praised her study partner for working hard by being serious, and then Tian confessed that she did not work hard because she was not serious. Tian stated:

> Her time is partly spent in doing home chores… She studies hard and she is serious in her learning... She asks questions a lot. Her will power is much stronger than I... I did not study seriously at junior middle school. I did not understand many parts of the concepts and laws, and I did not do anything to improve it.

For another example, Wei considered being wholehearted as one of the two qualities for a student to learn science:

> To learn science well, two things [qualities] are important. First your brain has to run fast, based on a good understanding. Second is being earnest. Being earnest means to put all your heart in learning, and [then] your thinking can be comprehensive.

2) Seeking for high efficiency

Students being wholehearted in learning science probably had also invested a lot of time, but their focus was on the efficiency of learning, instead of on the absolute quantity of time invested. In many cases, these students reported there was no need to invest all their time in learning and they wanted to strike a balance between work and rest. After a good rest, they could learn wholeheartedly and retain high efficiency of learning. For example, Chang thought that a student who invested too much time in learning would lose flexibility in applying concepts and laws. Chang stated:

> I think one should strike a balance between work and rest. One should work hard, but not like a wonk (死用功). Otherwise he would not know flexibility. For example, he could only use one method or one formula, but when the

problem changes, he cannot solve it.

Although Chang did not use the exact word ‘efficiency’ when he talked about the students whom he called “wonks”, he was opposing the low efficiency caused by overly investing too much time. Later Chang talked about playing basketball and he asserted that playing basketball would not interfere with his study and contrarily it could help with his learning efficiency:

> I would play basketball when I want to relax. I do not think playing basketball will interfere with my study, because after a while of active relaxation, my study will be more efficient.

For another example, Shi reported that his mother did not think it a good idea to study for a long time without relaxation. When Shi was reporting his mother’s comments, the author could tell that Shi really agreed with his mother. Shi stated:

> My mother does not appreciate wonks (死用功). She said one has to know how to learn [i.e., striking balance between work and rest]. My mother encouraged me to learn some arts, such as playing guitar. I also learnt to swim, to play badminton, and basketball. She hopes I can go out to do sports, instead of staying at home all the time.

3) Planning qualitatively

The students with a view of working hard as being wholehearted reported that they planned qualitatively, instead of planning quantitatively as how much time to invest or how many problems to practice. These students focused on the quality of the work planned for a specific time, i.e., the efficiency of learning. For example, some students in this study reported that they would plan to review the concepts after class, before doing problems, before going to sleep, or before exams. Since the task was for understanding the concepts, normally they would not plan an absolute time period for the task. The following are three quotes of the students who planned qualitatively:

> Before doing problems, I would review the content just learnt, because my comprehension may not be well enough. I would engage a comprehensive review before exams, about a week in advance. (Qun)
>
> I may not completely understand what my teacher taught at class. I go over them after class. I finish all my homework at the same day. (Dong)
>
> I have daily plans, that is, to finish all the homework, read textbooks, summarize what the teacher taught... (Dan)

4) Emphasizing awareness and control

Students with a view of working hard as being wholehearted reported that they were aware of their learning activities and monitored them accordingly. The awareness and control over their learning processes provided evidence to be wholehearted and increased their learning efficiency. For example, Li reported that her conscience helped her be aware of and control what she was doing:

> I have a good control over myself. I have known that I should finish what I should do before doing something else since I was in elementary school…I wanted to watch TV too, but I told myself that I would be left behind if I watched TV while my classmates were studying hard... If I did something else instead of doing what I should do, my heart would not be at ease.

For another example, Dai stated that some of his classmates worked hard as being wholehearted and controlling themselves, while some other classmates were not working hard because their heart was not in learning and they did not control themselves. Dai articulated:

> They work hard, and all their hearts and souls are on learning. They can focus on learning and resist temptations. While for those who have less control, their efficiency was low, because their heart was on something else.

In summary, the data suggested that there existed two views of working hard. Some students tended to regard working hard as investing a great amount of time, while some other students tended to regard working hard as being wholehearted. The rationale for the students to appreciate investing a lot of time was reported as that they thought hardship was an indispensable part of learning process, while for the students with a view of working hard as being whole hearted, they thought high efficiency was the focus of their learning science. The students with a view of working hard as investing time tended to make quantitative plans as how much time to invest and they stressed the function of willpower in executing these plans; while the students with a view of working hard as being wholehearted tended to make qualitative plans and they emphasized the role that awareness and control played in achieving high learning efficiency.

4.2.7 Category seven: learning science as improving oneself

The students in this study reported that they regarded learning science as a way of improving themselves. Three subcategories were developed from the interview data: self-perfection, changing destiny, and serving family and nation. Self-perfection was a belief of students that they can grow morally, intellectually and socially by learning science. Changing destiny was a belief that they can achieve their utilitarian goals such as going to university and having a good future by learning science. Serving the family and nation was an altruistic belief that they can accomplish by learning science. Figure 4.7 offers a visual representation of the category.

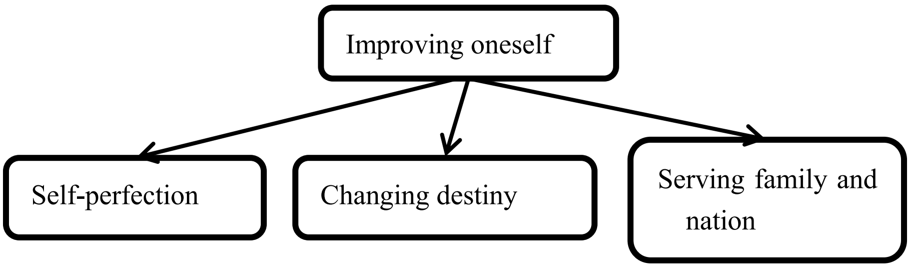

Figure 4.7 Structure of ‘Improving oneself’

4.2.7.1 Improving oneself as self-perfection

Some students in this study reported that they regarded learning science as a process of developing their intellect and their deportments. They considered that they could cultivate and improve their moral, intellectual and social qualities by learning science.

Firstly, these students believed that their intellect was malleable for better quality after cultivation. In other words, they must believe that their intellect can be improved so that they could orient their efforts towards it. The following are two quotes that reflect the view that they can improve their intellect by cultivation.

> Being intelligent means one’s brain runs fast. Practice makes perfect. After seeing a lot and practicing a lot, the student will become smarter by responding more quickly and solving problems more skillfully. (Wei)

> Intelligence can be improved. If they think that they can become smarter although they know that they are not that smart for now, they will work hard towards it, and gradually their intelligence will get improved. I do not think anybody was born stupid, only those who think they cannot learn and thus are not learning are stupid. (Dong)

Secondly, although many students in this study reported practical goals of learning science, such as competing over their classmates, going to university etc., which was discussed in section 4.2.2.2 and will be discussed in 4.2.7.2, the students with a view of self-perfection regarded learning science as process in which they grow as a person, i.e., to improve their moral, intellectual and social qualities. For example, Dong quoted his grandfather's words to express his view on why students should learn science:

> Many people think learning is to find a good job. But my grandfather told me that learning is not for fame or wealth. Learning is for self-improvement.

Ze argued that the practical goals should be the natural result of learning and what he sought after was growing as a person, or improving oneself:

> I think to learn is a motivation for itself. I think it is not right to think about going to a good high school and good university. Instead, one should think only about wanting to learn. Someone might jump down from a high building if his goal was not realized. One should have only the pure goal of improving himself, not some other practical aims.

Ze explained that improving himself meant that he would have sharper eyes and wiser mind:

> One's ideological and cognitive levels will improve. A person can have a deeper understanding of the world, have sharper eyes about things

> happened around him, and know how to deal with problems wisely in real life... It is ok to compete against others, but it would depart from the learning itself if the person wants to show off. I do not think it wrong to seek for ranking or going to a good school. I think they are the results of good learning, not the reasons to learn.

Growing as a person for Dai meant that the person was educated, cultured, and refined with high abilities:

> To learn is to improve one's ability. When you come out of school, you leave an impression of being literate and cultured. To talk with uncultured people is painful.

Improving oneself for Li meant that the person became more virtuous and honorable:

> Learning is a process of cultivation. Your morality will be improved and you can be more righteous and virtuous.

In summary, some students reported that to learn science was a process of improving their moral, intellectual and social qualities because they thought that these qualities could be malleable and learning science was the right forging process.

4.2.7.2 Improving oneself as changing destiny

Many students in this study reported that learning science could help them achieve their utilitarian goals such as going to a good school or university, having a good job in the future. All these goals are related to their life course after high school, and these students suggested that their learning science could influence or change their life course. Some students did not use the specific word 'destiny', while other students explicitly stated this goal. All these utilitarian goals can be named as changing their personal destiny.

The first form of changing destiny was to be able to enroll in a good high school or a good university. These students reported that going to a good school was the major motivating force for them to learn science. For example, Tian wanted to go to a good high school, and she could restrain herself from getting distracted with this goal in mind. She recounted her experience of motivating and controlling herself:

> When I was at grade 9, I wanted to enroll to a good high school. I wrote four big characters on a blank paper to me. The four characters are "learn for high school". The four characters are big in colored pens. I hang them in front of my desk. I can see it whenever I raise my head. When I wanted to read novels from my cellphone, I would look up. I may say to myself, just for a short while. But I hold the cellphone in my hand, and after fighting in my heart, I would put the cell phone down and started to work.

The second form of changing destiny was to have a good future. These students reported that they believed in a strong connection of their academic achievement in learning science and the quality of their future life. For example, Li claimed that working hard in learning science could lead her to a good future:

> First of all, I would not have a good future if I did not work hard. Secondly, I would be able to choose the career I like, instead of doing a random job or no job. At least, I must be able to feed myself.

These students reported how the connection between achievement in learning science and a good future made their studying life more meaningful. For example, Shuo shared his experience of being lost in his chores of everyday studying tasks and felt much better when he was aware of the connection between the chores and his future. Shuo stated:

> When I came to high school, I did not work hard [in learning science]... I had a period of being lost. I felt that what I was learning was useless. The days were too insipid and dull. I did not know what I learnt for. Now I feel much better because I am thinking of a good university, a good career.

The third form of changing destiny was to change fate. To change fate is a more abstract and perhaps much stronger motivation than simply wanting a better future. Also the data suggested that students from the countryside, rather than those from the big cities, reported an intense feeling of the mission to change their fate. These students stated that they would have to be a poor peasant or low income worker for the rest of their life if they were not able to enroll to a university or college. For example, Yi described his parents' hope and his desire to leave the countryside:

> First of all it is the problem of finding a good job. For us from the countryside, it is difficult to find a good job without going to a good university. My father is a renovation worker, and I helped him during the holidays. The labor job is too tedious. Both my father and mother graduated from high school and they were not admitted to any university. So my parents hope that I can enter a university.

At one of the schools where I took interviews I saw a big banner on the wall, 'knowledge changes fate'. When I asked Chang for his opinion on this banner, he stated that the three-letter words were his motto. Here is the conversation:

> Chang: If you do not learn well, you will have almost no future. Now competition in society is very fierce. You will be eliminated if you do not have some level of knowledge. You will live at the bottom of the society. Only learning can change your fate.
>
> Interviewer: It seems that I saw a board at your school saying knowledge changes fate.
>
> Chang: Yes. And I believe in it. Learning can increase a person's knowledge and experience. You will have deep understandings of the world and society. Otherwise you will live blindly and be a

> slave of your fate. Knowledge can make you the master of your fate.

In summary, many students in this study reported that learning science could potentially change their personal destiny. Three forms of changing destiny emerged: enroll to a good school or university, have a good future, and change fate. All these goals are utilitarian in nature, but the degree of abstractness is different.

4.2.7.3 Improving oneself as to serve family and nation

Some students in this study reported altruistic motives in learning science. These students stated that they wanted to learn science so that they would have the abilities to take care of their parents and serve the nation in the future.

1) Family oriented

Most of the students in this study voluntarily talked about their parents and regarded having the ability to take care of their parents as a major reason for them to learn science. These students reported that they had to learn science well so that they could have a better future and their parent's wellbeing could be guaranteed. For example, students made the following statements:

> One motivation to learn science is that I hope I can share some responsibilities of my family when I grow up. They can live a happy life when they get old. (Fei)

> My parents paid a lot of efforts to support my learning for so many years, I will have to repay their great care when I grow up. (Dai)

> I will go to a good university, for the purpose of a better living in the future. Then my parents will have no need to worry about me. Their money will

> be used by themselves, and I will be able to feed myself. (Shi)

> My parents paid a lot of time and energy in supporting me to go to school... When I have a good job, I can support my parents…My parents loved me and supported me in my growing up. I should return their love and support when they are old. (Tian)

Apart from hoping to serve their family when they grow up, many students stated that to meet the expectations of their parents was a great inducement for them to learn science. For example, Ze stated that he wanted to meet his parents' expectations of being excellent in learning science and thus win honor for them:

> My motivation comes from the expectations from my parents. My good academic result and high ranking can win honor for my parents. (Ze)

Tian used a metaphor to describe the relationship of her learning and their parents' support: "I am their fruit. They planted me. If I grow well, they will feel proud." Xu stated that one of the motives of his classmates was to earn face/esteem for their parents:

> I think one of the motives is to earn face for parents. It would be humiliating for the parents if their child always ranks at the bottom of the class.

2) Serve the nation

The data suggested that not everybody considered that learning science was to serve the nation. They reported that they did not think there was a connection between learning science and serving the nation. For example, I mentioned that Confucius encouraged people to learn for the nation and asked my interviewee, Shan, if she and her classmates agreed to the idea. Shan answered definitely: "No, I do not think any of us has the thought of learning for the nation."

Although Dai acknowledged that a student should serve his nation, he argued that learning to serve the nation was too big a goal:

> As a Chinese, I certainly should serve our nation, but how many people are able to really serve the nation? To serve the nation would be a big empty word if one did not have the capabilities...

There are a considerable number of students in this study who reported that serving the nation was one of their most important motivations to learn science. The following statements are some examples:

> I think my motivation is in two sides. One side is to do something practical for the nation; another side is to enjoy life... (Shuo)
>
> The brands of cellphones are mostly from other countries. It is a pity that the local brands are not doing well. If I become a scientist, I can make more contributions to the country. (Tian)
>
> I now learn well, later can I serve a little for the nation. If I did not learn well, what could I do except from selling my labor? (Dong)

A few students reported that to learn for the nation was their strongest motivation for learning science. For example, Xu reported that he had held the motivation of learning for the nation since he was young. The following is the conversation:

Xu: In practical sense, the motives are to make some money and make a better living. In a bigger sense, the motive is to contribute to our nation.
I: Do you think it is your real motive to contribute to our nation?
Xu: Yes, it is. I think it as a motive from under my heart, a stronger motive than anything else. I want to make some contribution to our country, to make it stronger. If our country is not well, how can an individual succeed?

In summary, some students in this study reported altruistic motives in learning science, i.e., to learn science was to serve their family and the nation. They considered that learning science could make them capable in the future to bring happiness to their parents, and contribute to the development of the nation.

Summary

The students in this study reported that they regarded that learning science was a process of improving themselves. Three subcategories emerged: self-perfection, changing destiny, and serving family and nation. Most students considered that their intellect and deportments were malleable and learning science was a great process to forge and improve their intellect. Many students in this study reported that they thought learning science could potentially change their destiny: enroll to university and have a good future. Some students considered that learning science could let them capable in the future to help with the wellbeing of their parents and the prosperity of the nation.

4.3 The outcome space of Mainland Chinese students' conceptions of learning science

The outcome space refers to the relationship among the categories of the conceptions. Traditionally the outcome space is hierarchical in that some conceptions are regarded as being lower or at a surface level, while other conceptions are regarded as being higher or at a deep level. For example, 'memorization' has often been regarded as an inferior conception than ‘understanding’ in the literature, as discussed in chapter 2. Thus the traditional structure of the outcome space is a nested hierarchy. But as Akerlind (2005) pointed out, “the structure of an outcome space need not always take the form of a linear hierarchy of inclusiveness; branching structures or hierarchies are also a possibility.”

1) A unique structure

The outcome space of this study is proposed to have a unique structure rather than the traditional nested hierarchy on the basis of the finding that the categories of Mainland Chinese students’ conceptions of learning science were not hierarchical. In other words, this study did not find any category of conceptions of learning reported by these students that is superior or inferior to any other category. Thus the categories are proposed to be organized within a circle possessing equal status, indicating that no one was less important or more important than the other. Each category is an indispensable part of the complete whole conceptions of the cohort of Mainland Chinese learners in learning science. The outcome space of Chinese students’ conceptions of learning science is illustrated in figure 4.8. The equal sectors in the diagram are not to suggest that the frequency of students’ conceptions were reported to the same extent. Rather, the equal sectors emphasize the equivalent status of all the seven categories in their complete holistic conceptions of learning.

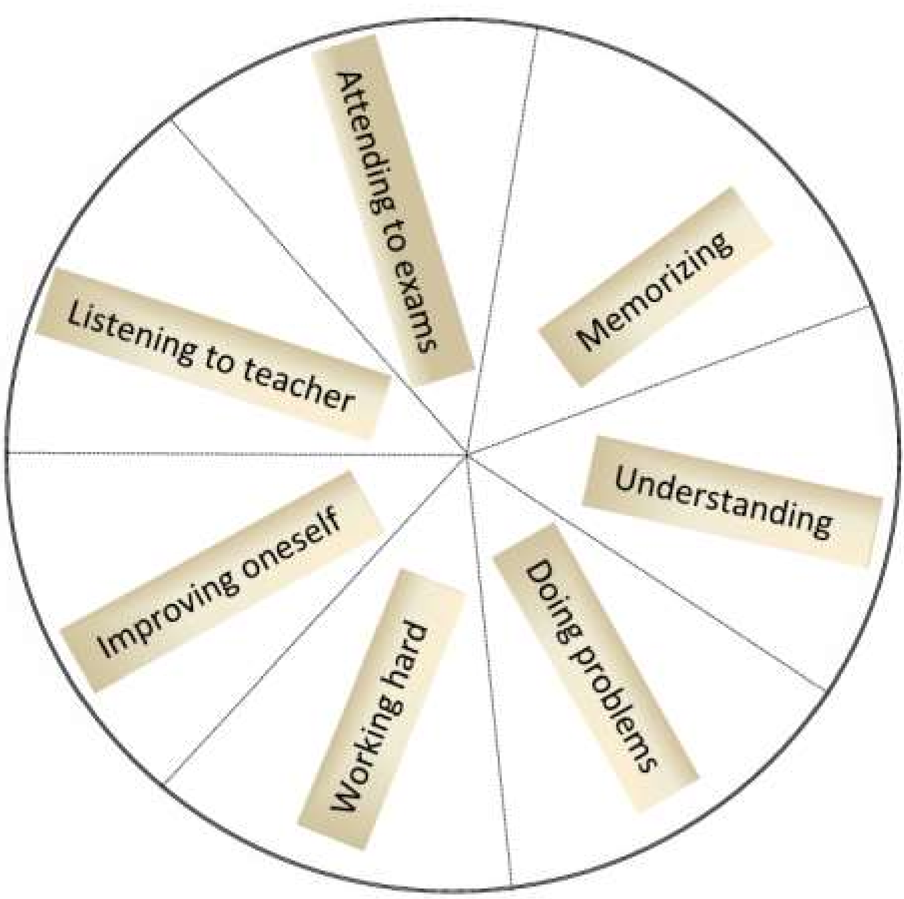

Figure 4.8 The structure of Mainland Chinese learners' conceptions of learning science

2) Justification of the nonhierarchical structure of the outcome space

The existence of the nonhierarchical structure of the conceptions of Mainland Chinese students in learning science can be justified from three different aspects of evidence: case studies, none mutual exclusiveness of the categories, and the interrelating connections among the categories.

1) Case studies: The study interviewed 96 students and almost all of them talked about all the seven categories of conceptions of learning science. That is to say, Chinese students did not regard learning science simply as listening to teacher or

doing problems. On the contrary they considered each category an indispensable part of a holistic view of learning science. This is supported by the case studies reported in section 4.4, although the goals of the case studies are more than providing evidence for the existence of a nonhierarchical structure of the conceptions of learning science for Mainland Chinese learners.

2) No mutual exclusiveness. Data analysis of the interviewed 96 Chinese students suggests that the lower level of conceptions listed in Marton's nested hierarchy and also identified in this study will not exclude the upper level of conceptions as the nested hierarchy indicated. For example, memorizing is regarded as the lower level conception in Marton's hierarchy, and understanding is regarded as the higher level conception. The literature (Marton, 1993; Biggs, 1996) and my data reveal that memorizing often comes after or before a deep understanding of the knowledge being memorized. This study did not find any Chinese student who thought that memorization was not indispensable from understanding. For example, Dong said:

> I think the knowledge of science subjects must be understood first before putting it into memory. Otherwise you cannot have a good memory of the knowledge. Even if you can memorize a law or a formula with the help of many times of repetition, you cannot use it without a good understanding. So it would be meaningless just to memorize some facts without a good comprehension.

Although the literature supports the uniqueness of Chinese learners in that they integrate memorization with understanding, it is still the tradition for researchers, including some researchers from Asian (e.g., Tsai, 2004), to categorize 'memorizing' as a lower conception of learning. The structure suggested helps to explain this contradiction.

3) Interrelating connections: The fact that all the students in this study reported more than one category of conceptions of learning and some of them reported all the categories implies that these students held a holistic view of learning science, i.e., learning science involves all the learning processes. This holistic view of science learning suggests that the seven categories of conceptions are interconnected components of a dynamic system of learning science. In this study, the students reported multiple-way relationships among the seven categories, and the multiple-way relationships are illustrated in figure 4.10.

'Working hard' is the base of science learning according to students' descriptions of their learning processes. No matter what they do, either listening to the teacher, memorizing information, deepening their understanding, doing problems, taking exams, or improving themselves, they reported that they must put all their hearts in learning science or invest as much time as possible. On the other hand, students reported that high efficacy achieved in these activities would motivate them to work harder and thus create a much solid foundation for all the processes of learning science.

'Understanding' and 'memorization' are bound together as one component with respect to the relationship with other categories, because they were reported closely combined. 'Listening to teacher' is connected with 'memorization and understanding' because students reported that being attentive to their teacher helped them remember information easily and understand it deeply. ‘Listening to teacher’ is connected with ‘doing problems’ since students reported that they learnt how to do problems by listening to their teacher. ‘Listening to teacher’ is also connected to ‘attending to exams’ and ‘improving oneself’ since students reported that they had to listen to their teacher in order to improve their abilities and do well in exams. On the other hand, positive achievement in these processes, such as deep understanding, proficiency in solving problems, or performing well in exams, would enhance their self-efficacy and further their engagement in listening to the teacher.

‘Improving oneself’ is related to all other categories as is ‘attending to exams.’ In the diagram this researcher intentionally placed the two categories to two opposite sides because some students reported that doing well in exams was their ultimate goals of learning science, while some other students reported self-improvement was their fundamental goals of learning science. While for the latter group of students, ‘attending to exams’ was one means to reach their goals of self-improvement. This difference does not mean that ‘improving oneself’ and ‘attending to exams’ are mutually exclusive, because some students reported that they can better attend to exams if they have improved themselves, and others reported that they attend to exams so as to improve themselves.

‘Doing problems’ is related to all other categories as well. The students in this study reported that being able to do problems is the result of listening to teacher and memorizing and understanding information; and at the same time, doing problems can improve more engagement in listening to the teacher, better retaining and understanding of information, and higher scores in exams. In addition, many students in this study reported the connection between doing problems and improving themselves.

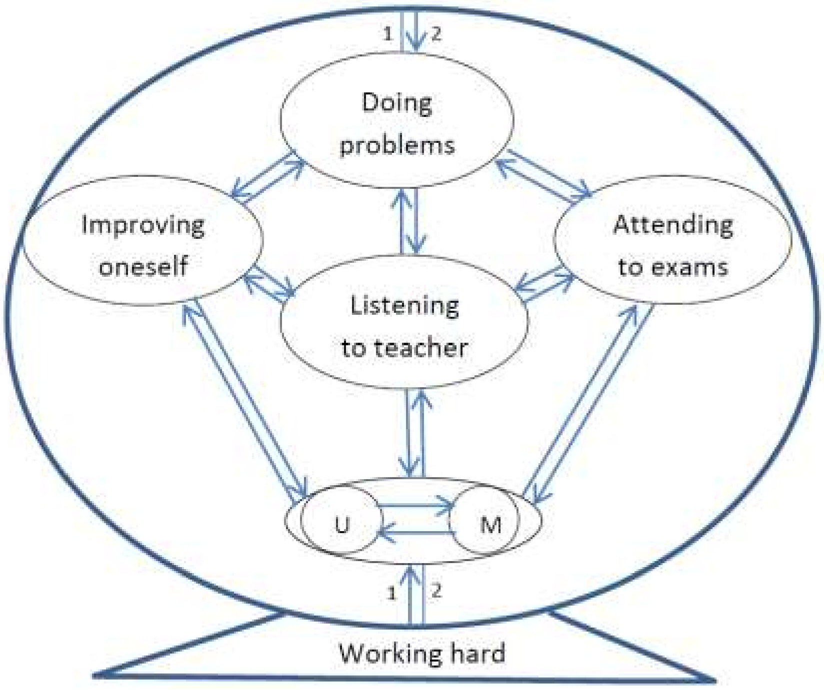

Figure 4.10 The interrelating connection among the categories (U: Understanding; M: Memorization; Direction lines with the same number mean two segments of one direction line, and represent the connection between 'U and M' and 'doing problems)

In summary, the seven categories of conceptions of learning science are interconnected, and they should be placed in a structure enjoying similar status and weight, instead of sitting in the nested hierarchy in which some categories are superior while some others are inferior. Please note that figure 4.10 does not represent the outcome space because outcome space is the relationship of the categories that correspond to different groups of people. More specifically, when one category is more complex than and thus superior to another category, it means that one group of people have more complex and superior conception than that of another group of people. For example, if somebody claims that “memorizing” is lower than “understanding,” the person is talking about the two group of students who have different conceptions of learning, i.e., they either think learning is “memorizing” or “understanding.” However, this study found that Mainland Chinese students consider that learning is a holistic structure that consists of all the seven categories, and the figure 4.10 just depicts the internal relationships of the seven categories for the same group of students.

4.4 Case study

The case study in this study intends to describe and interpret students’ lived experiences in learning science in a ‘longitudinal’ way, i.e., to report all the categories of conceptions of learning of one student, compared with the previous ‘transverse’ analysis that focused on common themes across all the participants (section 4.2 and 4.3). Apart from assisting with the triangulation of the findings from the transverse analysis, supporting the unique structure of the outcome space of the conceptions of learning science of the Mainland Chinese students, providing exemplars of different groups of students with similar understandings of learning science, this researcher hopes that the case studies can shine light on the individuals’ unique worlds of learning science, which are worthy to be appreciated and understood.

4.4.1 Jiayi

Jiayi was an 18 year-old female student in grade 12 at a country school in

Hebei Province. Both her parents were farmers who had junior middle school diploma. Jiayi reported that her parents were busy making a hard living but supported her schooling wholeheartedly. Jiayi reported that she had been always ranked top three until she learnt physics. Jiayi reported how she learnt science and how she should learn science. The seven categories of conceptions of learning science developed by the transverse analysis are applicable to describe and interpret Jiayi's experience and views of learning science.

1) Listening to the teacher

Jiayi understood that learning science involved listening to the teacher. When she talked about how she learnt science, Jiayi reported difficulty in following her physics teacher. Jiayi stated:

> I felt that I have not entered the door of learning physics yet since I started to study physics in grade 8…I did not know whether it was my teacher who taught too fast, or it was my thinking that was too slow. I felt that I could not follow my teacher.

Jiayi reported that she asked her teacher to slow down, but it did not work out. She explained:

> There are students in my class who are interested in learning science, and they seem not bothered by the speed of teaching. I asked my teacher to slow down, and my teacher slowed down a little bit in the beginning but got fast again, perhaps out of the habit teaching fast.

I was a little doubtful when Jiayi stated that she asked her teacher to slow down, because in my experience of teaching science in China for over ten years, it is very rare for a student to ask the teacher to slow down. But later after I found out that

Jiayi was quite close to her teachers because of her high ranking in class and most importantly because she was a student leader, the monitor (班长) in her class, it was explicable for her to raise her voice at class. When she found that she still could not follow her teacher well, she went on to seek for reasons from her own, because her classmates seemed fine with their teacher's pace of teaching.

In fact it was not accurate that Jiayi could not follow her teacher of physics at all. This was supported when she talked about doing problems, which will be discussed in detail later in 5) doing problems. Although Jiayi admitted that not being able to follow her teacher was a problem, especially in the part of electricity, she stated that the problem was not too serious.

> Interviewer: How serious was the problem of not following your teacher?
> Jiayi: I could not follow my teacher when I was studying electricity. I could not understand the circuit. Later when I figured it out, it got better.

Because Jiayi stated that she did not learn physics well, I asked her how she considered that she should learn physics. Jiayi answered with certainty that she should listen to the teacher:

> It is certain that one should listen to the teacher attentively and follow his train of thoughts. If one problem was not understood, one has to read the notes and think about it carefully.

Later when she talked about how she worked hard in learning science, I asked her a follow-up question of how exactly she worked hard, and she answered by listening to the teacher attentively. Jiayi explained:

> When I was in grade 7 and 8, I did not have to listen to the teacher because I could solve the problems after reading the samples. But when I got to grade 9, especially at high school, I found out that I had to listen to the teacher, or else I was not be able to solve problems.

In summary, Jiayi considered that listening to the teacher was a principal way of learning science although she reported some difficulty in following her teacher of physics. Based on the above quotes, Jiayi's view of listening to the teacher falls to the first subcategory, 'listening to the teacher unquestioningly', because Jiayi raised no doubt in listening to her teacher. On the contrary, Jiayi tried her best to follow her teacher, although sometimes with some difficulty.

2) Memorization

Apart from that one should listen to the teacher attentively, to remember the formulas was the second point Jiayi made on how one should learn science, and she made no further suggestions on how one should learn science. Jiayi stated: "One should remember the formulas, otherwise he cannot solve problems." Ironically Jiayi reported that she could not know how to solve problems although she has memorized the formulas, which will be discussed later in detail.

Jiayi stated that memorization with understanding was very important in learning science. She stated:

> Understanding was very important; otherwise you cannot solve problems although you have remembered the formulas. It won't work if you just memorize by rote and substitute values into the formula (死记，死套).

Now that Jiayi reported the importance of understanding in memorization of formulas, but at the same time she also reported difficulty in doing problems (discussed later), I asked her the follow-up question of how her understanding was. The following was the conversation:

> Interviewer: How was your understanding of the memorized formulas? For instance you have remembered 10 formulas, how well can you understand them, 100%, 80%, or less than 50%?
>
> Jiayi: Perhaps less than 50% (一知半解).

The word "perhaps" plus the irresolute tone reflected Jiayi's frustration and a little uneasiness of not being able to have a good understanding that she knew she should have. The issue of understanding will continue to be discussed later.

With regards to learning chemistry and biology, Jiayi also emphasized the importance of memorization with understanding. Jiayi stated:

> For chemistry, there is much knowledge that needs to be understood and then put into memory, such as the equations, the types, the precipitations, the change of colors, etc. Thus memorization is very important to learn chemistry. As for biology, I am interested in it, and thus I want to memorize the knowledge. Just because there is so much that I cannot see, such as the cell, the organelles, my comprehension is not much enough.

Jiayi considered that her understanding of the information in biology was not enough, although the word 'enough' is subjective and relative. Jiayi's acknowledgement of her limited understanding indicated that Jiayi had the conception that memorization should be united with understanding. However Jiayi had to depend on repetition when she could not understand the information. Jiayi claimed that she would want to remember the information for many times when she was interested. She stated:

> Interest is the quality one should possess to learn science, because if one was not interested in learning science, he would not want to remember the knowledge. If one was interested in science, he would go to memorize the information, and he would remember it after some times of repetition.

In summary, Jiayi regarded memorization as a major way to learn science, and she reported that one should memorize information with understanding, but in reality she had to use repetition as a major way of memorization because of her difficulty in understanding the formulas and scientific facts.

3) Understanding

Jiayi reported the importance of understanding, but at the same time she reported powerlessness of reaching a good understanding. Jiayi stated:

> I tried to understand the formulas, and I read the textbook for many times trying to understand the concepts, but I do not know why, it seems that I could only understand a little bit.

This researcher was curious to know how exactly her understanding of the concepts was, and why her understanding could not be developed as she wished. Thus this researcher asked her a specific question about the relationship between work and energy.

> Interviewer: Have you learnt work and energy?
> Jiayi: Yes, I have.
> Interviewer: When did you learn them?
> Jiayi: At senior grade 1 [grade 10].
> Interviewer: What are work and energy, and what is the relationship between them?
> Jiayi: Work is ‘w’, and w = F D; Energy is mgh, and also 1/2 mv^2. The relationship? Eh, they have the same units, but they are not the same,

> aren't they? There is a formula, is it the kinetic energy theorem? Yes, it is.

Jiayi has remembered the formulas, but her description of the concepts lacked richness. Jiayi did not tell that work is a process quantity and energy is a state quantity. Although she recollected the formula, Jiayi did not describe what the formula meant. This researcher could identify that Jiayi's understanding of the concepts based on her answers was not deep.

Jiayi's report of how she tried to develop understanding might explain why she did not achieve the desired level of understanding. Firstly, Jiayi did not report that she previewed her classes, while about one half of the students in this study reported that they did regularly. Secondly, although Jiayi considered that she should review from time to time, she reported a lack of time for reviewing her lessons. Jiayi stated:

> One should review as often as possible (学而时习之), but all my time is spent either to attend classes or to finish my assignments. I really have no time to review.

Thirdly, Jiayi reported that summarization helped her in understanding the concepts and laws, but she mainly depended on her teacher's summarization. Jiayi stated:

> If my teacher summarized the knowledge before exams, I felt that my understanding was ok, and then I could solve some problems. But if my teacher did not summarize the knowledge before tests, I felt confused and I did not know which concept or law to use.

I asked her if she summarized the knowledge, and she said she did. Jiayi stated: "Before tests I would copy the formulas to notebooks." In Jiayi's view, to copy formulas was equivalent to summarizing the knowledge. Jiayi's simplified view of summarization may be one of the factors that lead to her reported failure in understanding the concepts.

In summary, Jiayi reported knowing the importance of understanding and she tried to develop her understanding by reading the textbooks, but her understanding of the concepts and laws was not satisfactory. Jiayi reported that she should review her classes, but she reported not having the time to do the reviews. Jiayi reported that she made summaries, but she equated coping formulas to making summaries. Jiayi's not previewing and reviewing her classes and not making summaries in an optimal way may contribute to her failure in reaching her desired level of understanding.

4) Doing problems

Jiayi talked about doing problems throughout the interview, and in her mind it seems that learning science was primarily about doing problems. Jiayi talked about her difficulty in solving problems and the measures she should take to improve her situation.

I asked Jiayi how she learnt physics, and Jiayi answered that she felt she had not entered the door yet, in other words, she was not sure of how she should learn physics. Jiayi had this negative feeling mainly because she could not solve problems. Jiayi stated:

> I have been learning physics for over four years since grade 8, but I feel that I have not learnt how to learn physics (没有入门). I would look for a formula based on the given quantities, and then substitute the numbers (找公式，套公式), but I could not gain any credit in solving complex problems.

As mentioned earlier, Jiayi talked that she must listen to the teacher; otherwise she could not know how to do problems. However, listening to his teacher could not guarantee that she could solve the problems. Jiayi reported that she still had great difficulty in solving problems even after her teacher demonstrated solving sample problems. Jiayi stated:

> I can understand my teacher's train of thoughts, but when it is time for me to solve a problem, I feel at a loss and cannot find out a trail of thought (摸不着头脑，找不到思绪).

Jiayi narrated how she might improve her situation. The first measure she said that she should take was to read more books and practice doing more problems. Jiayi stated:

> I should read more books and increase the amount of practice (加大练习量). Apart from reading textbooks, I should read reviewing-materials and reference books, in which there are samples and exercises.

The second measure Jiayi reported was that she should review the wrongly-solved notebooks. Jiayi stated:

> I had a notebook to which I copied wrongly-solved problems, but I do not use it too often. I wish I could use it more regularly.

One reason Jiayi reported was that she did not have the time. The other reason Jiayi reported indirectly was that she gradually lost interested in learning physics, and this will be discussed in the next section, attending to exams.

In summary, Jiayi regarded learning science as primarily about doing problems. Jiayi's frustration of not being able to solve problems caused her to doubt her own learning processes. Jiayi reflected that she should read more books for better understanding, practice doing more problems, and review the wrongly-solved problems more regularly.

5) Attending to exams

Jiayi mentioned the word ‘exams’ at least ten times during the interview, which suggests that exams were important for her. Jiayi reported that her parents hoped to see her good grades, but she failed to achieve good grades after coming to high school. Jiayi stated:

> My parents hoped that I can do well in exams, but after coming to high school my grades began to deteriorate, mainly caused by my low scores in physics. Now I am ranked about over 100 in my school [her school has about 500 students in grade 12]. Although I am ranked top five in my class [the school divided students into classes based on grades], I feel a little discouraged. I do not know where I should focus on my power. No matter what I do, I cannot catch up with those top students.

Jiayi’s low scores of physics greatly reduced her enthusiasm in learning physics. Jiayi stated:

> The first time I got a low mark I felt unhappy, but it did not affect my interest in learning physics. The second time I got a low mark I felt that I still had chances to catch up. When I kept getting low scores, I lost hope and interest in learning physics. I did not want to learn physics any more.

Certainly Jiayi had to learn physics although she did not want to. Jiayi’s reluctance in learning physics caused her to spend less time in learning physics, and less time caused her more difficulties in exams. Jiayi stated:

> Every time I had to take a test of physics, I would feel very nervous. I knew I would fail, but I hoped for good luck. Luck comes with effort, thus it was natural I did not have the luck. But still I felt sad when I saw my low scores. Then I wanted to do something to make a change.

Jiayi tried her best to avoid distress the exams of physics gave her, and very fortunately Jiayi was not bad in chemistry and biology, thus Jiayi could be still ranked high enough to maintain her self-esteem. Jiayi stated:

> My chemistry and biology were not bad since I had a good memory. Although my physics gave me low marks, the combined three was not that bad. I am glad the three subjects are combined as one.

In summary, Jiayi reported that she wanted to catch up with the top students, but her low scores in physics exams shattered this hope and wore out her interest in learning physics.

6) Working hard

Jiayi reported that working hard was important for learning science. Jiayi stated that she was still good at math even if she did not work hard in math, but for science, especially for physics, she had to work hard. Jiayi stated:

> Math was easy for me. I could learn math well only after reading some sample problems. But for science, I had to work hard, otherwise I cannot learn it (学不会).

Although Jiayi's low scores dampened her enthusiasm in learning physics, she said she had to persist on because she did not want to disappoint her parents and teachers, which is discussed later in detail. Jiayi stated:

> It is painful to learn physics, but I had to learn it…I would force myself to

> work hard at physics. For example, when I did not know how to solve a problem, I would try to restrain my impetus to give up. I would think of my parents…then I would manage to stay on the problem, and sometimes I would review my notebooks or textbooks trying to find out the solution.

Jiayi reported that one must learn science wholeheartedly. Jiayi stated that she had a good habit of monitoring herself so that nothing could distract her from her learning activities. Jiayi stated:

> I can monitor and incite myself. I never go to play before finishing my homework. If one was too relaxed and played too much, the person would become restless and he cannot learn science wholeheartedly. I had a classmate who stayed at internet bars for whole nights, how could he learn science well without putting his heart in learning?

In summary, Jiayi reported that she persisted in learning science although learning physics was difficult and somewhat painful for her. Jiayi regarded that learning science required whole-heartedness, and she thought that she could monitor her own behaviors and put all her hearts into learning science.

7) Improving oneself

Jiayi not only regarded learning science as a process of improving herself, but also elevated learning science as being more than a personal behavior. Jiayi stated that learning science was not for her own cause, but rather it was for her parents, and also for her teachers. Jiayi stated:

> My parent have great hopes for me, thus learning was not only my own business. My parents have done too much for me. If I did not study wholeheartedly, and if I could not enroll to a good university, my parents

> would be greatly disappointed.

Learning science was a way to change Jiayi's destiny, that is, to enroll to a good university. This is Jiayi's personal aspiration, but at the same time, it is also her parents' dream. In fact her parents' high expectations gave her more incentive to learn wholeheartedly. Jiayi stated:

> Whenever I feel tired or discouraged, I would think of my parents' expectations and their hard work. Then I would feel stronger and vigorous.

Jiayi claimed that she had to learn science well so that she could continue with her education after high school. If she failed, not only her parents, but also her teachers would get disappointed. Jiayi stated:

> From elementary school to high school, all my teachers have been kind and cared for me. If I did not go to university and became a farmer after high school, I would feel guilty towards my teachers.

In summary, Jiayi combined her own aspiration to change her destiny by learning science with the expectations of her parents and teachers, and thus learning science was not only a way to accomplish Jiayi's personal ambition, but also a way to repay her parents' efforts and her teachers' nurturance.

Summary

Jiayi was an obedient girl who was very considerate of her parents' expectations and wellbeing. Jiayi worked hard and put all her heart into learning. Jiayi was academically good at all subjects except physics. She failed in physics exams too often and thus lost interest in learning physics. Jiayi reported having a big problem in understanding the scientific concepts and laws, and as a result she could not follow her teacher at class and she could not solve complex problems. Apart from being obtuse in understanding, not previewing, summarizing, reviewing the content may have contributed to her low achievement in learning physics. That Jiayi's conceptions of learning consist of all the seven categories provides a piece of evidence for the existence of the unique holistic nonhierarchical structure of Mainland Chinese students' conceptions of learning science.

4.4.2 Kun

Kun was a male student who was born and raised in a big city in northern China. Kun's parents were both workers who had high school diplomas. Kun reported that his parents were too busy to tutor him, but they gave him general advice such as what to do at class and after class. Kun reported that he liked to learn science and he could get 90% of questions right in exams. In the following, Kun's experience and views of learning science were analyzed and interpreted and again reflected the seven categories of the conceptions.

1) Listening to the teacher

Kun claimed that one must listen to the teacher attentively at class. Kun reported detailed procedures that ensured the efficiency of listening to his teachers. Firstly, Kun stated that he always previewed the class so that he knew what he was going to learn and to which part he should pay extra attention. Kun stated:

> Before class I would preview the content I was going to learn, and marked the places that I did not quite understand. When I had enough time, I would study the content extensively. I would ask questions and tried to answer them. The part that I fully understood would need my extra attention at class.

Secondly, Kun reported that he engaged in the listening activity on his own initiative. Kun stated that he would compare his understanding with his teacher's descriptions, and he would not get distracted at all. Kun stated:

> I would follow my teacher's train of thought. At the same time I would compare my understanding with my teacher's explanations. Because all my focus is on listening to the teacher, and my brain is running fast, there is no chance for me to get distracted.

Thirdly, Kun claimed that one must know how to listen to the teacher and why one should listen to the teacher. Kun pointed out that being able to follow the teacher was not equal to have learnt the concept or have learnt how to solve problems. The student must mentally process the content carefully and comprehensively. Kun stated:

> Some of my classmates thought that they have learnt the concepts and learnt how to solve problems after they understood their teacher's instruction. In fact one has to mentally process the knowledge very carefully after class. For me I always rethink and organize the knowledge after listening to the teacher. I would neaten the knowledge in my notebook. I would redo the problems my teacher taught at class, because redoing the problems was the real process for me to learn how to solve problems.

Kun's experience of neatening the scientific knowledge resonated with that of many other students, such as reviewing the scientific knowledge after class. Neatening the scientific knowledge, i.e., organizing the scientific knowledge in a tidy way, was also reviewing the knowledge. Yet neatening the scientific knowledge involved more mental processes than simply going over the content. In addition, Kun was one of the students in this study who reported the importance of redoing the problem that the teacher had demonstrated.

2) Memorization

Like many other students, Kun also reported that chemistry and biology required a lot of memorization. “The chemical properties of elements and chemical equations need to be memorized.” As for why he needed to remember so much information, Kun provided with a frank and simple answer: “Only after you remember the information, you are able to do problems.”

Apart from the information his teachers required to remember, Kun also suggested remembering the information frequently encountered in solving problems. This resonates with the suggestion made by other students that derived conclusions should be memorized. Kun stated:

> If a chemical equation showed up frequently in problems, I would remember it. Usually these equations are not required to remember by my teacher. But after remembering it, I will be fast to respond to similar problems in the future.

Kun claimed that a good understanding of the information would allow him to memorize the information easily. Kun stated:

> It is easy to remember the concepts after you understand them. At class I could remember most of the content because I understood them thoroughly. After class I would review and summarize them, and they are naturally memorized into my mind.

3) Understanding

Kun claimed that understanding the basic knowledge, i.e., the concepts and laws, was the foundation of solving problems. Kun stated:

> Basic knowledge is very important. Without understanding the basic knowledge, that is, the concepts and laws, there is no way to solve problems.

Kun reported many ways to develop his understanding, such as listening to the teacher, previewing, reviewing, and summarization. Reading textbooks and reference books was an important way Kun reported to preview, review and summarize the scientific knowledge. Kun stated:

> Besides listening to my teacher attentively at class, after class I read extensively. I read my textbooks at least twice, once is before the class and the other time is after the class. Studying the textbooks carefully is indispensable to fully understand the knowledge. I also bought and studied some reference books, which describe the knowledge in a different angle and most of the time in a systematic way.

Kun also reported that he often asked questions both of himself and of his teacher in order to have a deep understanding. Kun stated:

> Knowledge has a synonym, 学问, which is composed by two characters 学 (study) and 问(ask questions). Thus I asked a lot of questions. I asked questions of myself when I was reading textbooks and listening to my teacher. I asked questions of my teacher whenever I was not sure of my own understanding.

4) Doing problems

Like many other students in this study, Kun considered that learning science was to solve all kinds of problems. For example when he talked about listening to the teacher, he claimed that one had to redo the problem so as to really learn how to solve problems. When he talked about memorization and understanding, he claimed that both memorization and understanding were the precondition of doing problems.

Kun regarded doing problems as a way of applying the scientific knowledge. Kun stated that he liked science because the scientific knowledge came from the real world and when he was doing problems, he was applying the scientific knowledge in solving problems of the real world. Kun explained:

> I liked to learn physics, chemistry and biology, because they are connected closely to the real world. All the concepts were developed from the real world, and when I do problems, I am applying the scientific knowledge to the real world. Almost all the problems are from the real world.

Kun reported that it was his goal to be proficient in solving problems, but he did not recommend the tactic of doing a sea of problems. Kun advocated for the approach of deep understanding of solving one problem and typifying it for a set of problems. Kun stated:

> It is not efficient to do too many problems. I would study one problem and understand the procedures thoroughly. If I did not do it right, I would find out why and try another similar one. After doing two or three similar problems, I would be very fast to solve this type of problems in exams.

5) Attending to exams

Kun considered exams important because the exam scores indicated how well he learnt science and the ranking based on the exam scores showed how competent he was in class. Kun claimed that he was good at science and his ranking was high. Kun stated:

> I am good at science because my scores are about 90% on average. I was ranked top 3 at grade 10, and this year since I am in the advanced class and all my classmates are competitive, I am ranked about 10 among 50 students in my class.

Kun argued that the competition for higher scores and higher rankings created a positive learning environment. Kun stated:

> My teacher encouraged us to find a competitor who is higher in ranking. All of us have a goal, i.e., to catch up with or surpass our competitors. Thus all of us are enthusiastic in learning and our class morale is high.

Kun shared a piece of his learning experience in which a low exam score provoked him in making a complete change. Kun recounted that he had a bad year in grade 7. He did not study seriously and indulged in computer games. The low score in the final exam greatly upset him and he decided to transfer to another school to have a new start. Kun narrated:

> When I was in Grade 7, I was addicted to computer games. I really could not control myself until I saw my very low score of the final exam. I felt humiliated and I could not raise my head. I wanted to make a change. Then I talked with my father and we decided to transfer to a new school. I put all my heart in learning and never played computer games after I went to the other school.

6) Working hard

Kun believed that working hard was the requisite quality that a student must possess, and the wholeheartedness was the nucleus of working hard. Kun commented on working hard several times during the interview, and the expression he often used was 好好学习, which can be translated literally as ‘good good study’ by thousands of people around the world. The real meaning of the expression was 'study wholeheartedly.' Kun stated:

> The most important quality a student should possess is 好好学习 (study wholeheartedly). Only through hard work can a student learn science well. I do not know who could achieve academic excellence without putting a lot of efforts.

Another characteristic of working hard Kun pointed out was to learn with autonomy. Kun stated as long as one knows from the bottom of their heart that they should learn, there would be no need for outer pressure or external discipline. Kun stated:

> As long as students know that they should study, they would study spontaneously. They would have no time to care for unimportant matters. When they really want to learn, they will not need their teachers or parents to push them.

Kun recounted how he changed from a game addict to a hard worker. The essence of this change was a sudden awareness of the incongruity between his goals and his actions. Kun stated:

> I was addicted to computer games when I was in grade 7. I was not aware that playing too much computer games would ruin my dream until I saw the low score of the final exam. After transferring to another school, and up to now, I have not played computer games for once. I cannot afford getting submerged in games and losing my focus on learning.

7) Improving oneself

Kun considered learning science as a process to develop his capabilities and preparing him to serve the society. First of all, Kun believed that one's capabilities can be developed by learning science, regardless of the student's intellect, which he thought somewhat malleable. Kun stated:

> I think one's intellect can be improved, but it may take a long time and a lot of efforts. Nevertheless, one's abilities can be developed, no matter how smart the person is. Learning science is the right process to develop our abilities. I believe the abilities to solve science problems can be transferrable to solve other problems in the future.

Kun continued to state that the reason to develop transferrable capabilities was that he wanted to be able to serve the society in the future. By society Kun was referring to community or the nation. Kun explained:

> I strongly believe that I was born to be serviceable (天生我材必有用). I know I am not a genius, but after working hard, I will possess the qualities and capabilities to serve the society. I am not sure what I will be yet in the future, but the capabilities I developed at school will definitely allow me make contributions to the society.

Kun also talked about serving his family with the abilities developed at school. In his mind his family's wellbeing was closely related to his future. Kun stated:

> My parents did not go to university and their fate is almost fixed. They cannot have a good future unless I could have a successful career (事业有成). I am not seeking for fame or wealth, but I am not repulsive to them either. I will naturally have certain position and certain income that could help with my parents.

Summary

Kun reported that he valued understanding in learning science and he took various measures to improve his understanding of the scientific knowledge, such as by studying his textbooks and reference books carefully and comprehensively before and after class. Kun claimed that being able to follow the teacher did not mean a good understanding because mentally processing the information after class, for example, by neatening and organizing the information, was a must. Kun suggested that one should redo the problem the teacher demonstrated in order to really learn how to solve problems. Kun was once a game addict but he repented and reported that he had never played computer games since he decided to make a change and transferred to another school. Kun maintained that having and being aware of one's goals was the essence of learning wholeheartedly. Kun regarded learning science as a way to improve himself and prepare him with capabilities to serve his family and the nation.

The unique holistic structure of the outcome space of Mainland Chinese students' conceptions of learning science, i.e., the conception circle in which each category of conceptions of learning share an equivalent position with others, is verified by the case study, in which both Jiayi and Kun reported all the seven categories in their conceptions of learning science. Jiayi and Kun considered that they should listen to their teacher, attend to exams, memorize and understand information, practice solving problems, work hard, and improve themselves. However their conceptions of learning are qualitatively different in each category. For example, with regards to 'listening to the teacher,' although all of them considered it very important to listen to their teacher, Jiayi reported difficulty in following her physics teacher and did not report strategies to change the situation. In contrast, Kun reported high effectiveness of class listening and the strategies that helped him to improve the efficiency, such as being mentally active, pre-studying the content and re-organizing the information in his mind. Thus the variety of conceptions of learning resides inside the categories rather than between the categories.

Chapter Summary

This chapter presented students' conceptions of learning science. Section 4.2 described seven categories of conceptions of learning science emerged from the rich data. In each category, two or more subcategories were identified and reported with exemplary quotes. Section 4.3 presented the relationship among the seven categories. Firstly a conception circle was proposed in which all the seven categories reside in a circle sharing equivalent importance in the processes of learning science. Secondly a concept map was proposed to illustrate the multiple-way connections among the categories. Section 4.4 presented a case study which served to verify the conception circle and to improve understanding on individual students' unique lived experiences of learning science.

Chapter 5 Origins of the conceptions of learning

Analysis of the 96 interviews suggests that there are five sources from which students constructed their conceptions of learning science. These five sources are: learning experience, parents, teachers, peers, and traditional values. A conceptual structure is proposed in which the five sources exert their influences on conceptions of learning through different channels, as illustrated in figure 5.1.

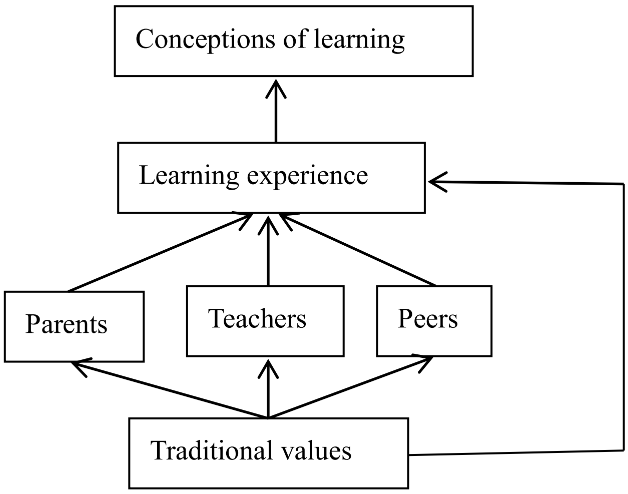

Figure 5.1 Structure of the influences on conceptions of learning

The figure proposes that conceptions of learning were developed from a collective influence of the five sources. Parents, teachers, and peers influence conceptions of learning through the mediator, ‘learning experience’. Traditional values have shaped the conceptions of parents, teachers, and peers, and thus influenced students’ learning experience indirectly. The data of this study suggested that the second channel existed through which traditional values could influence students’ learning experience directly, as the right arrow line in the diagram indicates.

In the following, the mechanism of the influences of the five sources on students' conceptions of learning is discussed.

5.1 Learning experience

The data suggested that students' learning experience was a direct source from which students learnt how to learn science. Traditional values, plus parents, teachers and peers, had to interact with the 'learning experience' to influence students' conceptions of learning.

First of all, about one third of the students in this study stated that they learnt how to learn science through their own learning experiences. For example, after Li talked about the importance of deep understanding of knowledge and the necessity of practice in her learning science, she stated that she got these conceptions from her experience. She said:

> I discovered the strategies slowly from my own learning experiences. To be specific, I tried to detect my flaws in my learning science. I knew that I was not good enough in many aspects. I thought I should sum up, discover, and reflect on my learning processes. Later I put the reflected thoughts into practice. Then gradually I knew how to learn science.

For another example, Hui reported that she knew that mechanical memorization was less effective than meaningful memorization. When answering how she knew it, she made a similar statement to Li's that she got the notion from experience.

> In fact I generalize it from my experience. When I learn art subjects, there are many things to remember. I am not a quick person to memorize things,

> but after I understand it, I can memorize it easily. For science it is similar in remembering things.

For the third example, Tian reported that learning was a process of accumulation of knowledge through hard work, and she explained that she developed the idea by considering her successful and unsuccessful learning experiences:

> My experience taught me that I must work hard to accumulate a solid understanding of knowledge. I did not study seriously at the first two years of my junior middle school. At that time when I did not know how to solve a problem, I would copy the solutions from a classmate. As a result there was too much knowledge that I did not understand. At junior grade three I knew it was time to work hard. I took after-school classes. I bought several reference books. I kept on doing problems without stop. I would note down difficult questions, and discussed them with my classmates, or went online to search for a solution, or to ask my teacher for help. That was really laborious a year, but I was glad that I was able to enroll to high school because of my hard work.

Secondly, the students acknowledged the influences from their parents, teachers, and peers, but they stated they had to explore the suggested ideas themselves so that they could really assimilate the suggestions. For example, Dan stated that his teachers taught him some method, but he had to try it out. Only after the application of the method proved effective, did the method become an element of his conception of learning. Dan stated:

> Sometimes my teachers would instruct us on how to learn science, but easier said than done. Some of my classmates do not know how to learn science although my teachers have taught them. I guess they did not practice the methods enough. For me, I always try to understand what my teacher really suggested, and try it out. After enough practice, the method became part of my learning strategies.

For the second example, Xu stated that his teachers showed him the door of learning science, but it was by his own learning experience that he learnt how to learn science. Xu explained:

> At the beginning I was not conscious how I learnt science, and I just did what I was told. When things went bad, I began to reflect on how I should learn science. I explored one way or another until I found out an effective way. Gradually I gained some insights on how to learn science.

In summary, the students in this study reported that they learnt how to learn science by trials and explorations. They would retain the suggested methods by their parents, teachers, or peers that proved being efficient, and integrated them to their conceptions of learning.

5.2 Influences from parents

When students talked about their learning science, they automatically acknowledged the guidance and influence of their parents. The various forms of guidance and active involvement created positive and successful learning experiences, from which students developed their ideas of how they should learn science. Two themes emerged from the transcripts in how parents influenced students' learning to learn science: caring, and tutoring.

1) Caring about learning

Students reported that their parents cared about their learning very much. Parents' caring about their children's learning would exemplify their values on education and their conceptions of learning, and as a result would influence their children's values and conceptions of learning. For example, Wen reported that his parents cared for his learning very much by asking him about his study at school every day and giving him guidance on how to learn science both in general and in specific detail.

> Every day when I go back home from school, my parents would ask me about how things went at school. They often ask me if I have any questions or if I followed my teachers well at class. I feel pressured to put all my heart and soul in my study, otherwise I cannot study well and they will be worried about me.

The caring of Wen's parents for his study influenced Wen's learning behavior and his ideas of how he should learn science. Based on the above quote, Wen's conceptions of 'listening to the teacher', and 'working hard,' i.e., putting all his hearts and soul into his learning, reflect the influence of his parents great care for his learning.

Most students expressed their appreciation for their parents' care and support, but a few students reported their dislike of their parents' caring too much about their learning. For example, Xiong said: "My mother liked to nag (唠叨) about my study". The word 'nag' might be the closest translation of the Chinese word '唠叨', but the Chinese word conveys more meaning than 'nag'. When parents are 唠叨，they show their care and concerns by asking questions and giving guidance, but the student may not like the constant care, urging, and pressure. The reason may be that he thought the influence of his parents had been too much, and he should be responsible for his own learning.

Parents showed their care in different ways based on their values and the resources they had. Students reported that parents from the countryside did not have the means for their children to attend after-school classes or to be instructed by a tutor. But they tried everything they can to help their children learn. For example, Dong said:

> My parents are farmers. They do not know much about my courses' content, and they cannot directly help me. When I cannot solve a problem in finishing my homework, my parents would take me to ask the senior students in my village. Sometimes my parents took me to see a relative for help.

Dong did not say why her parents took her around for help, but the action itself implied that learning is important. This was consistent with Dong's later statement that her parents hoped her to be able to go to college and have a good future. In Dong's parents' minds, they thought learning could change their daughter's fate. In addition, the action of walking a long distance for help told Dong that understanding was important, and asking for help was a way to reach a good understanding.

2) Tutoring

Students reported that their parents taught them how to learn science in two ways. One way was to give direct instructions on some exact content, and the other way was to give general suggestions about procedures for learning. It was found that the parents who gave direct instructions on how to learn exact contents usually had university degrees, and they tended to have good understanding of science and how it should be learnt. For example, Jin reported that her father was an electrical engineer and often tutored her in math and physics. When her father tutored her, he not only told her how to solve the problem, but showed her what things were important in order to solve the problem. Jin recounted:

> My father learnt engineering at university. He often tutors me in math and physics. I would ask my father if I have a problem that I do not know how to solve. My father would start by questioning me about the knowledge involved. He wanted me to make sure that I have a solid understanding of the knowledge before applying it to problems. Then he would ask me to describe the problem verbally and in diagram. Quite often he only gave me some hint and I would know how to do it.

The great tutoring that Jin's father provided strongly shaped Jin's conception of learning science, especially on the importance of understanding the fundamental concepts.

Students reported that their parents would offer suggestions on how to learn science regardless of their educational background. For example, Gao's parents graduated only from primary school, yet still they exerted influence on Gao's conceptions of learning. The suggestions they provided included listening to teacher, doing homework, striking balance between work and rest, and ask questions. Gao stated:

> My parents care for my study, but they do not instruct me since they do not have much education. I lived at school and went back home once every two weeks or three weeks. Whenever I go back home, my mom would ask me how my learning is. She would remind me of listening to my teachers at class and doing my homework on time. My father would remind me of striking a balance between working hard and taking rests. My father told me not to be shy in asking questions.

Ming reported that his parents often inspired him to study hard so that he could be like those successful people who went to university and lived admirable lives.

Ming stated:

> My parents did not hesitate to pay a lot of money for me to enroll at this school. My parents often inspire me by talking about the people who went to university from our village. When they return home to visit their parents, they drive good cars, which is very admirable. You must study hard and become one of them in the future.

In summary, the students in this study reported that their parents cared for their learning and tutored them on how to learn science. Both the caring and tutoring processes shaped students' conceptions of learning.

5.3 Influence from teachers

It was found that teachers played an essential role in shaping students' conceptions of learning. Two themes emerged in how teachers exerted their influences: unconsciously teaching their students how to learn science, or consciously giving instructions on how students should engage in their learning activities.

1) Unintentional influence

Most students in this study did not say that their teachers intentionally taught them how to learn science, and a few students said that their teachers never taught them how to learn science, but when these students talked about how they engaged in science learning, they would frequently mention their teachers' involvement, and their teachers' involvement often conveyed information on how to learn science, although students were not often aware of this information, or aware of getting this information. For example, Meng talked about how his teacher enforced the requirement that students must listen to him. The teacher was teaching the students how to learn by giving punishment and rebuke for not listening to him at class. Meng explained:

> It is certainly important to listen to teacher at class... All of us must listen to the teacher. My teacher would punish the students who were not attentive. Once I was daydreaming at class when I was caught, and I was sent to the hall. Later he explained to me why it was important to be attentive at class.

Although Meng's teacher did not verbally teach the whole class to be attentive, he used his action to clearly inform his students that listening to him at class was important and required. Similarly, Lele talked about why she thought memorization was important:

> My physics teacher would ask us to recite the laws and scientific conceps… At the beginning of the class my teacher would check if we have remembered the laws. It would be embarrassing when I was called and I do not know the concept. In addition, I cannot do well in exams if I do not remember the important concepts and laws.

Lele's teacher enforced the importance of memorization by checking it at class and in exams. Because of the enforcement from her teacher, Lele gradually learnt that memorization was an important procedure to learn science.

Doing experiments should be part of learning science, and the science curriculum of Mainland Chinese schools explicitly required students to do experiments, but it was found that in the schools in Shandong province where I made interviews, the students were not given enough opportunities to do experiments as required. As a result, the students in these schools thought it acceptable not doing experiments, as long as they could remember the procedures and conclusions of the experiments so that they could pass the exams. For example, Lei did not think it mattered if doing the experiments or not. Lei explained:

> Sometimes our teacher would demonstrate how to do the experiments and let us remember the steps. I think it is enough. We can do a lot of experiments after going to university. I do not think there is much difference doing the experiments or not. It is ok to remember the things that will be tested.

In summary, the students in this study suggested that their teachers influenced unintentionally their conceptions of learning through classroom teaching, in which some ideas of learning science were transferred and reinforced.

2) Intentional influence

Some students in this study reported that their teachers explicitly taught them how to learn science. More specifically, these students recounted that their teachers taught them how to remember, understand, and apply scientific concepts. They also reported that their teachers instructed them to form good learning habits, inspired them to work hard and to set up goals.

Sometimes when a teacher was teaching one strategy, the teacher could communicate many of his ideas in learning science to his students. For example, Lei reported that his teachers taught them to analyze and copy the wrongly-solved problems onto a notebook and review them regularly. By teaching students to use wrongly-solved problems, Lei's teacher stressed the importance of understanding, thoroughness in thinking, memorization, and transference of problem-solving skills. Lei recounted:

> My physics teacher asked us to have a notebook of wrongly-solved problems. He said that it was necessary to analyze why the problem was wrongly solved. When I copied the problem to my notebook, I would ask myself if it was due to misunderstanding or incomplete thinking. My teacher asked us to review the notebook regularly, so that we could better remember and understand the knowledge, and transfer the problem-solving thought process to other problems.

As previously explained, many students in this study reported that they learnt science by doing a large number of problems, although some students reported that they disapproved this method. These students considered that it was necessary to do a large number of problems, and they must do enough problems before being proficient in solving problems. The origin of this conception is probably from their teachers, because these students reported that their science teachers often gave them a large amount of problems to practice, and at the same time the teacher might tell them why it was necessary to do so. For example, Juan recounted that her science teacher told her that the reason for her not being able to solve problems was because she had not practiced enough:

> …I still could not solve a problem after understanding how my teacher solved a problem. My teacher said it was because the problems I did were not enough. My teacher told me that I must practice enough problems before I could fully understand the concept, and apply the knowledge skillfully.

Students reported that their teachers taught them how to solve problems. For example, Xu explained how his physics teacher taught them how to abstract the physical process:

> My physics teacher taught us how to solve problems of physics. At first we must be able to abstract the physical process or format from the given

> conditions, then use the learnt knowledge to solve the problem patiently. If you learnt the way and form a habit of abstracting physical processes, you will be quick to know the processes as soon as you finish reading the problem.

Students' conception that the essence of doing problems was to understand knowledge and develop abilities also came from their teachers. For example Mei said:

> My teacher said a person's inborn ability was similar, and being smart is the result of cultivation. The more problems I did, the more I should understand, and the more skillful I would be in solving problems.

Students' conception that learning requires hard work can also be influenced by their teachers. Teachers would tell their students to work harder if they did not perform well in exams. For example, Yao said his teacher scolded him harshly for his lack of effort in learning science, and then he began to work harder and made a great progress. Yao recounted:

> I did not know what I learnt for when I was at junior middle school. Although my parents said that I would not have a future if I did not study hard, I did not take their words into my heart. My teacher scolded me harshly for several times. My self-esteem was hurt. I thought why I could not study harder. Then I worked hard for an entire year at grade nine. After coming to this school, all my classmates are academically strong and all work hard. It would be an alien if I did not work hard.

In the above narrative, Yao mentioned that not only his parents, teachers, but also his peers affected his conceptions of learning. In the following, the influence of peers is to be discussed.

In summary, the students of this study reported that their teachers influenced both unintentionally and intentionally on their learning experience and their conceptions of learning science.

5.4 Influence from peers

The students in this study reported influences from their classmates. Two themes of influence from classmates emerged: competition and modeling. Competition would incite students to think and reflect on their learning processes, and thus possibly seek to improve and develop their conceptions of learning. Modelling would help students to substantiate or modify their conceptions of learning by observing their models or 'anti-models'.

1) Competition

Students reported that they would target some student, usually with a higher rank, to compete against. Students' conceptions of learning, such as valuing exams, requiring hard work, improving oneself, all mingled with the idea of competition. For example, Cai explained how his teacher encouraged them to set up goals for competition and how the competition helped him in learning.

> Every time before a new semester, our teacher would let us state our goals, such as some classmate to surpass. I would choose a classmate who is always ahead of me in ranking…I made plans as to what I should do so that I can improve myself. I would surely work very hard, listen to the teacher attentively, and do more problems…After knowing the examination result and my ranking compared with my competitor, I reflected on my learning by examining where I did well and where I need improvement.

Cai substantiated his conceptions of learning, such as improving himself, listening to the teacher, and working hard, by planning and reflecting on his learning experience so as to compete against his rival. Cai had to work hard to improve himself so that he could surpass his competitor in exams. In other words, to surpass his classmates in ranking, he needed a real improvement of his knowledge and abilities. Cai was not the only student who cherished competition, because for these students, to compete against one's classmates was just one means to the end of improving oneself. For example, Pan was very concerned about how well he competed against his classmates, but he did not stop at thinking about the ranking. Pan understood that in order to beat his classmates, he had to work hard to improve himself. Pan stated:

> I had the strong motivation not to rank behind. I said to myself, "I will not drop down". So it was as if I used a whip to urge me on. My achievement was not much greater than that of others, but I paid much more than others. I do not regret, since I have learnt a lot and improved myself.

Pan was flexible in his goal of not ranking behind, i.e., it was ok for his ranking "not much greater than that of others", since he was satisfied that his hard work improved himself in knowledge and abilities. The 'ok' ranking and the satisfaction of his self-improvement consolidated his conceptions of learning, such as working hard and improving oneself.

2) Modelling

The interview data suggested that peer students could influence a student's conceptions of learning by modelling. Two ways of modelling were identified: positive modelling and negative modelling. Positive modelling means that positive learning behaviors and positive ideas were modelled by peer students, while negative modeling, or 'anti-modeling,' does not mean negative behaviors were modelled. On the contrary, the negative behaviors and ideas were criticized and despised in anti-modelling. How modelling and anti-modelling influenced students' conceptions of learning is discussed in the following.

Firstly, the students in this study reported positive modelling by which they observed their classmates' learning behaviors and reinforced or modified their own learning processes and their conceptions of learning. For example, the notion of 'listening to the teacher' was often consolidated and reinforced by modelling. To illustrate, Sui stated that all 'good' students were listening to the teacher attentively, and thus he substantiated his view that listening to the teacher was vital to learn science. Sui explained:

> Being attentive to teacher at class is the most important quality to learn science. When you look around, all good students are listening to the teacher attentively. Only those students who fool around and kill the time are not.

The notion that learning science required hard work was also reported to be reinforced by modelling. For example, Xin thought it necessary to get up very early each day because all his classmates get up at that time. The following is the conversation:

> Interviewer: When do you get up in the morning?
> Xin: 5:30 am.
> Interviewer: Are you required to get up at 5:30?
> Xin: We are required to get up at 6:10, but all my classmates get up at 5:30. After getting up, we will go to the classroom to read.

For another example, Shan reported that she would study hard when she observed her classmates were working hard. Shan recounted:

> I would look around and see my classmates studying hard. I would talk to myself: you have to study hard; otherwise you would lag behind…

Secondly, the students in this study reported that 'anti-modelling' reinforced their conceptions of learning by observing the students who are devoid of expected behaviors and anticipant of negative consequences, such as failing in exams or even disciplinary penalties. For example, Cai strengthened his belief that learning science commanded hard work by watching some his peers who played too much. Cai stated:

> I have classmates who are smarter than I am, and think faster than I do. But they do not have a right attitude towards their learning. They do not put all their effort into learning, and as a result their learning is not that good.

For another example, Yi consolidated his view that that one should study wholeheartedly by reflecting on the failure of his classmate who was addicted to playing computer games. Yi recalled:

> I had a classmate who was addicted to play computer games. He did not finish junior middle school and now he rests at home doing nothing. That means he put everything in the games, including his future.

In summary, the students in this study reported two themes of influence from their peer classmates: competition and modeling. Competition incited students to think and reflect on their learning processes, and developed their conceptions of learning. Positive modelling improved students' conceptions of learning by observing their models' great learning behaviors. Anti-modelling reinforced their conceptions of learning by watching the students who lacked the expected behaviors and anticipated low achievements.

5.5 Influence from traditional values

It is proposed that students' conceptions of learning developed from the interaction between the external influences and students' own learning experiences, which is illustrated in figure 4.5.1. 'Traditional values' is placed at the base of the structure and predicates the conceptions of learning. Traditional values can pass on to students through parents, teachers and peers, or by mass media or educational materials. The study suggested that the values students embraced deeply affected their conceptions of learning science. In the following, how students' values shaped their conceptions of learning is to be discussed.

The first category, listening to teacher, is consistent with the traditional idea of 'respecting teachers' (尊师) and the Confucian Cardinal Guides (三纲), which dictates that students should obey their superiors, including their parents, teachers, and elders. This is also consistent with Hofstedes' finding that Chinese culture has higher power distance index (see section 2.5.4 for details). The study suggested that Chinese students hold the belief that they should respect and obey their teachers. For example, Shan reported that she did not want to ask her teacher when she had a question, because she thought that teachers and students are not equal in social status, and asking her teacher was not as comfortable as asking her classmates. Shan explained:

> Shan: When I do not know how to solve a problem, I may feel uncomfortable to ask my teacher, so I ask my classmates.
> I: Why do you feel uncomfortable to ask your teacher?
> Shan: Because teacher and student are not equal. I did not dare to ask my teacher.

Although Shan did not directly state that she should obey and respect her teacher, in her above quote Shan expressed her awe of her teachers and this awe implied that teachers were in a higher respectful position.

For another example, Wei reported that she still respected and listened to her teacher even though the teacher could not make the class active and interesting by connecting scientific concepts with everyday life, and she respected and understood the teacher even though the teacher lost temper and made her uncomfortable. Wei explained:

> If the teacher could not energize the classroom and just listed the concepts on the board, I would still listen to the teacher carefully, grasp what the teacher teaches and add my own understanding by reflecting on what I learnt before…The teacher may yell at or scold the whole class, and this makes me uncomfortable, but I understand him and do not lose my respect of him because of this.

The second category, attending to exams, can be traced to the Confucian notion of 学而优则仕 (He who excels in learning can be an official), and the thousand-year-long imperial examinations, which intended to select the best potential candidates to serve as administrative officials. Students reported that they had to take numerous exams as well as the fate-deciding entrance exams. Exams entailed competition, and no student could evade it although some students reported dislike of competition, which was in harmony with the Taoist idea of natural inaction and no competition (与世无争). For example, Shan claimed that she “was not a person who likes to compete” with her classmates. The third subcategory, assessing, was coherent with the Taoist idea of letting nature take its course (顺其自然). Students with ‘assessing’ ideas considered that ranking was the natural result of their learning, and they disapproved of the aspiration for high ranking. For example, Yu argued:

> I think a good score, a good ranking, and going to a good school are the results of good learning, and they are not the reasons to learn.

The third category, memorizing, and the fourth category, understanding, were interrelated, and the intertwinement of memorization and understanding can be traced to Confucius’ dictum 学而不思则罔，思而不学则殆 (Learning without thinking is blindness; while thinking without learning is idleness). Ancient Chinese scholars had to memorize many classics and in a way learning was equivalent to memorizing, and in addition, thinking would help understanding. Thus the dictum can be translated literally as ‘memorizing without understanding is blindness, and understanding without memorization is idleness’. Over half the students in this study mentioned the importance of memorization in learning science, and also the importance of understanding in memorization. These conceptions should be the accumulative result of many influences, including the impact of the traditional values and Confucius’ dictums on learning. Some students in this study voluntarily quoted the dictum about the relationship between learning and thinking, or between rememorizing and understanding. For example, Yao quoted Confucius’ dictum when he talked about how memorization with repetition was not as optimal as memorization with understanding.

> It would be inapplicable and less effective when you just memorized the textbook content without asking why. 学而不思则罔，思而不学则殆 (Learning without thinking is blindness; while thinking without learning is idleness). It would be a waste of time just memorizing something that you do not understand, because you do not understand it and you cannot use it.

In the fifth category, doing problems, students reported doing enough problems and finding patterns in order to be proficient in solving problems. All these views can be traced to traditional values that students treasured. For example, Yi quoted the idiom 熟能生巧 (practice makes perfect) and the dictum 精益求精 (always striving for improvement) from the Analects of Confucius when he talked about the necessity of doing a lot of problems.

> I strongly believe that practice makes perfect and second best is not good enough (精益求精). I have to do as many problems as possible so that I can really understand the concepts and accurately solve all sorts of problems.

Students quoted Confucius' maxim 举一反三 (draw inferences about other cases from one instance) to illuminate the necessity for finding patterns in solving problems:

> To understand and follow what the teacher teaches is enough for biology, but not enough for physics, since physics has too many unpredictable problems. Physics needs 举一反三 （draw inferences about other cases from one instance）（Dong）
>
> 举一反三 (to draw inferences about other cases from one instance) is easier said than done. Apart from practicing my hands, the significance of doing too many problems is not much. Sometimes I want to do as many problems as possible, but in fact it is not as meaningful as to stop and think over a problem just done, so that I can find patterns and 举一反三.　(Li)

The sixth category, requiring hard work, is a natural derivative of Chinese culture that highly advocates hard work. Students quoted idioms, proverbs, and Confucius' maxims when they were describing why learning science required hard work. For example, Chang quoted a famous poem about why a person should work hard at young age: “There is saying that I learnt from elementary school and I think it is very true. 少壮不努力老大徒伤悲（If you do not work hard when being young, what you have when being old is nothing but sorrow）.” Hui quoted an allusion when she talked about traditional values: “My learning is influenced by old traditions, like 凿壁偷光（to bore a hole on the wall in order to get some light to read）”. Xu quoted a saying from the Analects of Confucius to show the importance of perseverance:

> Perseverance is a very important quality to learn science. 岁寒，然后知松柏之后凋也 (only after it gets cold can you notice that the leaves of pine trees have not fallen yet). Only through hardship can a tough person be tested.

The seventh category, improving oneself, coincides with Confucius’ notion of ‘self-perfection’ and ‘self-cultivation’. Students reported quotes and ideas that are consistent with these traditional values. For example, Shi used the idiom 安身立命 (to establish one’s position in society) to explain his idea that learning was to improve one’s abilities:

> Confucius or Mencius said 安身立命 (to establish one’s position in society). For a person to function in the society he must have knowledge, life abilities, and communication skills.

For another example, Liu used the idiom 知书达理 (educated and cultured) to express his understanding why he should learn science. Liu explained:

> Learning is a process of improving a person’s abilities, characters, and manners. After learning science and other subjects, a person can be 知书达理 (educated and cultured), otherwise a person would look unrefined and less civilized.

Xu took the late premier Zhou’s famous remark 为中华崛起而读书（to read and learn for the rise of China）as his goals. Xu's goal was consistent with Confucius' maxim 修身齐家平天下 (Cultivate oneself, put family in order, and run the country). Xu said one must have the abilities before being able to serve the country.

> To learn for the nation has been well imprinted in my head since I was young... I like Premier Zhou's motto, "to read and learn for the rise of China…I now learn well, later can I serve a little for the country. If I do not learn well, what can I do except dong some insignificant menial labor?

In summary, when students articulated their conceptions of learning they voluntarily quoted idioms, proverbs and sayings that they believed. These idioms, proverbs, and sayings are from various sources, such as Taoism, folk wisdom, or historical figures that reflected the traditional values, while the mostly quoted source was Confucius' Analects that represent core values of Chinese culture.

Summary

The study suggested that students' conceptions of learning were collectively influenced by five sources: personal learning experience, parents, teachers, peers, and traditional values. A conceptual structure was proposed that illustrated how students' conceptions of learning were developed from the interaction between the external influences and students' own learning experience. Traditional values influenced the conceptions of parents, teachers, and peers, who in turn influenced the student's learning experience and their conceptions. Parents influenced students' conceptions of learning through caring and tutoring. Teachers intentionally or unintentionally taught students how to learn science. Peers' influence on conceptions of learning was employed through competition and modelling. Students interacted with the external influences by trials and explorations and integrated the verified ideas into their conceptions of learning.

Chapter 6 Discussion

The purpose of this study was to understand and describe Chinese students' views and processes of learning science and how and why they learn science as they do. More specifically, it intends to answer the questions of what Chinese students report as their conceptions and processes of learning science, and what Chinese students report as the origins of their conceptions of learning science. In order to discuss findings of the research questions, this chapter is divided into five sections including: a review of data collection and analysis, a discussion of findings and conclusions, the contributions to the literature, the implications of the study, and limitations and suggested directions for future research.

6.1. Review of data collection and analysis

Utilizing a purposeful sampling model, 96 Mainland Chinese students were interviewed in May, June, and July of 2011. In order for the samples to be representative, the author went to 10 schools in 6 cities/counties of Hebei and Shandong province in China. Age, gender, region, and academic strength were considered in choosing the participants. The demographic characteristics of the participants are listed in table 2 on page 121.

The interview questions that are listed in the section 3.4.2.4 were designed to explore the answers to the research questions, i.e., what Chinese students report as their conceptions and processes of learning science, and what Chinese students report as the origins of their conceptions of learning science. These interview questions were adapted from Thomas and McRobbie (2001) and Thomas (2003, 2006b) and were proved successful to garner information from students regarding their metacognition including their conceptions of learning. Some flexibility was applied in interviews to be able to explore previously unconsidered details and ideas that emerged as interviews proceeded.

96 interviews were recorded and saved into audio files for analysis. All the recordings were listened to for multiple times and notes were taken during the screening investigation. Based on how detailed and representative the conversation was, 30 interviews were chosen to be transcribed and translated into English. A graduate student at University of Alberta who was fluent in both Chinese and English helped to check the accuracy of the transcription and translation. At last 226 pages of transcripts were documented as the major data resource.

Phenomenography aims at description, analysis, and understanding of experiences. Phenomenography provides a way of looking at collective human experience of phenomena holistically, while at the same time with a focus on the variety of conceptions within a group. The outcome of a phenomenographic study is called an outcome space made up of a set of related categories of description of the phenomenon. The categories of description represent a researcher's analysis and description of variation in a group of individual's accounts of ways of experiencing the phenomenon. The goal of this study is to describe, analyze and understand Mainland Chinese students' metacognition including their conceptions of learning science, and thus phenomenography is the appropriate methodology for this study.

The phenomenographic data analysis was both a process of discovery and an inductive bottom-up way of construction from transcripts (Green 2005). Multiple iterations of analysis were performed to understand and describe Mainland Chinese students' conceptions of learning science and their origins. The first iteration of analysis was to find the common themes across the participants by repetitively reviewing and coding the transcripts. The themes were organized into different categories and 6 pieces of A0 size paper were used to record and integrate the themes. The second iteration of analysis was carried out by using Nvivo, a computer software for qualitative data analysis. The purpose of utilizing Nvivo was to make sure that the data analysis was comprehensive and complete. Nvivo organized all codes (called nodes) into tree structures, in which general categories (parent nodes) are on top, followed by sub-categories and sub sub-categories (child and grand-child nodes). Then the categories and subcategories from the two iterations of analyses were compared and examined, with the common themes retained. Seven categories of conceptions of learning were identified, followed by about 40 sub-categories, and sub sub-categories. At last, the relationship among the categories was studied and an outcome space of the phenomenographic investigation was constructed. The third iteration of data analysis was case studies that depicted and concretized the categories and the outcome space.

6.2 Discussion of findings and conclusions

Findings of this research mainly include

- Description of Mainland Chinese students' metacognition including their conceptions of learning.
- A unique structure of the outcome space of a phenomenographic study.
- The origins of the conceptions of learning

Each of the findings is discussed in the following sections.

6.2.1 Mainland Chinese students' conceptions of learning

This study painted a vivid picture of the range of experiences of Mainland Chinese students' learning science. It described how the Mainland Chinese students considered they learnt science. This study explained how Mainland Chinese students conceived science learning and how they engaged in science learning processes. Seven categories of conceptions of learning of Mainland Chinese students were identified in this study: 1) listening to the teacher; 2) attending to exams; 3) memorizing; 4) understanding; 5) doing problems; 6) working hard; 7) improving oneself.

The first category, 'listening to the teacher', stands for the conception that students are to be attentive and obedient to their teachers at class. This conception is consistent with the Chinese culture that dictates an unbalanced power and distance relationship between teachers and students. Teachers possess the institutionalized authority and innate respect that demand students to be obedient and attentive. Students reported respect and obedience without conditions. In other words, even though the teacher's class was not interesting, or the teacher's attitude was annoying, the teacher can still enjoy students' respect and obedience. In a way this obedience without conditions helped students focus on their own efforts, and perhaps this is one reason that students did not report discipline problems in the classroom, and the teachers can concentrate in guiding students to learn. But it is worth noting that students reported that they were encouraged to take ownership in their studies.

The second category, tending to exams, refers to the conception that students highly valued exams. This conception may be a cultural product in the sense that Chinese culture has a history of 2000 year's imperial examination. The historical influence still exists and manifests itself in national university examinations and public exams for government officials. Chinese students have to take endless exams at schools. Apart from the nationwide or province-wide university and high school entrance exams at the end of senior and junior middle school years, and the routine midterm and final exams, there are all kinds of exams all the time, such as chapter exams, section exams, monthly exams, united exams, and mock exams. It is hard to imagine there would be a student who did not value exams or who saw learning as being irrelevant to exams in this culture. Thus in a sense, many students equated science learning as preparing for exams. But there existed a group of students who do not over value exams and thus who learn science beyond preparing for exams. The subcategory, 'assessing', reflects students' understanding of the significance of exams, that is, to assess their science learning. Students with 'assessing' conception regarded exams as an essential component of their science learning. 'Assessing' students tended to be motivated by the innate nature of learning science instead of by the outcome of competition and practical benefits of learning.

The third category, 'memorizing', and the fourth category, 'understanding' are two conceptions that are closely related to each other. It is worth noting that few students in this study regarded memorization as a low order or surface approach to learn science, as is reported predominately in the Western literature. Although some students admitted that in some occasions they had to put information into memory before a good understanding, most of students interviewed emphasized the importance of memorization with understanding. Memorization without understanding was often called 'mechanical' memorization, and regarded negatively as 'swallowing dates' (囫囵吞枣).

The fifth category, doing problems, refers to the conception that to learn science they have to do enough problems. Students reported that they spent much of their study time in doing problems every day, thus in a way for some students, learning science was to do problems. This is especially true for grade 9 and 12 students who focused all their time on preparing for exams by doing problems. It may be appropriate for some students to engage in lower order thinking while doing problems, but this study found doing problems is a sophisticated process which involves higher order thinking skills. Before applying knowledge to solve a problem, students reported needing a good understand of the knowledge. Then students would analyze the given conditions and required quantities, seek clues and methods, and evaluate results at the end. In addition, because the fierce competition, exams have to assess students' skills and abilities, sometimes creative ability, so that students with potentials to succeed in learning advanced science can be chosen for further education.

Thus students regard doing problems as an essential part of their science learning that contributes to good understanding of scientific knowledge and development of higher order thinking skills and abilities.

The wording of ‘doing problems’ instead of ‘solving problems’ was chosen to represent students’ conception of learning. The problems that the students in this study were talking about are content-based and pre-designed questions. Answering these questions mainly involves algorithmic step-by-step procedures. While solving problems often implies procedures/processes that doing pre-designed and content-based problems cannot cover, such as discovering and identifying a problem, generating, evaluating and selecting alternatives. In addition, solving problems often requires observing, experimenting, and modelling skills, creativity and lateral thinking, and cooperative and communicative competences. Doing the exam type problems apparently is very different from solving real life or scientific related problems.

The sixth category, working hard, refers to students’ understanding of how they should learn science. Students in this study considered hard work indispensable and crucial to their science learning. It is found that most students in this study conceived intelligence as malleable through hard work. Some students regarded hard work as painful investment for the happiness of future, while some other students enjoyed the process of working hard. Both views about hard work can be traced back to Chinese traditional values of appreciating hard work and Confucius’ teaching of the love of learning.

The seventh category, improving oneself, refers to the conception that learning is a process of self-improvement. Confucius' assertion that everybody can become a sage has been influencing Chinese for thousands of years, with no exception to these students as well. The conception of improving oneself is the manifestation of Confucian theory of human nature. Under this category, there exist subcategories of serving for parents and serving for the nation. These subcategories are closely related to the idea of self-perfection, since Chinese culture demands responsibilities for the collective, the fulfillment of which is one indication of self-perfection.

6.2.2 The structure of the outcome space

The outcome space, that is, the relationship among the categories of the conceptions, is found to have a unique structure. Traditionally the outcome space is hierarchical in that some conceptions are regarded as being at lower levels, while other conceptions are at higher levels. This study found a different structure in that all categories possess an equivalent status represented as a circle in which no category is superior or inferior to other categories. This means that the Mainland Chinese students in this study reported that to learn science they should listen to the teacher, attend to exams, memorize and understand scientific knowledge, do problems, work hard, and improve themselves. In other words, the Mainland Chinese students seem to think about learning holistically, and no student in this study reported conceiving learning science as only listening to teacher or solely doing problems, and no student considered that one category was inferior or superior to another category. They regarded each elements of the seven categories as exponents of their conceptions of learning science.

The variety within their conceptions of learning science lies in their variation in relation to the sub-categories instead of in the common seven categories which form a holistic circular structure. For example, all students in this study reported appreciating exams, but the reasons why they appreciated exams varied. The variety of why they valued exams was described in the three subcategories: avoiding distress, competing with peers, and assessing learning processes and outcomes. More specifically different students appreciated exams based on different priorities. Some students just wanted to survive and avoid distress, some others wanted to compete with peers and be ranked highly in class, while some students wanted to evaluate their learning processes and outcomes by attending to the exams. Therefore a holistic circular structure of conceptions of learning science does not contradict the notion that different students conceive and engage in science learning in different ways.

6.2.3 Origins of Mainland Chinese students' conceptions of learning

The students in this study reported five sources of conceptions of learning: personal learning experience, parents, teachers, peers, and traditional values. This answers the research questions of why students held these conceptions of learning, and how culture may have shaped these conceptions of learning.

Firstly, students reported that they learnt how to learn science by their own learning experience. Traditional values, as well as parents, teachers and peers, had to interact with students' learning experience to influence their conceptions of learning.

Students might have the tendency to attribute positive events to their own character, but it is reasonable to suggest that even though parents, teachers and peers had influenced them greatly, they had to interpret what was being told and tried it out. The students would be happy to keep those strategies that worked. If the students did not find the benefit in doing what was being suggested, they would ignore it. That is to say, students must learn how to learn by numerous experiments and trials. In addition, they may have explored their own ways of learning science, since they have their own experience in learning science. The students in this study reported learning science for 9 years from grade 4 to grade 12. They explored different methods and strategies in learning science and then reflected on them. In short, traditional values and the external influences interacted with students' learning experience to shape students' conceptions of learning.

Secondly, the students in this study reported that their parents played an important role in influencing their conceptions of learning science. Two themes were identified for the parents to exert this influence: caring about their learning and giving instructions on how to learn science. Three factors may have contributed to this great altruistic support: blood bondage, family orientation, and appreciation of education. The parents would do anything they can to support their children, even if they have to make sacrifices. When the parents cared about their children's learning, they would teach the students how to learn science, no matter what level of education they had. By caring about learning and tutoring how to learn, the parents' thoughts and understanding of learning interacted with students' learning experiences, and thus influenced their conceptions of learning.

Thirdly, the students in this study reported that their teachers intentionally or unintentionally taught them how to learn science. Some teachers did not intentionally teach their students how to learn science, although it might be expected of them. Lao-tzu's dictum, "giving somebody fish is not as well as teaching him how to fish" (授人以鱼不如授人以渔), should be known to every teacher, but the focus of the science teacher's job was for students to understand and apply the scientific knowledge so that the students might have satisfactory marks in exams. Possibly these teachers considered that teaching scientific concepts and solving problems denoted the ways for students to learn science. This is consistent with some students' claim that they preferred not being taught how to learn explicitly. Some students were aware of and acknowledged that their teachers unintentionally taught them how to learn science, while some other students were not aware of the implied information of how to learn science. The latter group of students reported being not sure of how to learn science and they wished that their teachers could give them more explicit instructions on how to learn science. In fact some teachers intentionally and explicitly taught their students how to learn science, such as how to remember, understand, and apply scientific concepts.

Fourthly, the students in this study reported that their peer classmates influenced their conceptions of learning, because Mainland Chinese students sit next to the same students all the time in the same classroom, and consequently they spend more time learning science with their classmates than with their teachers and parents.

Two themes emerged for peer students to influence the conceptions of learning: competition and modeling. Peer students are more than companions or friends with whom to discuss questions, and they have become the objectives to compete against in a classroom where scores and rankings are usually announced. Competition provoked students to think and reflect on their learning processes, and developed their conceptions of learning. Positive modelling improved students' conceptions of learning by observing their models' great learning behaviors. Anti-modelling strengthened their conceptions of learning by watching the students who lacked the expected behaviors and anticipated low achievements.

Lastly, cultural values permeated students' ideology and conceptions of learning by various means through many sources. Apart from the sources discussed above, i.e., parents, teachers, and peers, society at large influenced students' conceptions of learning by public media, such as TV and internet. In addition, the authorities' ideological preferences were embedded in the textbooks that greatly influenced students' worldviews and their conceptions of learning. One example is the late Premier's call for "learning for the rise of China", which was taught with Confucius' maxim 修身齐家平天下 (Cultivate oneself, put family in order, and run the country). As a result of these teachings, students reported patriotic goals in learning science. Students reported that they wanted to learn well and develop abilities so that they could serve the country. One salient finding was that students believed that they can improve their abilities by learning science. This notion was consistent with Confucianism's ideology 内圣外王 (saint inside and king outside), which means the learner will become as knowledgeable as a sage and possess high morality and great abilities like a king. This study found that all the seven categories of conceptions of learning science can be traced in some way to traditional values.

6.3 Contributions to the literature

1) The distinctiveness of Mainland Chinese students' conceptions of learning

No empirical studies have been found by this researcher up to date to describe Mainland Chinese students' metacognition including their conceptions of learning science. This study identified seven categories of conceptions of learning science, and the seven categories have commonality and difference compared with the categories of conceptions of learning developed in other countries and territories in the existing literature.

The first category, 'listening to the teacher', is a brand new category that no researcher has identified to date. 'Listening to the teacher' is a cultural phenomenon that might only exist in Confucian heritage societies. This category denotes that Mainland Chinese students show respect and give attention to their teachers without conditions. The essence of this category is the feature of obedience that is stressed and reinforced in Mainland Chinese schools.

The second category, 'attending to exams', is similar to Tsai's (2004) second category, 'preparing for tests'. Tsai's participants were also Chinese, although in Taiwan, yet they share the same tradition of Confucianism. There are commonalities and differences between the two categories. The common element is that exams and tests are important. The difference is that 'attending to exams' has more denotations than ‘preparing for tests’. ‘Preparing for tests’ suggests that the students regard learning science as activities preparing for exams. Nonetheless ‘attending to exams’ may or not regard learning as preparing for exams depending on the student’s understanding of the role the exams play. The ‘assessing’ students learnt science for developing understanding and improving abilities instead of simply for the sake of passing exams.

The third category, ‘memorizing’, is identical to Säljö’s (1979) second category, and similar to Marton’s (1993) ‘Memorizing and reproducing’. The fourth category, ‘understanding’, is similar to Säljö’s (1979) fourth category, ‘Making sense or abstracting meaning’, and identical to Marton’s (1993) fourth category. A key finding of this study is that ‘memorizing’ and ‘understanding’ are intermingled for these Mainland Chinese students. The students in this study reported that ‘understanding’ helped their ‘memorizing’ information, and thus they always tried to understand information before memorizing it. This finding was consistent with the findings that Chinese learners are not rote learners (Biggs, 1994, 1996, 2003; Kember and Gow, 1990; and Marton et al., 1993).

The fifth category, ‘doing problems’, is similar to Marton’s (1993) third category, ‘applying’, similar to Gustafson and Rowell’s (1995) second category, ‘solving problems’, and similar to Tsai’s (2004) third category, ‘calculating and practicing tutorial problems’. But ‘doing problems’ for Mainland Chinese students in this study does not only mean ‘calculating and practicing tutorial problems’. As discussed earlier, Mainland Chinese students do have to do problems that involve higher-order thinking skills. In other words, it is far from enough for Mainland Chinese students just to practice tutorial problems. In addition, 'doing problems' is closely intertwined with other conceptions of learning. When participants talked about 'doing problems', they have different degrees of understanding of why and how they do problems, and these understandings often embrace the ideas of listening to the teacher, memorizing and understanding knowledge, working hard and self-improvement.

The sixth category, 'working hard', is also not found yet in the literature of conceptions of learning. Chinese students are known as being diligent, but no research has identified it as a distinguished conception of learning. One of the reasons that Chinese students excel at international competitions may be that they have worked extremely hard because they believe that diligence instead of intelligence is a key attribute to success.

The seventh category, 'improving oneself', is similar to Marton's (1993) sixth category "Changing as a person" in a way but 'improving oneself' connotes more meanings than "changing as a person." Marton (1993) defined "changing as a person" as "seeing something in a different way" or "seeing oneself as a more capable person" (pp. 283–284). The subcategory 'improving oneself as perfection" overlaps with Marton's "changing as a person." The other subcategories, 'changing destiny' and 'serving family and nation' are unique for Chinese students. Chinese students in this study stated that learning can change a person's refinement, character, capabilities, future, and fate. As stated earlier, under the influence of Confucianism's advocacy for self-perfection, students reported that learning was a process to cultivate their abilities and refinement, so that they can have the fate controlled by their hands, and they can better serve their family and the nation.

2) The uniqueness of the structure of outcome space

This study suggested a circular holistic structure of the outcome space of the conceptions of learning science, which is not seen yet in the existing literature. In the literature of conceptions of learning, the outcome space is usually hierarchical, that is, all the categories of conceptions of learning are arranged hierarchically from a low level to a high level. However, the mutually exclusive categorical reasoning does not seem to apply to Mainland Chinese students on the bases of data analysis and interpretation. For example, 'memorizing' is regarded as a lower level conception than 'understanding' in Marton's hierarchy, but students in this study reported that their memorizing often comes after or before deep understanding of the knowledge being memorized.

A circular holistic structure means no category is lower or higher than other categories. Every category is an integral component of the holistic structure of the students' conceptions of learning. 'Holistic' does not only mean that each category sits in a circle that represents a complete identity, but also implies an intertwining relationship of the categories. Every category is related to other categories and thus the structure is a united whole unit.

3) An innovative interpretation of variation in phenomenographic research

Phenomenography looks at the collective experience with a focus on the variation among participants' experiencing the same phenomenon. Traditionally the variation exists between categories, i.e., different group of people would conceive the same phenomenon as belonging to different categories. For example, according to Marton et al. (1993), some students regarded learning as "increasing one's knowledge;" some students regarded learning as "memorizing and reproducing;" while some other students regarded learning as "applying."

As previously discussed, this research suggests that the Mainland Chinese students thought holistically about science learning and they regarded science learning as consisting of all the seven categories of conceptions of learning. In other words, there is no variation among the participants in conceiving science learning as 'listening to the teacher,' 'attending to exams,' and et cetera. The variation resides inside the categories. Different students reported different understandings of how and why they should 'listen to the teacher' or 'attend to exams.' Thus this study presents a new way to look at the variation embedded in phenomenographic research.

4) Connecting two research traditions

As stated earlier, there is much literature in studying metacognition and conceptions of learning, but separately, although some researchers such as Cano and Cardelle-Elawar (2004), Thomas (1999a, 2002, 2006c), and Vermunt and Vermetten (2004) suggested that metacognition and conceptions of learning are innately connected. This study redefined metacognition in the context of learning science. The familiar definition of metacognition, i.e., cognition about cognition, is an abstract concept that is not ready to be applied in studying students' learning science. In this study, metacognition is defined as students' knowing about learning, that is, students know what science learning is, how to learn science, and why do they learn science as they do. Meanwhile this operational definition of metacognition coincides with the meaning of conceptions of learning. Thus this study has made an attempt to connect the two prominent fields of research: metacognition and conceptions of learning.

6.4 Implications of the study

The findings of this research have practical implications for the stakeholders in education to better understand students' conceptions and processes of learning science. With a good understanding of how students perceive of science education and how they engage in science learning processes, educational authorities can make necessary reforms and draft policies to lead science education in culturally appropriate directions.

How students are evaluated is an issue that needs to be addressed. The study suggests that students in China are mainly evaluated by summative assessments, which are performed frequently. One consequence of relying too much on summative assessments is that students tend to regard science learning as passing exams or getting good grades or competing against their classmates. The true value of learning science, i.e., to be intrinsically interested in exploring the natural world, is suppressed and replaced by external incitements. Students may learn what is requested and may develop some skills to solve problems, but focusing on something else instead of on the science itself may be problematic in developing a lifelong interest to wonder and enquire about the natural world. It is implausible to stop summative assessments or abandon entrance examinations for universities and high schools. However, depending solely on once-for-all exams would exacerbate the exam-driven education of science. Formative assessments and term grades might be considered to decide the qualifications for higher educations, although ensuring accuracy of these results might be difficult.

This study suggests that some Chinese students are not given enough opportunities to take ownership of their learning. Students' academic tasks and time to engage in these tasks are mainly controlled by their teachers. Some students reported that they did not have time to learn what they wanted to because all their time is fully allocated to different subjects, even in the self-learning classes in the afternoons and evenings. One consequence of not being autonomous in learning is that the motivation to learn science is nothing but externally oriented, such as passing exams, going to university, or not disappointing their parents. Another consequence is that they might lose opportunities to develop their metacognitive abilities, such as predicting, planning, monitoring, and evaluating their learning processes. The 'holiday syndromes' reported by some students suggest that these students lack abilities to make plausible plans and monitor their behaviors during holidays. Giving students ownership of their learning and instructing them to plan, monitor and evaluate their learning will not only reduce holiday syndrome, but also empower them with metacognitive skills to become life-long learners.

Working too hard is not beneficial to students' health, their quality of life, and their full development as human beings. Rising at 6 am or earlier and staying up till 11 pm or later are common for Chinese students. Although some students reported that they were accustomed to not having enough time to sleep, it is not right for educators to build an environment that encourages students to do so. Advocating hardship in learning might mislead students to think that they would learn science well as long as they invest time. These students tend to be less metacognitive and lack strategies to improve their learning efficiency. Current hardship at school might deter them from becoming life-long learners in the future. Further, too much time devoted to academics would divest their choices to develop, for example, athletic competence, musical ability, and interpersonal skills.

Doing problems is not the same as solving problems. Chinese students spend many hours in doing problems, which may serve the purpose of grasping the concepts and passing tests. Since the problems are designed in a way for the students to employ the concepts, creative thinking and problem-solving skills might not be developed by doing a 'sea' of problems. In order to save time for preparing exams, some schools do not offer classes for experiments. The students just memorize the procedures and other information that is tested in exams. Students need to be provided with authentic situations from which they can abstract a problem, design problem-solving procedures, and employ concepts that may evolve different subjects.

Students' conceptions of learning reflect their learning processes and approaches and are in a way connected with their academic achievements, and thus high or low academic achievements may indicate effective or less effective learning processes, and sophisticated or less sophisticated conceptions of learning. The results suggest that science teachers should explicitly teach students how to learn and guide them to become metacognitive learners. For example, teachers should tell their students explicitly why they practice solving problems, and how they should solve problems. Science teachers should limit the number of problems assigned to students, instead, they can demonstrate or guide students to analyze and reflect on the procedures and the concepts that the problem involved.

Scientific inquiry is regarded as an effective way to learn science around the world. The Chinese national curriculum standards list scientific inquiry as one of their important goals of science education. However, in this study the students did not report scientific inquiry in their processes of learning science, and thus scientific inquiry is not in their conceptions of learning science. It can be inferred that the students in this study did not have rich experiences in learning science through scientific inquiry. Their teachers might have taught their classes with scientific inquiry in mind, but it is not clear how much emphasis was put on scientific inquiry and how much time was devoted in scientific inquiry. This might be another consequence of examination-driven curriculum, since too much focus on preparing for exams would diminish the importance of learning science through scientific inquiry.

Teaching and learning about the nature of science is almost a consensus goal of science education in many countries. The students in this study showed that they understood some nature of science from their conceptions of science, such as scientific worldview and scientific methods, but they reported nothing about the limit and tentativeness of scientific knowledge, or social and cultural influences on scientific enterprises. This is understandable because the Chinese standards for science education did not define the nature of science and did not give teachers' suggestions on how to teach the nature of science.

In summary, the findings of this study suggest that students' conceptions of learning and their learning processes should be considered when drafting policies in science education reform and when teachers plan and conduct their science lessons. Other forms of assessment such as formative and self or peer evaluations should be adopted so as to ease the side effects of once-for-all entrance examinations. Students should be given more ownership of their learning so that they have more opportunities to develop their metacognitive skills and intrinsic interest in learning science. More authentic situations and experiments should be designed to foster students' higher-order thinking and problem-solving skills, instead of doing a 'sea' of content-based problems. Scientific inquiry and the nature of science should be integrated into students' processes of learning science.

6.5 Limitations and suggestions for future research

Although 96 students were chosen from 10 schools in 6 cities/counties, the participants are only from two provinces, and thus are difficult to be representative of all of Mainland China that has 23 provinces, 5 self-governed districts, 4 municipalities directly under the jurisdiction of the Central Government, and 2 special administrative regions. For example, the students from Shandong province in this study considered that doing experiments is not important because they reported few opportunities to do experiments. The students from Hebei province considered it necessary to do experiments, but none of the participants voluntarily reported that doing experiments is important for them to learn science. As the variability in curriculum standards and the matriculation exams across Mainland China, it would be difficult and thus inappropriate to conclude that all Mainland Chinese students do not regard doing experiments as being important in learning science. To highlight the limitation and scope of this study, the sample locations, Hebei and Shandong provinces, are included in the thesis title. It is suggested that students from other part of China will be included in the future research, although it might be difficult to do so because of time and funding constraints.

The origins of the conceptions of learning were found in this study, however, how these sources found their way into students' minds, or in other words, how students' conceptions of learning were shaped by these sources, may need further exploration. Although a conceptual structure of how the five sources exerted influence on students' conceptions of learning was proposed, perhaps further evidence is needed to support this structure, and quantitative methodology will be needed to verify its authenticity.

This study provided evidence that traditional values influenced students' conceptions of learning, but it would be more illuminating if the mechanism of how these values caused the development of some conceptions of learning was investigated. In addition, the structure of the traditional values could be studied, and then how the structure of the traditional values would interact with that of the conceptions of learning could be explored.

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Appendix 1: Interview Introduction letters and Consent forms

1）Introduction letter to student

Date

Dear Student,

I would like to invite you to take part in the research project, **How Mainland Chinese Learn to Learn Science** that aims to help understand your knowledge, control and awareness and origins of your science learning processes. This research is a major part of my PhD study at the University of Alberta. To date little if any research on this topic has been undertaken in the People's Republic of China, and this study will be highly valuable for informing educational development and education programmes within the People's Republic of China and worldwide, and for contributing to the general understanding of students' learning processes and how they develop.

Your participation in this study is purely voluntary and you are under no obligation to agree to participate. Your full participation in the study would involve you being interviewed by me about your science learning processes and their origins for around 45 minutes. Please note that only some students will be selected for interviews. There may be a need to conduct a shorter (less than 20 minute) follow-up interview to check information from the first interview and if this is the case you may again chose to participate or not to participate.

You will be able to opt out of the study at any point up until three months after the data has been collected, simply by informing Mr Zhao Zhangiang (at the email address below) or your teacher who will pass on your request to Mr Zhao that you do not wish to continue to participate. In the event you withdraw your participation any data that has been collected from you will be removed from the data set.

Results of the study will be presented at academic and professional conferences and may appear in academic and professional journals. Research reports might include direct quotes made by you but your name will not be used. Other identifying information (e.g., your name, school, class and/or teacher) will also be omitted whenever the results are made public. This will help ensure your privacy, anonymity, and confidentiality. The study will comply with the University of Alberta Standards for the Protection of Human Research Participants. For further information of these standards you can see http://www.uofaweb.ualberta.ca/gfcpolicymanual/policymanualsection66.cfm.

Only the researcher, Mr Zhao Zhanqiang will have access to the raw data which will be stored securely at all times at the University of Alberta. Once data has been digitized (within one month of collection) all identification will be removed and names will be replaced with pseudonyms and codes. The data used in the study will be securely stored for a minimum of five years and will then be destroyed.

The plan for this study has been reviewed for its adherence to ethical guidelines and approved by the Faculties of Education, Extension and Augustana Research Ethics Board (EEA REB) at the University of Alberta. For questions regarding participant rights and ethical conduct of research, contact the Chair of the EEA REB at 780-492-3751.

Two copies of this form will be provided. One copy should be signed and returned, and the other copy should be kept for your records.

If you have any concerns or questions about this study please feel free to contact:

Mr Zhao Zhanqiang 1-86-8502-1398, zhanqiang.zhao@ualberta. or his supervisor

Dr. Greg Thomas 780-492-5671, gthomas1@ualberta.ca

Thank you very much for considering this request.

Sincerely,

Zhanqiang Zhao, PhD. Candidate in Science Education
Dr. Greg Thomas, Associate Professor (Science Education)

2) Introduction letter to parents

Date

Dear Parent/Guardian,

I would like to invite you to grant consent for your son/daughter to take part in the research project, **How Mainland Chinese Students Learn to Learn Science** that aims to help understand their knowledge, control and awareness and origins of their science learning processes. This research is a major part of my PhD study at the University of Alberta. To date little if any research on this topic has been undertaken in the People's Republic of China, and this study will be highly valuable for informing educational development and education programmes within the People's Republic of China and worldwide, and for contributing to the general understanding students' learning processes and how they develop.

Please note that you are under no obligation to agree to have your son or daughter participate in this project. Their full participation in the study would involve them being interviewed by me about their science learning processes and the origins of those processes for around 45 minutes. Please note that only some students will be selected for interviews. There may be a need to conduct a shorter (less than 20 minute) follow-up interview to check information from the first interview and if this is the case your son or daughter may again chose to participate or not to participate.

You, or your son or daughter will be able to withdraw your consent for them to be involved in the study at any point up until three months after the data has been collected, simply by informing Mr Zhao Zhangiang (at the email address below) or your teacher who will pass on your request to Mr Zhao that you/he/she does not wish to continue to participate. In the event that you or your child withdraws consent for participation any data that has been collected from your child will be removed from the data set.

Results of the study will be presented at academic and professional conferences and may appear in academic and professional journals. Research reports might include direct quotes made by your child but their name will not be used. Other identifying information (e.g., your child's name, school, class and/or teacher) will also be omitted whenever the results are made public. This will help ensure your child's privacy, anonymity, and confidentiality. The study will comply with the University of Alberta Standards for the Protection of Human Research Participants. For further information of these standards you can see http://www.uofaweb.ualberta.ca/gfcpolicymanual/policymanualsection66.cfm.

Only the researcher, Mr Zhao Zhangiang will have access to the raw data which will be stored securely at all times at the University of Alberta. Once data has been digitized (within one month of collection) all identification will be removed and names will be replaced with pseudonyms and codes. The data used in the study will be securely stored for a minimum of five years and will then be destroyed.

The plan for this study has been reviewed for its adherence to ethical guidelines and approved by the Faculties of Education, Extension and Augustana Research Ethics Board (EEA REB) at the University of Alberta. For questions regarding participant rights and ethical conduct of research, contact the Chair of the EEA REB at 780-492-3751.

Two copies of this form will be provided. One copy should be signed and returned, and the other copy should be kept for your records.

If you have any concerns or questions about this study please feel free to contact:

Mr Zhao Zhangiang 1-86-8502-1398, zhanqiang.zhao@ualberta, or his supervisor

Dr. Greg Thomas 780-492-5671, gthomas1@ualberta.ca

Thank you very much for considering this request.

Sincerely,

3) Consent from for students of or above 18 years old

Consent Form (Student)

Please sign the form below to indicate your willingness to take part in the study described above.

I, ____, have read the accompanying information letter and give my informed consent to participate in the research study, **How Mainland Chinese Students Learn to Learn Science,** conducted by Mr Zhao Zhangiang.

I hereby agree to (Please tick each item you consent to):

- ○ be interviewed by the researcher about my science learning processes and their origins for a period of around 45 minutes,
- ○ be interviewed for a shorter (less than 20 minute) interview, if necessary, to check information from the first interview.

In agreeing to take part in this study, I understand that:

- I am under no obligation to participate
- Even after giving my consent to take part, I may discontinue my participation without penalty at anytime. I may withdraw information that was already collected by contacting Mr. Zhao or my teacher within three months of the collection of that data.
- Information that I provide will be treated as confidential. Direct quotes from me may be used in research reports (i.e., presentations and publications), but my name and other identifying information will be changed or omitted.
- Research reports will be used for academic and professional presentations (e.g. conferences, workshops) as well as academic and professional publications.

I understand that I am under no obligation to participate in this study and that I can withdraw from the study after which any information or data that directly link to me as an individual will be excluded from the study.

____

(print name)

____ ____________________

(signature) (date)

The plan for this study has been reviewed for its adherence to ethical guidelines and approved by the Faculties of Education, Extension and Augustana Research Ethics Board (EEA REB) at the University of Alberta. For questions regarding participant rights and ethical conduct of research, contact the Chair of the EEA REB at 780-492-3751.

4) Consent form for students under 18 years old

Assent Form (Student under 18 years old)

Please sign the form below to indicate your willingness to take part in the study described above.

I, ____, have read the accompanying information letter and give my informed assent to participate in the research study, **How Mainland Chinese Students Learn to Learn Science,** conducted by Mr Zhao Zhangiang.

I hereby agree to (Please tick each item you consent to):

- o be interviewed by the researcher about my science learning processes and their origins for a period of around 45 minutes,
- o be interviewed for a shorter (less than 20 minute) interview, if necessary, to check information from the first interview.

In agreeing to take part in this study, I understand that:

- I am under no obligation to participate

- Even after giving my consent to take part, I may discontinue my participation without penalty at anytime. I may withdraw information that was already collected by contacting Mr. Zhao or my teacher within three months of the collection of that data.

- Information that I provide will be treated as confidential. Direct quotes from me may be used in research reports (i.e., presentations and publications), but my name and other identifying information will be changed or omitted.

- Research reports will be used for academic and professional presentations (e.g. conferences, workshops) as well as academic and professional publications.

I understand that I am under no obligation to participate in this study and that I can withdraw from the study after which any information or data that directly link to me as an individual will be excluded from the study.

____
(print name)

____ ________________
(signature) (date)

The plan for this study has been reviewed for its adherence to ethical guidelines and approved by the Faculties of Education, Extension and Augustana Research Ethics Board (EEA REB) at the University of Alberta. For questions regarding participant rights and ethical conduct of research, contact the Chair of the EEA REB at 780-492-3751.

5) Introduction letter in Chinese

日期

亲爱的同学，

兹邀请你参加一个国际研究项目，**中国学生如何学会学习科学学科**。该研究目的是研究你在学习物理、化学和生物的过程中所运用的元认知知识，元认知控制，和元认知体验以及这些元认知的渊源。该研究是我在加拿大埃尔伯塔大学博士学

习的重要内容。迄今为止中国学术界对该话题的研究几乎是零。你的参与将对中国以及世界范围内的科学教育事业和科学家对学习过程的深入理解做出贡献。

你的参与是纯自愿性质的。你没有义务必须参加该科学研究。在该研究中我们将花费大约 45 分钟的时间，对你科学学科学习过程中的元认知以及其渊源进行探讨。请注意只有一些学生会被选出来参加访谈。第一次访谈后，有可能参加很短的（不超过 20 分钟）的后继访谈，目的是检查第一次访谈信息的准确性。同意地你也有权利选择参加或者不参加该后继访谈。

在访谈后的三个月内，你可以选择退出该研究。方法是给我写邮件（邮箱在本页下端）或者让你老师转达你的意愿。你选择退出该研究后，你的访谈内容将从数据库中删除。

该研究的内容将会发表在国际学术期刊上或者在国际学术会议上交流。研究报告可能会直接引用访谈的内容，但是你的名字不会在学术期刊上出现。其它的个人信息，比如名字、学校、班级、老师等也将略去。这样做的目的是保护你的隐私权。该研究将符合埃尔伯塔大学的人文科学参与者保护标准。该标准的详细信息请见 http://www.uofaweb.ualberta.ca/gfcpolicymanual/policymanualsection66.cfm.

只有本研究者，赵占强，才有权接触访谈内容。该数据库将会安全保存在埃尔伯塔大学。可能有研究助理参与誊写录音或者翻译访谈内容。一旦访谈内容电子化后（一个月内），所有的名字和个人信息将会被化名或者编码所取代。该研究的数据将被妥善保存至少 5 年，其后将被销毁。

该研究计划已经被埃尔伯塔大学教育研究职业道德委员会(EEA REB)审查并通过。有关参与者的权利和研究行为规范，请拨打电话 780-492-3751 联系 EEA REB 委员会主席。

该表一式两份。一份签名上交，一份自己保留。

如果你有任何问题，请放心联系我本人，或者我的导师托马斯博士。

本人电话：1-86-8502-1398,　邮箱：zhanqiang.zhao@ualberta.
托马斯博士电话：780-492-5671，邮箱：　gthomas1@ualberta.ca

非常感谢你的参与。

赵占强
加拿大埃尔伯塔大学科学教育博士研究生

6) Consent form for students of and above 18 years old in Chinese

同意书（学生）

请在下方签名，表明你同意参加该研究。

我，____，已经阅读研究说明，愿意参加赵博士所开展的科学研究：中国学生如何学会学习科学学科。

我在此同意（请在你同意的条目上打勾）

- o 和研究者探讨我学习理科内容所运用的元认知及其渊源，时间大约 45 分钟。
- o 和研究者讨论第一次访谈内容的信息，时间少于 20 分钟。

在同意参加该研究的同时，我明白：

- 我没有义务必须参加。
- 即使我同意参加，我也可以随时撤销参与而不受任何惩罚。我可以在访谈三个月内通过联系赵先生或者我老师要求撤销访谈信息。
- 我提供的信息都是保密的。国际会议或者学术期刊上的研究报告可能会引用我的信息，但是我的个人信息将不会显示。
- 研究报告将会在学术会议或者专业期刊上发表。

我明白我没有义务必须参加该科学研究，而且我能够在访谈后提出撤销要求，有关我的任何信息和数据都将不会出现在该研究中。

____

(请清楚地写上你的名字)

____ ____________________

(签名) (日期)

该研究计划已经被埃尔伯塔大学教育研究职业道德委员会(EEA REB)审查并通过。有关参与者的权利和研究行为规范，请拨打电话 780-492-3751 联系 EEA REB 委员会主席。

7) Introduction letter for parents of students under 18 years old in Chinese

日期
亲爱的家长/监护人：

兹邀请您的儿子/女儿参加一个国际研究项目，**中国学生如何学会学习科学学科**。该研究目的是研究你在学习物理、化学和生物的过程中所运用的元认知知识，元认知控制，和元认知体验以及这些元认知的渊源。该研究是我在加拿大埃尔伯塔大学博士学习的重要内容。迄今为止中国学术界对该话题的研究几乎是零。你儿子/女儿的参与将对中国以及世界范围内的科学教育事业和科学家对学习过程的深入理解做出贡献。

请注意你没有义务必须让你儿子/女儿参与该科学研究。在该研究中我们将花费大约 45 分钟的时间，对你儿子/女儿在理科学习过程中的元认知以及其渊源进行探讨。请注意只有一些学生会被选出来参加访谈。第一次访谈后，有可能参加很短的（不超过 20 分钟）的后继访谈，目的是检查第一次访谈信息的准确性。同意地你也有权利让你儿子/女儿选择参加或者不参加该后继访谈。

在访谈后的三个月内，你或者你孩子可以选择退出该研究。方法是给我写邮件（邮箱在本页下端）或者让你老师转达你的意愿。你们选择退出该研究后，你孩子的访谈　　将从数据库中删除。

该研究的内容将会发表在国际学术期刊上或者在国际学术会议上交流。研究报告可能会直接引用访谈的内容，但是你的名字不会在学术期刊上出现。其它的个人信息，比如名字、学校、班级、老师等也将略去。这样做的目的是保护你的隐私权。该研究将符合埃尔伯塔大学的人文科学参与者保护标准。该标准的详细信息请见 http://www.uofaweb.ualberta.ca/gfcpolicymanual/policymanualsection66.cfm.

只有本研究者，赵占强，才有权接触访谈内容。该数据库将会安全保存在埃尔伯塔大学。可能有研究助理参与誊写录音或者翻译访谈内容。一旦访谈内容电子化后（一个月内），所有的名字和个人信息将会被化名或者编码所取代。该研究的数据将被妥善保存至少 5 年，其后将被销毁。

该研究计划已经被埃尔伯塔大学教育研究职业道德委员会(EEA REB)审查并通过。有关参与者的权利和研究行为规范，请拨打电话 780-492-3751 联系 EEA REB 委员会主席。

该表一式两份。一份签名上交，一份自己保留。

如果你有任何问题，请放心联系我本人，或者我的导师托马斯博士
本人电话：1-86-8502-1398,　邮箱：zhanqiang.zhao@ualberta.
托马斯博士电话：780-492-5671，邮箱：　gthomas1@ualberta.ca

非常感谢你的参与。

赵占强
加拿大埃尔伯塔大学科学教育博士研究生

8) Consent form for parents of students who are under 18 years old in Chinese

同意书（未满 18 岁学生的家长）

请在下方签名，表明你同意你的孩子参加该研究。

我，____，已经阅读研究说明，同意我孩子参加赵博士所开展的科学研究：中国学生如何学会学习科学学科。

我在此同意孩子（请在你同意的条目上打勾）

- o 和研究者探讨他/她学习理科内容所运用的元认知及其渊源，时间大约 45 分钟。
- o 和研究者讨论第一次访谈内容的信息，时间少于 20 分钟。

在同意孩子参加该研究的同时，我明白：

- 孩子没有义务必须参加。
- 即使我孩子同意参加，他/她也可以随时撤销参与而不受任何惩罚。他/她可以在访谈三个月内通过联系赵先生或者我老师要求撤销访谈信息。
- 我孩子提供的信息都是保密的。国际会议或者学术期刊上的研究报告可能会引用他/她的信息，但是个人信息将不会显示。
- 研究报告将会在学术会议或者专业期刊上发表。

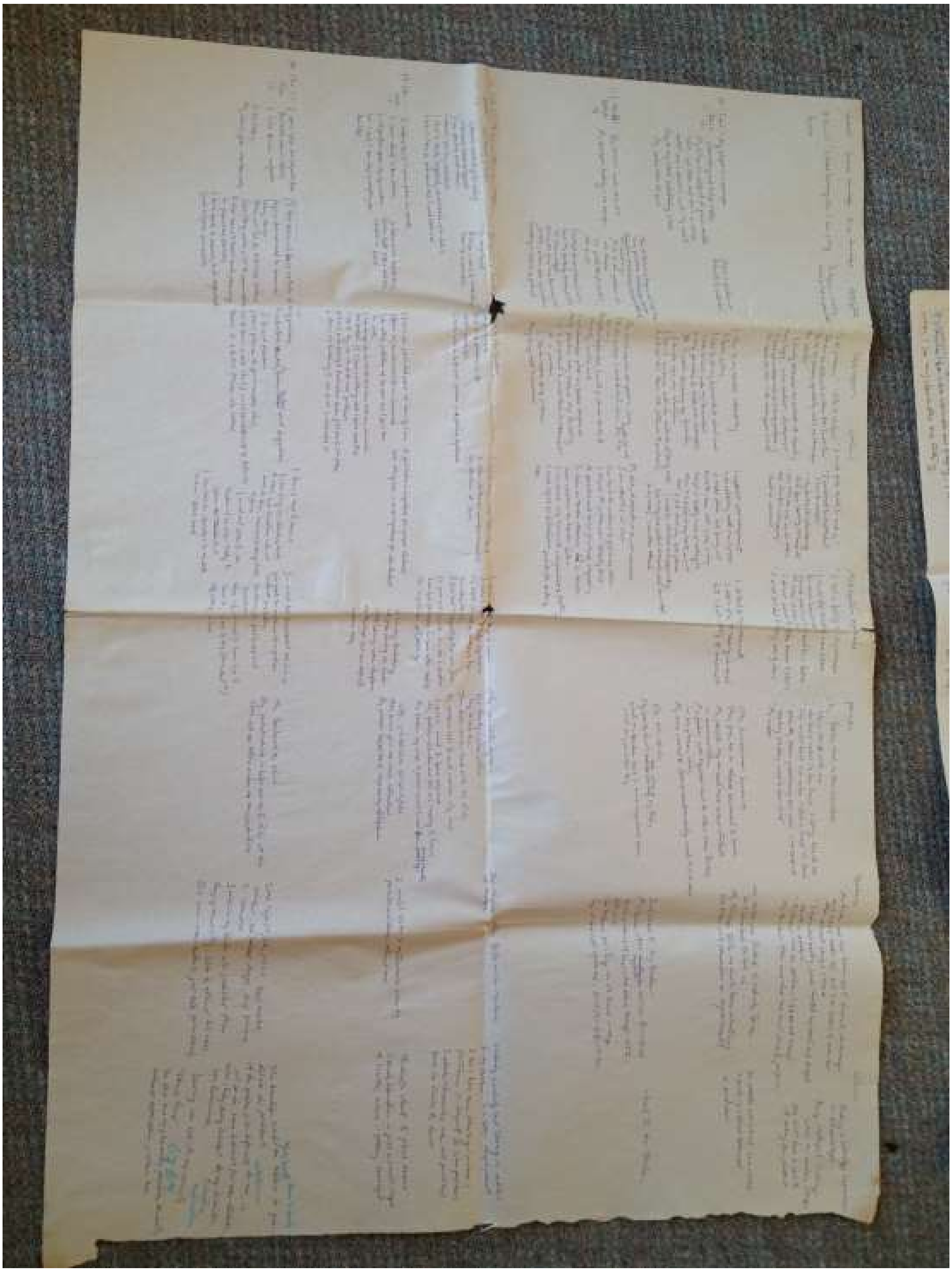
我明白没有义务让孩子必须参加该科学研究，而且我孩子能够在访谈后提出撤销要求，有关我孩子的任何信息和数据都将不会出现在该研究中。

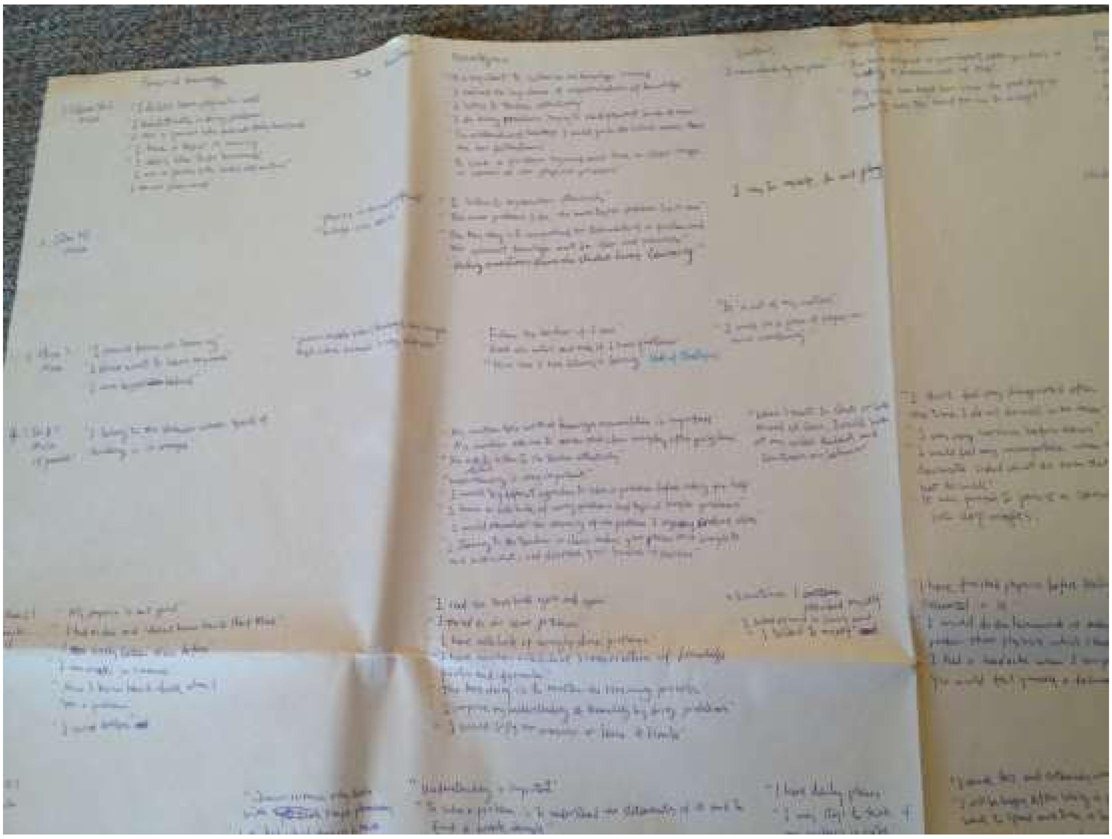
____
(请清楚地写上你的名字)

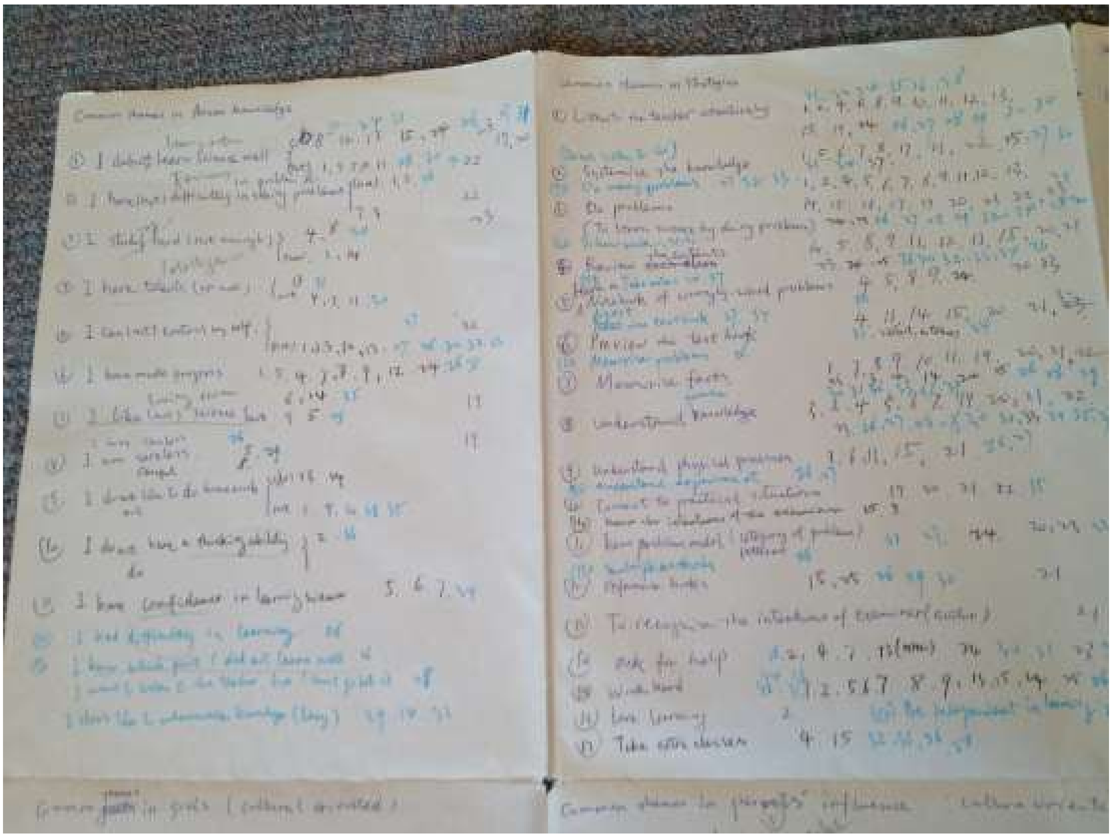
____ ____________________
(签名) (日期)

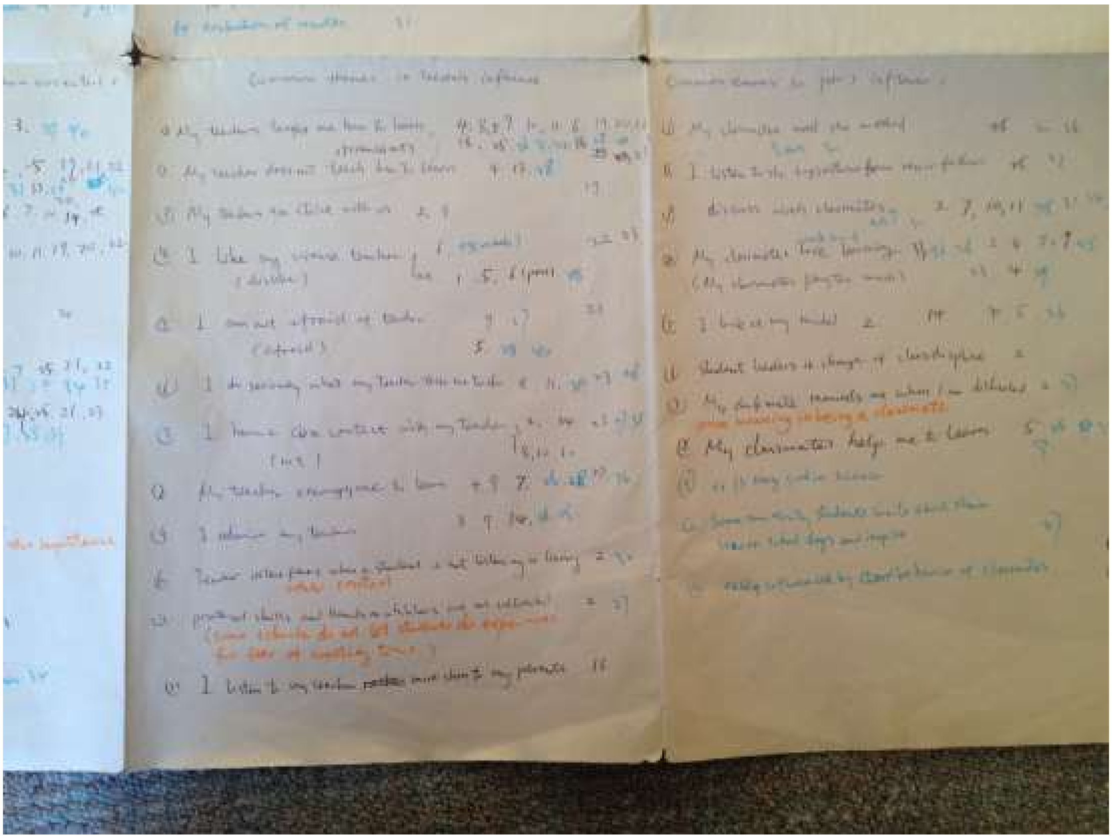
该研究计划已经被埃尔伯塔大学教育研究职业道德委员会(EEA REB)审查并通过。有关参与者的权利和研究行为规范，请拨打电话 780-492-3751 联系 EEA REB 委员会主席。

Appendix 2 Pictures of data processing

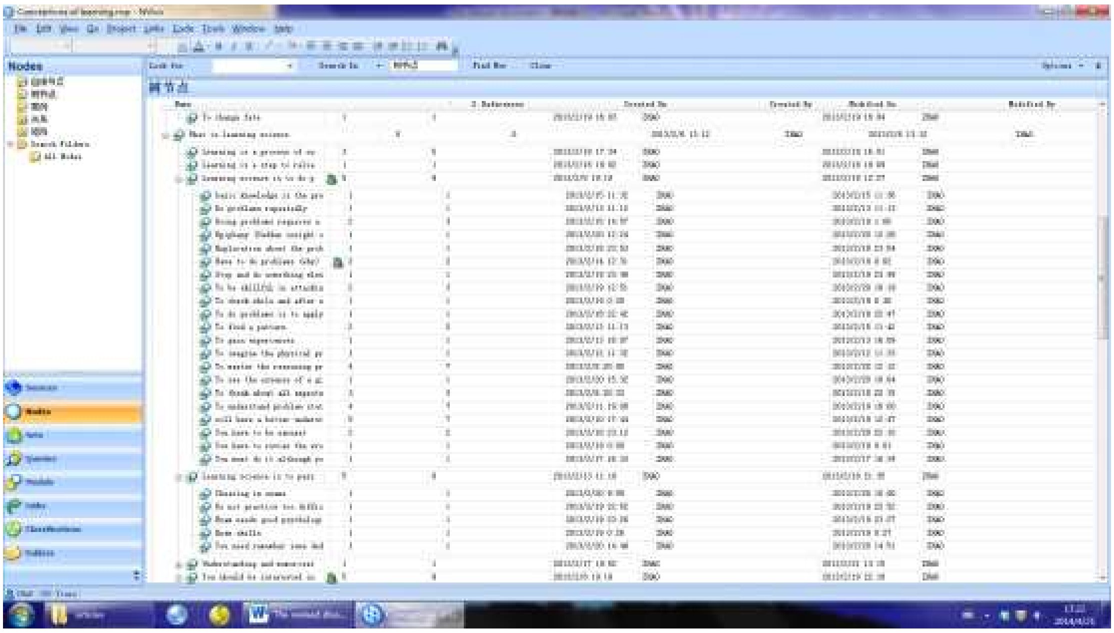


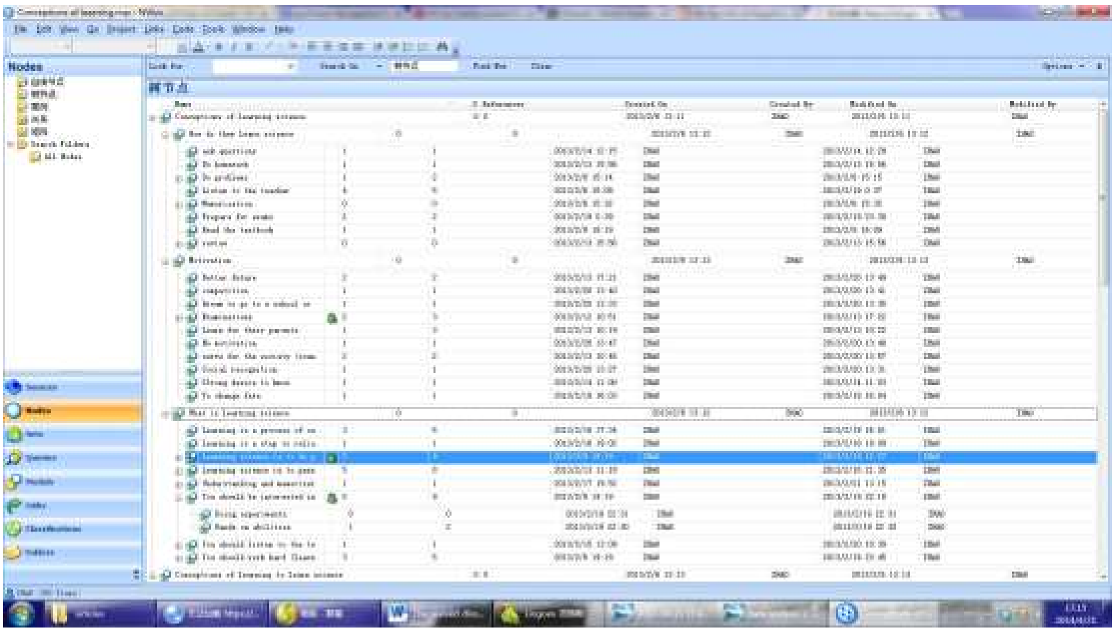


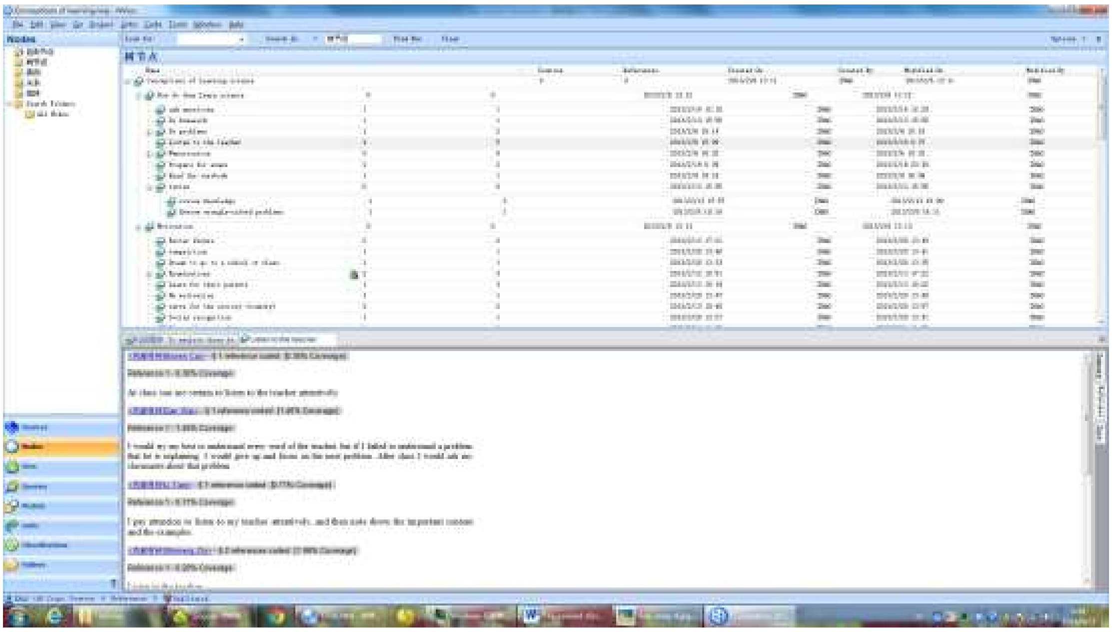


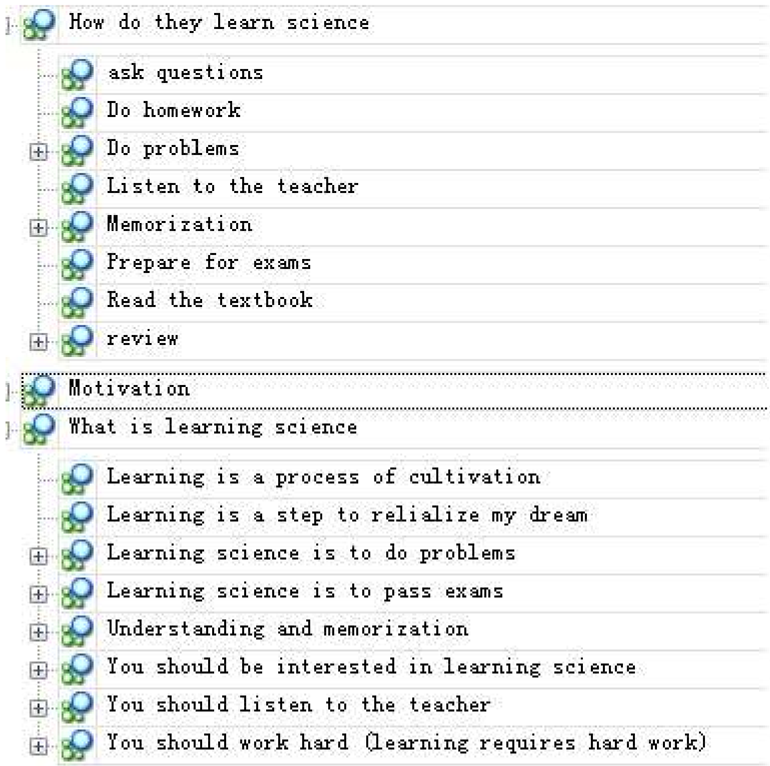


Appendix 3 Screen shots of Nvivo data analysis








How do they learn science
ask questions
Do homework
Do problems
Listen to the teacher
Memorization
Prepare for exams
Read the textbook
review
Motivation
What is learning science
Learning is a process of cultivation
Learning is a step to relialize my dream
Learning science is to do problems
Learning science is to pass exams
Understanding and memorization
You should be interested in learning science
You should listen to the teacher
You should work hard (learning requires hard work)