THE RELATIONSHIP BETWEEN REFORMED TEACHING AND STUDENTS' CREATIVITY IN A CHINESE MIDDLE SCHOOL

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Abstract

Current education reform in both the United States and China promotes a reformed inquiry-based approach based on the constructivist learning theory. This study contributes to the research literature by exploring the relationship between reformed science teaching and students' creativity. Chinese education is often criticized for a lack of creativity by some news media (Stack, 2011). This study was designed to explore the creativity of students and the extent to which inquiry instruction is used in the science classroom. The study used a convenience sample of two classes from a middle school located in Wuhu city, Anhui province, China. A total of 120 students and 3 science teachers participated. A mixed-methods research approach was adopted for integrated explanation. Student surveys, the Torrance Test of Creative Thinking (TTCT), Verbal, Reformed Teaching Observation Protocol (RTOP), and semi-structured interview were utilized as research tools for collecting quantitative and qualitative data. The findings indicate that there was a positive relationship between reformed teaching and students' creativity ($F(2, 117) = 19.760, p<.001$). Classroom observation generally indicated that the participating teachers were skillful at promoting conceptual understanding and provoking high-level thinking. However, evidence of student-centered instruction was less apparent. The semi-structured interviews with participating teachers showed a positive attitude toward inquiry-based teaching but also revealed several challenges. The findings from the Verbal TTCT and classroom observation provided evidence of Chinese students' creativity. Directions for future research are provided.

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Chapter 1: Introduction

Introduction

In recent years, there are many studies showing that the education in China, especially the education of science and technology, is catching up to education in the United States (Cheng, 2012). The result of the 2009 Programme for International Student Assessment (PISA) show that Chinese students from Shanghai achieved the best ranking in mathematics, science, and reading; however, the score of the United States is slightly above the average line (OECD, 2010). Shanghai does not represent the whole country of China. Instead, as a pearl of China, Shanghai schools are an epitome of the most advanced schools in Chinese education. Many other regions in China, such as rural areas and western China, which are not as economically developed as Shanghai, are likely to compromise the ranking of China overall in international testing.

Besides the influence of economy, Chinese science education has developed based on a unique and complex integration of history and culture, which also makes China quite different from western counties in the development of the science education. Historically, ancient China was influenced by a culture of Taoism for discovering the nature world. This ideology asks people not to change and take control of, but to conform to nature and to seek a harmony between nature and humans. The philosophy of science for a long time was dominated by Taoism with “inquiry” referring more to getting along with nature rather than an investigation of nature (Abd-El-Khalick et al., 2004). Until the beginning of nineteenth century, when China was impacted drastically by western cultures and technologies, scientific inquiry gradually gave way to using scientific methods to explore nature world. Western science education was introduced into China in the end of the nineteenth century (Lewin 1987; Wang 1997). During the Great

Proletarian Culture Revolution (1966-76), there was a common and strong belief that practice was superior to theory. This belief finally faded with the end of the revolution. Dramatically, after 1976, a renewal of emphasis on scientific concept and theory, logical thinking, and problem solving has again dominated Chinese science education (Sadanand, 1996). To date, the main body of science education system in China is characterized by national curricula and textbooks, teacher-centered instructions, and high expectations on tests (Guan & Meng, 2007; Su, Z., et al., 1994).

Although the teacher-centered, text-based, and exam-oriented instruction is still popular and widely applied in many science classrooms in China nowadays, there are more and more voices of criticism against the existing traditional teaching style. Generally, these criticisms can be divided into three major topics. First, Chinese students have been described as “test-takers” with “high intelligence but low ability” (Guo, 2005; Su, Z. et al., 1994), accusing the exam-oriented education system in China. People think that over focusing on testing will restrict both students and teachers in the educational process. Second, Chinese students are passive learners who are suffering from “cram education”. “Cram education” or “cram school” is a common phenomenon in many Asian countries (Fitzpatrick, 2010; Roesgaard, 2006; Wei & Chen, 2010). There is a common belief that students will learn more when they are delivered to and infused more. Third, Chinese students are accused of generally lack of creativity. This issue has been argued for many years and is still a hot topic today. News media criticized Chinese students’ high achievements in international tests come at the cost of lacking creativity and imagination (Stack, 2011). Chinese educators often compare primary and secondary education between China and the United States and blame traditional Chinese education for strangling students’ nature of creativity (Wang & Yang, 2010). Finally, although it is the 21st century now, blackboard, chalk, and the textbook are still regarded as the most dominant tools of instruction in China. There is a big gap in development and application of educational technology between China and western countries.

No matter the “test-takers” or the products of “cram education”, the common criticism is pointing to the essential lack of creativity. In fact, this criticism does not come from out of nowhere. It comes from the socialist ideology with an emphasis on Marxism in China. One of the Marxist basic philosophical standpoints are that the only reality is the material world. The human mind is only a reflection of the material world, and the mind does not exist without the material world (Engels, 1976). This Marxist materialism had been misinterpreted and overemphasized during the ten-year period of the Great Proletarian Culture Revolution. One of the direct influences of this overemphasis on the material world is that the importance of the human mind and thinking process is seriously underestimated. Creativity was regarded as an unrealistic and unpractical idea, which is not as important as really building something that can be used directly.

However, creativity, as a human phenomenon and human intelligence, is naturally embedded in human development (Wadaani, 2015), and its essence is not influenced by exterior factors, such as policy, geography, and history. In China, despite the culture difference compared to the West, there are many terms for creativity which are used in everyday and everywhere, including chuang zuo (创作), chuang jian (创见), chuang zao (创造), chuang yi (创意), and chuang xin (创新), referring to work, sight, making, idea, and newness, respectively (Chan, 2007). Other Chinese words point out the characteristics of creativity, such as ge xin (革新), du te (独特) and yuan chuang (原创), meaning revolutionarily new, uniquely special, and original made, respectively (Chan, 2004; Chan, 2007).

Meanwhile, it is easy to notice that “inquiry” has been the “gold standard” in science education. In the United States, current science education reforms (i.e., American Association for the Advancement of Science [AAAS], 1990; National Research Council [NRC], 2013) emphasize not only inquiry-related skills (e.g., identifying problems, formulating research questions, design and implementing investigations, analyzing data, defending hypotheses, and communicating) but also understanding about inquiry and nature of science. Although a student-oriented, inquiry-based approach has not yet become the major form of science education in China (Kohn, 2000; Weiss et al., 2001), using an inquiry-based approach in science education is one of the most important themes in many countries (Abd-El-Khalick et al., 2004). Anderson (2002) characterized Inquiry, “as the central word used to characterize good science teaching and learning.”

The Ministry of Education (MOE) (2001a) of China released the Basic Education Curriculum Reform Outline (Trial) as the initiation of the eighth curriculum reform. According to Zhong (2006), there are three transformations in the Outline: the transformation from “centralization” to “decentralization” in curriculum policy, the transformation from “scientific discipline-centered curriculum” to “society construction-centered curriculum” in curriculum paradigm, and the transformation from “transmission-centered teaching” to “inquiry-centered teaching” in teaching paradigm. The reformed curriculum aims to switch the emphasis from passive, reception-oriented learning to an emphasis on participation, exploration, and hands-on experiences (Li & Ni, 2011).

For implementing su zhi jiao yu (素质教育), referring to qualities-oriented education which is the opposite of exam-oriented education, the Curriculum Reform Outline specified several objectives to improve the individual’s quality in all aspects. One of the objectives is to cultivate creative spirit (MOE, 2001a). Specifically, the new curriculum standards have linked learners' life experiences and actual social realities to the previously emphasized knowledge acquisition and skills development to develop creativity, innovative spirit and practice capabilities (Zhou & Zhu, 2007). The Comprehensive Practice Activities is compulsory for primary through senior high schools as an experimental curriculum centering on student activities and social skills to develop learner's problem-solving capacity, creative abilities, and practice competencies (Zhou & Zhu, 2007).

Problem Statement and Purpose

First, current reform documents in the United States and China (e.g. AAAS, 1990; NRC, 2013; MOE, 2001a) both recommend using inquiry-based teaching and the need for cultivating students' creativity. However, literature that links scientific inquiry with creativity are only based on theoretical analyses (e.g., Barrow, 2010; Kind & Kind, 2007). The major purpose of this study is for providing a research-based analysis of the relationship between students' creativity and inquiry based-teaching to encourage creativity with scientific inquiry.

Second, international tests, such as PISA 2015 and TIMSS 2015 (OECD, 2016; Provasnik et al., 2016), have reported that students in many Asian countries, such as China, Korea, and Singapore, perform better in mathematics and science than the students in the United States. These test reports only reveal problems, however, without any explanation. This study of science education in China offers an opportunity for feedback to the international community for implementing an inquiry-based approach. This study also aims to consider the "frontline" of the current science education reform in China to acquire first-hand data for better investigation of inquiry, creativity, and the relationship between them. Additionally, teacher belief as an important fact capable of influencing the reform process will also be analyzed and discussed.

Third, under the traditional curriculum and teaching method, Chinese students' thinking has been trained in a fixed mode that is, especially in science, "read question – find variables – choose formula – calculate and find answer." Only the most efficient way to solve the problem will be taught and encouraged to learn and use. To find only the one best standard answers is regarded as the supreme purpose since the correct answer is the key to achieving high test scores. However, many scholars and educators (Li & Zhang, 2002; Qin, 2016) have criticized the cons of the traditional approach for compromising students' creativity. At the same time, the influence of Marxist materialism brings us at least a partial understanding that the thinking process is not as important as the material world, so that teaching for creativity is less efficient than teaching for "the correct answer." The current education reform in China arouses the research interest of this study in finding whether Chinese students currently still lack creativity; or finding that the lack of creativity is merely a cliché.

In addition, gender difference in creativity is overstated in daily life in China, which implies a strong belief that boys are more creative than girls. However, empirical studies of gender difference in creative ability have shown inconsistent findings revealing in every possible outcome from creativity measurements. There are studies to indicate either men surpassed women (Cox, 2002; Dollinger, Dollinger, & Centeno, 2005) or women outperform men in creative ability (Reuter et al., 2005; Wolfradt & Pretz, 2001). However, other studies have found no significant difference between male and female in creativity (Kaufman, Baer, & Gentile, 2004). Current study also contains the purpose of investigating gender differences in the predictive model.

Research Questions

To address the purpose of this study, several research questions are presented as follows:

1. What is the relationship between reformed science teaching and students' creativity and does gender difference significantly contribute to this relationship?
2. To what extent is inquiry-based used in the science classroom?
3. What are teachers' beliefs about using an inquiry-based teaching approach?
4. To what extent do middle school science students display creativity?

Research Hypotheses

The hypotheses are made based on the review of literature and previous observation and experience:

1. There is a significant positive relationship between reformed science teaching and students' creativity and gender difference significantly contributes to this relationship.
2. In the observed science classes, teachers use methods of scientific inquiry.
3. Teachers believe in the advantage of inquiry-based teaching. Teachers understand relevant inquiry concepts and are willing to apply them in their teaching.
4. Chinese students exhibit creative ability in generating novel and useful ideas.

Significance of the Study

Education should be without borders. In an international view, studying science education in different educational systems provides multiple points of access to the same overall goal – developing students' scientific literacy. For this purpose, although science education in China has a different historical and cultural background, current reform demand has shown a highly consistency with the reform approaches in the United States and in other western countries. There are even some signs that the results of science education reform in China may be catching up or even surpassing those in the United States. To study of reform-based science education in China provides an international perspective of science education reform for academic communities worldwide.

Kind and Kind (2007) found the only empirical intervention study to test the effect of using inquiry approach to train students' creativity was a quasi-experimental study which was conducted by Bills (1971). In this study, the control group was a traditional class while the experiment group was taught with open-ended inquiry tasks for divergent thinking. Unfortunately, Bills (1971) found that there was no significant effect of using inquiry science to increase students' creativity. Aside from this insufficient experimental evidence, this author found no research-based study on the relationship between inquiry and creativity. Furthermore, there are only several research studies on scientific creativity in China (e.g. Hu & Han, 2015; Hu et al., 2004; Lu & Yang, 2010) but none of them indicates the relationship between creativity and inquiry-based approach in science education. This study will contribute to current the literature on the link between students' creativity and reform-based teaching. The primary aim of this study is to identify and describe the relationship between creativity and scientific inquiry based on a first-hand data analysis. This study will therefore illuminate new directions for future research.

This study will also provide an up-close observation on the science education reform movement in China. Since the current science education reform in China, especially the reform in science curriculum and instruction, is similar with the reform in most western countries such as the United States, studying and organizing relevant literature is necessary to assist in promoting such reform. In this study, an understanding of the practical obstacles during the transition from the traditional approach to a new reformed one will be revealed and discussed and will therefore be of interest to teachers, teacher educators, and researchers in both China and western countries.

Teacher beliefs are another importance element to be considered since teachers are the main vehicles for implementing reform in schools. The outcomes of reform efforts are directly influenced by teachers' beliefs (Gregoire, 2003; Sarason, 1996). Teachers are critical components to reform because it is they who will decide whether to use constructivist epistemology in their classrooms (Beck, Czemiak, & Lumpe, 2000). If teachers' beliefs of reform are ignored, the reform process will be unlikely to move forward (Cuban, 1990). Identifying and considering teachers' beliefs is essential in identify the factors influencing science teachers' implementation of inquiry-based approach in their classrooms.

Considering the cliché that Chinese students have high test-taking skills but low creative abilities, one of the purposes of this study is to give a research-based point of view by stepping into a real classroom to determine whether such a cliché has merit or is merely a biased overstatement. In this study, students' creative thinking will be measured in Torrance Tests of Creative Thinking (Torrance, 1974), the results of which will be carefully analyzed and presented graphically for a visual explanation. The results and discussion will also serve as a reference for future comparative studies between Chinese students and students from other countries, or for the comparison among Chinese students (e.g., rural vs urban).

As mixed-method research, this study contains both quantitative and qualitative data for not only objectively uncovering "what's going on" but also generating explanations or theories with an insider's view to facilitate further investigations. The results from this study will also benefit science teachers in both China and the United States to improve their teaching from reviewing the similar problems that are revealed here. The author believes that the results found in the current study can also be adapted into other education systems pursuing similar reform ideals and goals.

Chapter 2: Literature Review

Learning Theories

The purpose in presenting and comparing two well known, but often viewed as contradictory, learning theories is to emphasize the intrinsically strong relationship between learning and teaching. Effective teaching requires not only pedagogical content knowledge (Shulman, 1987) but also pedagogical learner knowledge (Grimmett & MacKinnon, 1992). A good teacher should know well what to teach and how to teach. This fundamental construct emphasizes the importance of a thorough understanding of how students learn important to improve teaching quality, and students' learning performance. Learning and teaching, although each their own unique area of practice and expertise, can be regarded as an integration of daily educational activities each closely entwined with the other.

Behaviorism and constructivism are the two learning theories that form the theoretical framework for this study. The study is based on a constructivist point of view with a focus on investigating students' creativity. Although behaviorism as a learning theory is often regarded as the opposite of constructivism, this study contains behaviorism as an example of the traditional science education for a better understanding of today's education reform. In addition, constructionism is also discussed for supporting and completing a broader image of constructivism.

Behaviorism.

The teacher-centered, text-based and exam-oriented structure of traditional Chinese education is an expression and application of behaviorism learning theory. For many years, the earlier previous curriculum and instruction reform texts and plans in China emphasized a behaviorist point of view in education (Zhong, 2006). The behaviorist model in Chinese schools emphasizes the importance of direct instruction and lectures, in which students are regarded as passive receivers. Su, Su, and Goldstein (1944) demonstrated that "Reviews and repeated drills of exercises are employed by the Chinese teachers as the major mechanisms to control and consolidate teaching and learning in the classroom" (p.259).

There are many theorists (e.g., Bandura & Walters, 1963; Hull, 1943; Pavlov, 1897; Skinner, 1974; Thorndike, 1905; Watson, 1913 etc.) who have contributed to research on behaviorism. As the father of behaviorism, John B. Watson first brought out Behaviorism in his article, Psychology as the Behaviorist View It (Watson, 1913). Watson (1930) defined learning as a stimulus-response connection, in which an individual learns to respond through unconditional stimulus. Behaviorist view regards learning as a change in external behavior achieved using reinforcement to shape the behavior. People learn new things when they receive a positive reinforcement while abandoning old knowledge when receiving a negative reinforcement (Belkin & Gray, 1977). External stimuli, such as reward or punishment, have a direct influence on human learning behavior. Consequently, human mental states and processes can be directed by a behaviorist point of view (Freiberg, 1999; Moore, 2011; Winn, 1990). The American psychologist, B. F. Skinner wrote:

> Teaching is the arrangement of contingencies of reinforcement under which students learn. They learn without teaching in their natural environments, but teachers arrange special contingencies which expedite learning, hastening the appearance of behavior which would otherwise be acquired slowly or making sure of the appearance of behavior which otherwise never occur. (Skinner, 1968, p.64)

Influenced by positivism (Amsel, 1989), behaviorism emphasize an “objective” rather than “subjective” point of view in learning process. As Bichelmeyer and Hsu (1999, p.3) stated, “The behaviorist epistemology is grounded in objectivism, which assumes that there is a single reality external to individuals”, behaviorism assumes that a learner is essentially passive, as an unreflective responder, responding to environmental stimuli.

In a behaviorist view, the teacher’s role is like a designer and programmer who determines how and what to teach with objectives based on target behavior. A behaviorist teacher usually arranges all learning sequences for students to shape their responses towards successful outcomes step by step. In the line with that, the term programmed instruction refers to “a system of teaching and learning within which pre-established subject matter is broken down into small, discrete steps and carefully organized into a logical Literacy Information and sequence in which it can be learned readily by the students” (Bigge & Shermis, 2004, p.113). According to Ertmer and Newby (1993) and Bichelmeyer and Hsu (1999), teacher’s job in behaviorist learning theory includes: determining what kind of instruction can elicit the desired responses; organizing learning materials, in which prompts are paired with target stimuli; keeping efficient records of each student’s progress as the track of stimulus-response progress; and structuring the learning environment so that students can make correct responses and receive reinforcement.

Constructivism.

Unlike the traditional, behaviorist education, under current science education reform approaches, science teachers will shift to a more inquiry-based and constructivist instruction (Beck, Czerniak, & Lumpe, 2000; Levitt, 2002). It is notable that the theory of constructivist learning has had a broad impact on learning and teaching within many education reform movements since 1960s. In China, the instructional paradigm has remained unchanged for decades until the New Curriculum in 2001(Zhong, 2006). One goal of the recent curriculum reform in China is "to change curriculum implementation from an over-emphasis on receptive learning, rote memorization and repetitive mechanical training to students' active participation, motivated inquiry and hands-on experiences, and develop learners' capacity for collection and processing information, acquiring new knowledge, problem-solving and communication-cooperation" (Zhou & Zhu, 2007, P.45).

Generally, constructivists believe that all humans construct their own knowledge through a process of discovery and problem-solving. Mascolo and Fischer (2005) described learning as "the philosophical and scientific position that knowledge arises through a process of active construction". The difference between behaviorist and constructivist view of education is as following:

> Where behaviorism views knowledge as resulting from a finding process, constructivism views knowledge as the natural consequence of a constructive process. Where behaviorism views learning as an active process of acquiring knowledge, constructivism views learning as an active process of constructing knowledge. Finally, where behaviorism views instruction as the process of providing knowledge, constructivism views instruction as the process of supporting construction of knowledge. (Bichelmeyer & Hsu, 1999, p. 4)

There are many different types of constructivism, among the most popular are cognitive constructivism and social constructivism. Cognitive constructivism developed from the ideas of Jean Piaget and emphasizes emphases the importance of individual cognitive process (Bruner, 1961; Osborne & Wittrock, 1983; Piaget, 1978; von Glasersfield, 1987). This cognitive approach focuses on mental process rather than observable behavior. Cognitive constructivists believe that humans will not be able to understand and use the information which is directly given to them. Instead, they must "construct" their own knowledge through experience.

On the other hand, social constructivism outlined by Lev Vygotsky, emphasizes the importance of culture and society context of cognitive development (Derry, 1999; Gergen, 1985; Lemke, 2001; McMahon, 1997; Vygotsky, 1978).

> From the very first days of the child's development, his activities acquire a meaning of their own in a system of social behavior and, being directed towards a definite purpose, are frequently refracted through the prism of the child's environment. The path from object to child and from child to object passes through another person. This complex human structure is the product of a developmental process deeply rooted in the links between individual and social history. (Vygotsky, 1978, p. 30)

Social constructivists believe that individuals build meaning through their interactions with each other and with the environment in which they live. They also believe that knowledge is a socially and culturally constructed human product (Ernest, 1998; Gredler, 2008; Prat & Floden, 1994) and that learning only happens when it is regarded as a social process. Therefore, knowledge is acquired through the process of actively engaging in social activities:

> Knowledge is never acquired passively, because novelty cannot be handled except through assimilation to a cognitive structure the experiencing subject already has. Indeed, the subject does not perceive an experience as novel until it generates a perturbation relative to some expected result. Only at that point the experience may lead to an accommodation and thus to a novel conceptual structure that reestablishes a relative

> equilibrium. In this context, it is necessary to emphasize the most frequent source of perturbations for the developing cognitive subject is the interaction with others. (von Glasersfeld, 1989, p. 136.)

Even though there are different variants of constructivism (Phillip, 1995), important commonalities can be found (Palmer, 2005). Palmer (2005) indicated that both cognitive constructivist and social constructivist views regard learning "as an active rather than a passive process, as ultimately each individual reconstructs his/her own understandings in response to environmental stimuli." Additionally, Powell and Kalina (2009) pointed out that both cognitive and social constructivists value the inquiry or question and answer method, claim that guided forms of teaching or facilitation are necessary, and view the teacher's role as a facilitator or guide, rather than a director or dictator.

One con aimed at constructivist learning, proposed by Jones, M., & Brader-Araje (2002), is that individual's prior experience cannot be sufficient to construct knowledge, because different experiences make everything and anything count equally as knowledge. To point out the inadequacy of this point of view, von Glasersfeld used "viability" to describe the truth in constructivism:

> Viability… is relative to a context of goals and purposes. But these goals and purposes are not limited to the concrete or material. In science, for instance, there is, beyond the goal of solving specific problems, the goal of constructing as coherent a model of the experiential world as possible. (von Glasersfeld, 1992, p. 7)

A more common argument of constructivist learning among teacher educators and researchers is that the minimally guided approach will bring more confusions and frustrations to students (Brown & Campione, 1994). However, constructivist learning does not ignore the importance of teachers and teaching. Instead of being a lecture deliverer, a constructivist teacher is more like a facilitator who coaches, mediates, prompts, and helps students to achieve their learning goals. According to Seymour Papert:

> The constructionist attitude to teaching is not at all dismissive because it is minimalist - the goal is to teach in such a way as to produce the most learning for the least teaching. Of course, this cannot be achieved simply by reducing the quantity of teaching while leaving everything unchanged. The principle other necessary change parallels an African proverb: If a man is hungry you can give him a fish, but it is better to give him a line and teach him to catch fish himself. (Papert, 1993, p.139)

Constructionism.

Kafai and Resnick (1996) mentioned several dimensions by which constructionism differs from other learning theories. First, learners are most likely to be intellectually engaged when working on personally meaningful activities and projects. Second, learners can make connections with knowledge in different ways. Third, constructionist learning environments encourage multiple learning styles and multiple representations of knowledge. Inspired by the constructivist learning theory, constructionism advocates student-centered, active learning, in which students acquire new knowledge through prior knowledge and experience. Meanwhile, constructionism holds that building knowledge occurs most effectively when the learner is engaged in tangible and sharable activities (Cakir, 2008). The relationship between constructionism and constructivism is explained by Papert:

> We understand "constructionism" as including, but going beyond, what Piaget would call "constructivism." The word with the v expresses the theory that knowledge is built by the learner, not supplied by the teacher. The word with the n expresses the further idea that this happens especially felicitously when the learner is engaged in the construction of something external or at least shareable . . . a sand castle, a machine, a computer program, a book. This leads us to a model using a cycle of internalization of what is outside, then externalization of what is inside and so on. (Papert, 1990, p. 3)

Papert's constructionism shares similar goals with Piaget's constructivism but the means are different (Ackermann, 2001). According to Ackermann (2001), Papert and Piaget are both constructivists and developmentalists in that they believe children build their own cognitive tools, with which they keep construct knowledge. However, Papert and Harel (1991) suggested that "diving into" situations are a powerful means of gaining understanding. McLellan's (1996) perspective on situated learning indicates that learning cannot be achieved or looked at separately from the context in which it occurs. The major assumptions of situated learning include (1) knowledge is acquired constantly through construction, (2) knowledge must be learned in an authentic context, and (3) knowledge can be gained within interactions between individuals (Orgill, 2007). Situated learning theory provides "part of a theoretical justification for 'inquiry-based' approaches to science teaching and learning," as learning through authentic activities is emphasized" (Scott, Asoko, & Leach, 2007, p. 45).

Science Education Reform

The term "scientific literacy" has been used to describe the ability to apply scientific knowledge to make informed decisions regarding personal and societal problems (Lederman, 2004). For scientific literacy, helping students develop adequate conceptions of nature of science (NOS) and scientific inquiry has been a perennial objective in science education (AAAS, 1990, 1993; Klopfer, 1969; NRC, 2013; National Science Teachers Association [NSTA], 1982). Current science teaching reforms and standards documents in the United States put an emphasis on nature of science and scientific inquiry (AAAS, 1990, 1993; NRC, 2013). NSTA (2004) recommended all K-16 teachers to use scientific inquiry in science classroom.

In the recent curriculum reform in China, the Chinese MOE (2001a) require a transformation from “transmission-centered teaching” to “inquiry-centered teaching” in the teaching paradigm within the document Basic Education Curriculum Reform Outline (Trial) (Zhong, 2006). In line with the Outline, the New Curriculum Standard on science education requires students to learn based on the understanding and ability of scientific inquiry and to grasp scientific inquiry skills (MOE, 2001a). Comparing with traditional science education, an inquiry-based process makes students more active and constructivist learners (Anderson, 2002).

Nature of science.

NOS refers to the epistemology of science, science as a way of knowing, or the values and beliefs inherent to scientific knowledge or the development of scientific knowledge (Lederman, 2004). In brief, NOS can be understood as “ideas about science” and “how science works.” Hurd (1960) state NOS explicitly as a major aim of science teaching:

> There are two major aims of science-teaching; one is knowledge, and the other is enterprise. From science courses, pupils should acquire a useful command of science concepts and principles. Science is more than a collection of isolated and assorted

facts . . . A student should learn something about the character of scientific knowledge, how it has been developed, and how it is used. (p. 34)

NOS is a “fertile hybrid arena” and contains various social studies of science, such as history, sociology, and philosophy of science (McComas, Clough, & Almazroa, 1998). For science educators, NOS is used to describe “the intersection of issues addressed by the philosophy, history, sociology, and psychology of science as they apply to and potentially impact science teaching and learning” (McComas, Clough, & Almazroa, 1998, p. 5). The approximate degree to which each one of the four disciplines adds to NOS is shown in Figure 1.

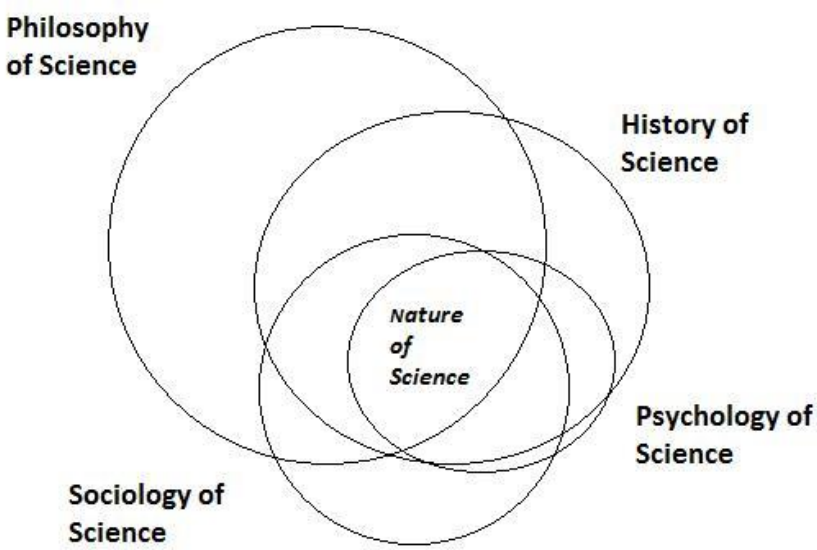


Figure 1. The Disciplines That Add to the Nature of Science (McComas & Olson, 1998, p. 50)

Accurately conveying NOS is common to most science education curricula worldwide. McComas and Olson (1998) analyzed eight standards documents in the United States, Australia, England/Wales, New Zealand, and Canada to reveal common elements of NOS. In China, NOS has become a topic of concern in science education reform documents (e.g., MOE 2001b) and academic books (e.g., Liu, 2004; Yu, 2002; Zhang, 2004).

There is also evidence suggesting that knowledge of NOS not only assists students in science learning, such as science content and science understanding (Manuel, 1981; Martin, 1972; Songer & Linn, 1991), but also helps teachers to enhance their instruction. Matthews (1994) proved that a firm grounding in NOS is likely to enhance teachers' ability to implement conceptual change models of instruction. It requires teachers' interest and study in NOS to assist in understanding the cognitive development of students' learning (Matthews, 1994; Wandersee, 1986). Duschl (1987) also stated that teachers themselves need to have an adequate understanding of NOS to assist in the process of inquiry-based or constructivist teaching.

In science curriculum and instruction, NOS is viewed as having an important role from these aspects (Lederman, 2004, p. 304): Scientific knowledge is tentative (subject to change), empirically-based (based on and/or derived at least partially from observations of the natural world), subjective (theory-laden, involves individual or group interpretation), necessarily involves human inference, imagination, and creativity (involves the invention of explanations), and is socially and culturally embedded (influenced by the society/culture in which science is practiced). Lederman (2004) also added the distinction between observations and inferences, and the functions of and relationships between scientific theories and laws as two additional important aspects.

Scientific inquiry.

The National Science Education Standards (NSES) defines scientific inquiry as “the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world” (NRC, 1996, p.23). These standards emphasize the central role of an inquiry-based model in the implementation of science curriculum. The learning goal for students is to gain a deep comprehension of scientific literacy (including science content and processes), rather than merely memorizing science facts and formulas. Consistent with social constructivist views of learning, inquiry environments engage students in seeking answers to questions, experiencing phenomena, sharing ideas, and developing explanations (Minstrell & Van Zee, 2000). There is evidence to indicate positive effects on student’s understanding of science content and processes in inquiry learning environments (e.g., Brown & Campione, 1994; Cognition and Technology Group at Vanderbilt, 1992; Metz, 1995). As Deboer (1991) wrote:

> If a single word had to be chosen to describe the goals of science educators during the 30-year period that began in the late 1950s, it would have to be inquiry. (p. 206)

Although the NSES does contain some recommendations for science teachers (NRC, 2000), there is no precise definition of inquiry teaching (Anderson, 2002). Wise and Okey (1983) identified a teaching technique called “inquiry-discovery” to be “more student-centered and less step-by-step teacher directed learning”. In a reformed science classroom, teachers “continue to modify and improve their instruction based on expanding knowledge of their students and their backgrounds, interests, and prior knowledge” (Bradbury, 2010). They also recognize that science is a social endeavor based on representing ideas grounded in evidence, and that scientific knowledge builds over time as new evidence surfaces (Michaels, Shouse, & Schweingruber, 2008).

In fact, it is impossible to generalize a single explicit inquiry teaching method that can help reforming science teaching because there is a wide variety of inquiry approaches (Anderson, 2002) and science classrooms are complex environments (Huffman, 2006). NSES also clarified that a single approach to science teaching is not recommended (NRC, 1996). Similarities can be found in Chinese science curriculum standards, "scientific inquiry method and process are various and there is no single mode (to do inquiry)" (MOE, 2011).

In a qualitative study, Bell, Blair, Crawford, and Lederman (2003) pointed out two dimensions of inquiry learning: six aspects of doing inquiry (formulating questions, designing investigations, dealing with data, constructing explanations, testing explanations against current scientific knowledge, and communicating results) and four aspects about inquiry (scientists use varied methods, scientists test ideas, scientists use current knowledge, and investigations may lead to more questions). Students are expected not only to master their inquiry skills but also to understand that there are multiple modes for doing inquiry; moreover, the "scientific method" cannot represent the whole of inquiry. Abd-El-Khalick et al. (2004) distinguished between "inquiry as means" (inquiry as an instructional approach) and "inquiry as ends" (inquiry as an instructional outcome). In an inquiry-based science class, the teacher facilitates inquiry-based activities rather than lectures to help students understand science content, understand NOS, conduct scientific inquiry, and develop inquiry skills.

The challenges for the application of scientific inquiry in the classroom are summarized as follows (Hanauer et al., 2006):

1. Teachers may manipulate classroom science to obtain the expected results;
2. Teachers' demonstrations merely simulate scientific inquiry;
3. The incomplete development of students' reasoning abilities may limit their ability to construct complex scientific arguments;
4. Scientific inquiry often requires detailed knowledge of a topic that students have yet to master.

In addition, textbooks may negatively impact the process of inquiry in science classrooms, when the content in the textbook is as a collection of facts rather than as an inquiry process (Eltinge & Roberts 1993). Jacoby and Spargo (1989) examined sixteen physical science textbooks from Britain, the United States, and South Africa, and found that "With the exception of one textbook . . ., all the texts examined revealed a predominance of an inductivist-expiricist approach" (p. 45). Through the reading of these textbooks, students will receive a definite view about the status of scientific knowledge and how that knowledge came to be (McComas, Clough, & Almazroa, 1998). Besides textbooks, other learning materials can also negatively impact students' inquiry skills and their notions about NOS. For instance, many laboratory activities are guided by cookbook type manuals which often views science as a pure verification without human influence.

A general distorted view of scientific inquiry which is extensively perpetrated in science classrooms is what is commonly referred to as the scientific method. The scientific method is a fixed set of steps which are considered that all scientists follow when to solve scientific problems. Lederman (2004, p. 309) describes the scientific method as "to memorize, recite, and follow as a recipe for success." In fact, by considering the science education reform, however, it is apparent that there is no single fixed set of steps that all scientists follow in investigations. Lederman

(2004) further pointed out that this single scientific method exists due to classical experimental design, which is used to present examples of scientific investigations in science textbooks. He indicates that it is not because of the consistency between investigations and the scientific method, but that the real problem is “experimental research is not representative of scientific investigations as a whole” (p. 310).

Science education is not only about experimental design. The student should learn science in a natural, flexible, and active way, in which they can construct their scientific knowledge relative to their prior experience and knowledge, with the guide and facilitation from their teachers to avoid simply following “recipes” from “cookbooks.” To be more effective in teaching science in an inquiry-based scenario, the BSCS 5E instructional model (also known as the 5E learning cycle) is suggested. (Biological Sciences Curriculum Study [BSCS], 2006). The 5E instructional model is an instructional strategy based on the constructivist approach, which also promotes scientific inquiry abilities (e.g., asking questions, designing experiments, developing and communicating scientific explanations) (Balci, Cakiroglu, & Tekkaya, 2006; Bybee & Landes 1988; Bybee et al., 2006). Empirical studies have supported using 5E instructional model for effective science learning and science teacher education (Guzel, 2016; Tural et al., 2010).

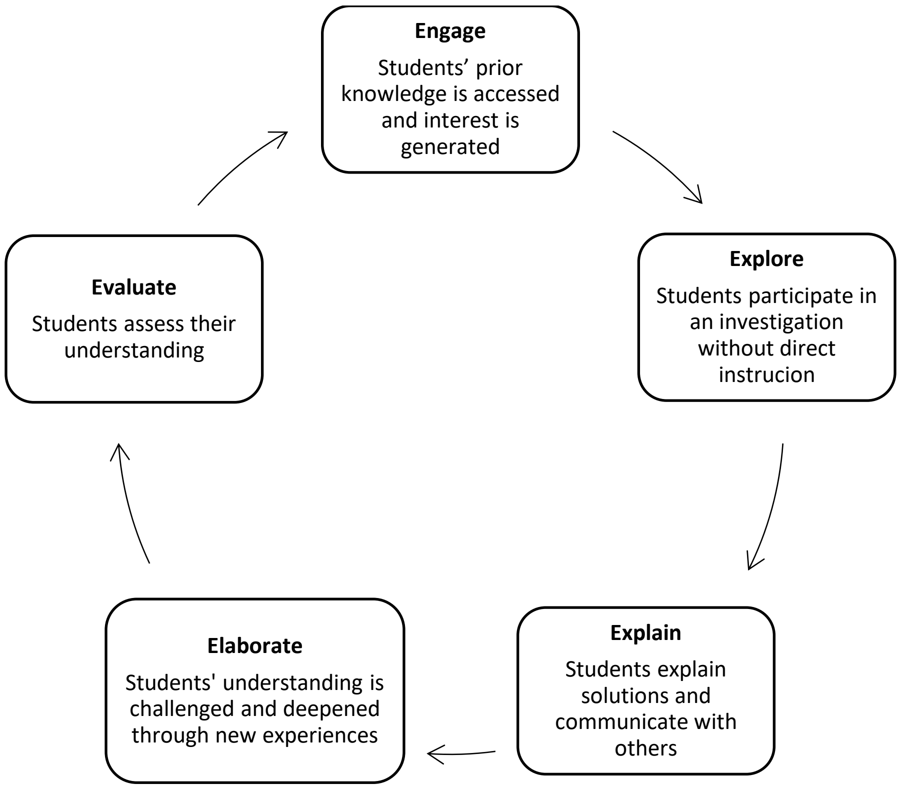


Figure 2. The 5E Instructional Model (the 5E Learning Cycle).

According to Bybee (1997), the 5E instructional model includes five phases: Engagement, Exploration, Explanation, Elaboration, and Evaluation. As shown in Figure 2, the Engagement stage involves generating interest and curiosity, raising questions, and assessing current/prior knowledge. The Exploration stage encourages students to work together without direct instruction. Teachers at this stage may ask probing questions to redirect students' investigations when necessary to facilitate students' conceptual change. In the Explanation stage, students explain possible solutions, listen to other students' explanations, and even question their own explanations. Elaboration encourages students to apply concepts and skills in new situations and reminds them of alternative explanations. The Evaluation stage allows student to assess themselves. It also provides teachers opportunities to evaluate student progress.

Teachers' beliefs.

In research examining science and mathematics instruction of teachers, Huffman, Thomas, and Lawrenz (2008) indicated a finding that "both science and mathematics teachers use reform strategies less than envisioned in the standards". Moreover, there are many possible factors that may influence the implementation of reform movements. For example, insufficient resources and supports can inhibit reform-based innovations (Washor & Mojkowski, 2006). Also, schools often resist dramatic changes from traditional practice of teaching and learning (Elmore, 2004).

In fact, to fully realize reform-based science curriculum and instruction, the role of teachers cannot be ignored because it is the teachers who implement reform. In a reform process, an essential component of education reform is teachers, who are also primary stakeholders. What teachers believe about education reform directly influences the outcome of reform efforts (Gregoire, 2003; Sarason, 1996). Since teachers' beliefs guide their actions in the classroom (Clark & Peterson, 1986; Cooney & Shealy, 1997; Thompson, 1992), it behooves teachers to be able to think differently about learning and teaching (Putnam et al., 1992). Therefore, changing beliefs is thought to be prerequisite to long-term, sustained change in practice (Richardson, 1996).

To facilitating the implementation and sustainability of education reform, one of the recommendations is that "teachers have to want the change" (Lawrenz, Huffman, & Lavoie, 2005). Initially, teachers may have a favorable or at least neutral attitude toward the change (Schneider, Brief, & Guzzo, 1996). For change to be implemented and sustained, teachers should have the power of making decisions during the whole process of change. That is, teachers must become the "owner" of change and who are intrinsically active, rather than “servant” who work with extrinsic pressure.

In an international study, Dinham and Scott (2004) found that the most rewarding aspects of teaching were intrinsic. Teachers were most dissatisfied with external pressures stemming from employers, governments, and society. Accordingly, when reforms are mandated or are incongruent with teachers’ beliefs, they contribute to feelings of vulnerability and emotional disturbance (Kelchtermans, 2005). Jones explained the relationship between teachers’ perspectives and external influences as following:

> Although setting, policy, and conditions may be imposed principally by external forces, they are not unaffected by a teacher’s goals and perspective.... Similarly, although teachers’ goals, beliefs, and perspectives are fundamentally internally constructed, they are definitely affected by conditions and policies. (Jones, 1997, p. 134)

Research indicates that teachers respond differently to current education reform. In science classrooms in the United States, some teachers are openly embracing reform-based practices (Crawford, 2000), while others are either unable or unwilling to modify their curriculum or instruction (Davis, 2003; Laplante, 1997; Yerrick, Parke, & Nugent, 1997). In China, according to Lee and Yin (2011), there were three categories of teachers reacting to education reform. The first category was the “losing-heart accommodators,” in which teachers were passionate about the reforms but lost enthusiasm afterwards. The second category was “drifting followers,” who merely followed national policies with little excitement. The last category was “cynical performers,” who resisted the reforms internally but superficially cooperated.

Creativity in Science Education

"To raise new questions, new possibilities, to regard old problems from a new angle, requires creative imagination and marks real advance in science."

— Albert Einstein

Most people would not doubt the importance of being creative in different fields. Unfortunately, to whom the question was asked, creativity is usually regarded as an abstract concept with more idealist results rather than realist processes. In fact, many teacher educators and researchers have been devoted to topics related to talented education and creativity to establish and organize a concrete definition and applications for educators to develop and improve their teaching practice for cultivating and fostering students' creativity.

The benefits of creativity are demonstrated across research findings. Generally, creativity contributes not only to societal advancement, such as new scientific findings, new art movements, and new social programs (Sternberg & Lubart, 1996), but also to personal learning and academic achievement (Garnham & Oakhill, 1994). According to Rubenstein, McCoach, and Siegle (2013), "construction may promote motivation, positive mental states, educational achievement, and development of personality within students". Apparently, creativity is becoming an increasingly important paradigm of practice. Human creativity closely influences our future (Csikszentmihalyi, 1996). In education, recent curriculum reforms in many countries have shown an explicit emphasis on creativity (see Burnard, 2006; Ferrari, Cachia, & Punie, 2009; Hui & Lau, 2010; Kaufman & Sternberg, 2006; Le Metais, 2003). Therefore, creativity has been playing an important role in education worldwide:

> The principal goal of education is to create men who are capable of doing things, not simply of repeating what other generations have done—men who are creative, inventive, and discoverers. The second goal of education is to form minds which can be critical, can verify, and not accept everything they are offered. (Ginsberg & Opper, 1969: p. 5)

What is creativity.

For more than half of a century, many researchers have worked on clarifying the meaning of creativity. It is necessary to understand the nature of creativity for understanding, guiding, and evaluating creativity enhancement efforts (Plucker & Callahan, 2008). Treffinger (1996) reviewed more than 100 different definitions of creativity from literature. Aleinikov, Kackmeister, and Koenig (2000) offered 101 contemporary definitions from children and adults. Since creativity is complex and widely used in different fields, there is no single, universally accepted definition (Treffinger, Young, Selby, & Shepardson, 2002).

Torrance (1993) described creative thinking as “the process of sensing difficulties, problems, gaps in information, missing elements, something askew; making guesses and formulating hypotheses about these deficiencies; evaluating and testing these guesses and hypotheses; possibly revising and retesting them; and, last, communicating the results” (p. 233). Gardner (1993) defined a creative person as one who “regularly solves problems, fashions products, or defines new questions in a domain in a way that is initially considered novel but that ultimately comes to be accepted in a particular cultural setting” (p. 35). Davis and Rimm (2004) concluded characteristics of creative persons including self-confidence, independence, risk-taking, energy, enthusiasm, adventurousness, curiosity, playfulness, humor, idealism, and reflectiveness. The term creativity is defined as “the tendency to generate or recognize ideas, alternatives, or possibilities that may be useful in solving problems, communicating with others, and entertaining ourselves and others" (Franken, 1994, p. 396). Similarly, Sternberg and Lubart (1996) considered creativity as the ability to produce novel and appropriate works at both individual level and societal level, and Plucker, Beghetto, and Dow (2004) defined creativity as "the interaction among aptitude, process, and environment by which an individual or group produces a perceptible product that is both novel and useful as defined within a social context" (p. 90). Although the ways to define creativity vary, there are commonalities which include generating new and novel ideas, interacting with others, and applying in a supportive environment (Czikszentmihalyi, 1996; Franken, 1994; Gardner, 1993; Plucker, Beghetto, & Dow, 2004; Runco, 2004a).

Nearly all the studies on creativity can be traced back to Guildford's work from the 1950s to the1970s. Based on the studies of human intelligence, Guilford (1950) concluded certain factors related to creativity: sensitivity to problems, ideational fluency, flexibility of set, ideational novelty, synthesizing ability, analyzing ability, reorganizing or redefining ability, span of ideational structure, and evaluating ability. In his Structure of the Intellect (SOI) model, Guildford (1956) attempted to construct the model with approximately forty intellectual factors, with those factors labelled into "thinking factors" or "memory factors". Guildford (1956) categorized the thinking factors as cognition (discovery), production (convergent thinking and divergent thinking), and evaluation. According to Guilford (1967), divergent thinking is a thought process or method used to generate creative ideas from across disciplines and fields. As an essential element of creative thinking, divergent thinking involves thinking in multiple directions, seeking changes, and investigating (Guilford, 1970).

Davis and Rimm (2004) organized several intellectual abilities that contribute to creativity. There are four classic Guilford/Torrance creative abilities are based on Guilford's

(Guilford, 1950, 1959, 1987) and Torrance's work (Torrance, 1962, 1965, 1979, 1980, 1987, 1995) - fluency, flexibility, originality, and elaboration. Fluency refers to the ability to produce quantities of ideas; flexibility is the ability to create different categories of ideas and take different approaches to solve a problem; originality, as uniqueness and nonconformity, is regarded as the ability to generate new and unique ideas that others are not likely to generate; elaboration is the important ability to expand an idea through adding details, developing and embellishing. Davis and Rimm (2004) also indicated that these four traditional abilities are not a definitive and exhaustive list of creative abilities; as some other thinking skills could be seen as important abilities for creative thinking and problem solving, for instance, higher-order thinking (Bloom, 1956), critical thinking, reasoning, planning, and organizing. To stimulate and strengthen creative abilities, such as fluency, flexibility, originality, and elaboration, Davis and Rimm (2004, p. 228) listed several useful types of practical exercises for teachers as follows:

- With "What would happen if . . .?" exercises, students list consequences for unlikely events.
- Thinking of product improvements is another type of open-ended question.
- Thinking of unusual uses for common objects is the single oldest creativity test item.
- Posing problems and paradoxes is intrinsically interesting and challenging.
- Design problems.

To consider whether and how creativity can be enhanced, creativity scholars have distinguished three different levels of creative impact: Big-C, little-c, and mini-c. According to Plucker and Callahan (2008), Big-C focuses on "individuals who have attained eminence in their respective field through a combination of staggering levels of productivity and lasting impact" (p. 142). Big-C occurs when an individual has a major impact on how other people think, feel and live their lives (e.g., Einstein, Mozart, Coltrane, and Picasso). Comparing to Big-C, little-c is used in everyday life and is more personal; as the novel and useful efforts of normal, everyday people, though they are not revolutionary, are still creative. Scholars and researchers have supported the consideration of everyday creativity (Csikszentmihalyi, 1996; Kaufman & Baer, 2006; Runco & Richards, 1998; Sternberg, Grigorenko, & Singer, 2004). A more personal level of creativity was demonstrated by researchers in order to recognize the existence of little-c creativity (Beghtto & Plucker, 2006; Cohen, 1989; Runco, 2004b; Sawyer et al., 2003). Beghetto and Kaufman (2007) defined mini-c as "the novel and personally meaningful interpretation of experiences, actions, and events" (p. 73). Mini-c creativity is a subjective self-discovery process occurring in learning and personal understanding (Beghetto & Kaufman, 2007; Beghtto & Plucker, 2006).

Many different creativity researchers have attempted to find the ways in which creativity may be assessed. Barron and Harrington (1981) pointed out that there was "a proliferation of studies" conducted by creativity investigators using an open-ended multiple solution format prior to 1915. The open-ended format and its alternatives have influenced many subsequent tests that have been used to measure creativity (see Andrews, 1930; McCloy and Meier 1931; Simpson, 1922; Thurstone, 1948; Welch, 1946). Unfortunately, such tests have largely fallen into disuse, and were exerting little influence at the time of Guilford's address (McLeod & Cropley, 1989). Since divergent thinking has been generally regarded as the backbone of creativity, many research articles use tests of divergent thinking to measure creativity. Guilford's (1967) Structure of the Intellect divergent production tests, Wallach and Kogan's (1965) divergent production test, and Torrance's (1974) Tests of Creative Thinking (TTCT) open a constructive path for development efforts and applications in measuring creativity. Most divergent assessments, which were conducted later, are similar to Guilford's SOI and the TTCT.

However, there are also many criticisms of creativity tests. As McLeod and Cropley (1989) concluded, three of the main criticisms of creativity tests have been that "different creativity tests measure different things; the tests tend to measure much the same trait as conventional IQ test; and assessed performance is, in any case, too dependent on the mere number of responses" (pp. 81-82). McLeod and Cropley (1989) indicated that a practical complaint of creativity tests is that it is "extremely time consuming" to score creativity tests for almost everything except fluency; a practical problem in deciding whether a response is highly original or totally bizarre. Meanwhile, it is inevitably difficult to develop standardized scoring procedures for creativity tests since the test itself does not intend to have pre-specified answers due to the very nature of creativity. Another issue with creativity tests is the consideration of an individual's interest. As Weiner (2000, p. 209) stated, "All creative work is a matter of passion," many creativity scholars claim the importance of intrinsic motivation for creative thinking and action (Amabile, 1998, 2001; Collins & Amabile, 1999; Cropley, 1997; Csikszentmihalyi, 1999; Runco, 1993; Torrance, 1995). According to Lemons (2011), test makers and test takers may have different views about the test; as "what test makers think may be interesting and motivating activities may not be viewed as such by the testees" (p. 2011). Thus, individual's creative potential or ability may be underestimated by low creativity test scores (Lemons, 2011). Thorndike (1997) also noted, "even with the best measures available, predictions in psychology and education are approximate…. healthy skepticism is required to keep from over-interpreting test scores, particularly when, as is usually the case, we are making predictions about individuals" (pp. 155-156).

Creative problem solving.

McLeod and Cropley (1989) defined problem solving as “an activity which requires productive thinking, and at the same time offers good opportunities for promoting it” (p. 166). Guilford (1977) emphasized that "problem solving and creative thinking are closely related. The very definitions of these two activities show logical connections. Creative thinking produces novel outcomes, and problem solving involves producing a new response to a new situation, which is a novel outcome" (p. 161). McLeod and Cropley (1989, p. 167) represented a series of steps for Creative Problem Solving (CPS) which is in the line with Torrance et al. (1978, p. 5) as follows:

1. Encounter a problem “situation;”
2. Brainstorm possible specific problems stemming from the situation that has been presented;
3. Operationalize the problem to be attacked, stating it clearly, i.e., in an “attackable” form;
4. Brainstorm alternative solutions;
5. Brainstorm criteria against which to judge alternative solutions;
6. Rank available solutions according to the criteria that have been adopted;
7. Select and improve the best solution, and present (“sell”) it for judging or adoption.

Creative problem-solving models have been used to describe a sequence of stages through which one might solve a problem creatively. As the best-known model, the Wallas Model (Wallas, 1926) described creative process through a set of stages, preparation, incubation, illumination, and verification. The preparation stage includes clarifying and defining the problem, need, or desire, gathering information, and examining and verifying the acceptability of solutions, especially previous unsuccessful ones. The incubation stage may be viewed as a period of "preconscious," "fringe conscious", "off-conscious", or "unconscious" activity that happen during daily activities (Davis & Rimm, 2004). It usually occurs when stepping back from the problem and letting minds contemplate. The illumination stage is a sudden experience, in which ideas arise suddenly from one's mind to contribute to a creative response. In the final verification stage, one carries activities to check whether the idea or solution works and whether what emerged from illumination is acceptable.

A two-stage model was introduced by Davis (1998) including a big idea stage and an elaboration stage. In this model, a creative person first seeks a big idea, which is new and exciting, to solve problem. This idea is usually found by applying creative thinking skills like brainstorming and synectics (see Gordon, 1961). Then, the individual uses creative thinking skills to develop, elaborate, and implement the idea that is found. For example, when a student tries to investigate a scientific phenomenon, he may start with a general idea or direction for the investigation, and then he sets up a plan and fills in the plan with more details to help him solve the problem. Either the big idea or the elaborated plan to make the big idea work needs creativity (Conklin & Frei, 2007). According to Conklin and Frei (2007), this two-stage model asks teachers to use modeling of strategies, explicit instruction to use these strategies, and sufficient time and opportunities for students to practice.

Another model is a five-stage model called the Creative Problem Solving (CPS) model (see Maker, 1982; Osborn, 1963; Parnes, 1981; Treffinger, Isaksen, & Dorval, 1994a, 1994b). The five core steps in the CPS model in Figure 3 include fact finding, problem finding, idea finding, solution finding (idea evaluation), and acceptance finding idea (idea implementation). In Figure 3, each step is connected by diverging and coverging lines, which represent divergent-thinking and convergent-thinking processes. For instance, one may first generate many ideas, and then only select the most promising ideas for later exploration. The fact finding stage involves “listing all you know about the problem or challenge” (Parnes, 1981). Parnes (1981) also recommended the use of who, what, when, where, why, and how questions. The problem finding stage is used to clarify the problem through listing alternative problem definitions. Idea finding is the brainstorming stage in which ideas are freely generated and listed. The fourth stage of solution finding involves selecting and strengthening solutions with the listed criteria for idea evaluation. In the final acceptance finding stage, an action plan (Treffinger, Isaksen, & Dorval, 1994a, 1994b) is created in order to think of “ways to get the best ideas into action” (Panes, 1981). In addition, Treffinger (1995) and his colleagues indicated that acceptance finding involves searching for assisters and resisters. According to Treffinger (1995), assisters represent people, places, materials, and times that will support the plan and contribute to successful implementation; resisters are obstacles that can interfere with acceptance, such as contrary people, insufficient materials, and missing things. One more stage was added in the CPS model by Isaksen and Treffinger (1985) to expand the model into six stages instead of five. In the sixth stage, “mess finding,” also known as “opportunity finding” or “objective finding,” a creative person senses issues, such as problems, challenges, or opportunities, which need to be tackled. Davis and Rimm (2004) concluded that the benefit to using CPS model is that it “improves students’ understanding of the creative process, exposes them to a rousing creative-think experience, and solves a problem” (p. 215).

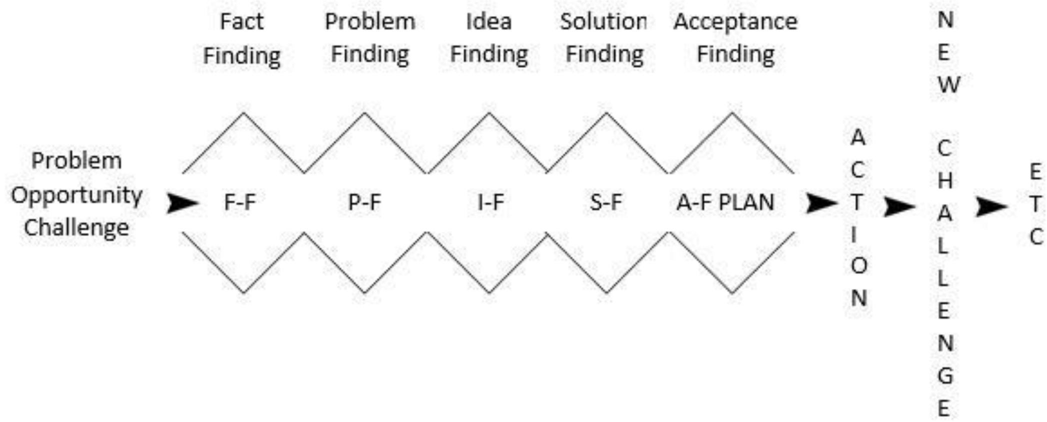


Figure 3. The Creative Problem Solving (CPS) Model (Davis & Rimm, 2004, p. 213).

Comparing CPS to the scientific method, McLeod and Cropley (1989) believed that CPS closely parallels the traditional scientific method, but diverges from it in two important respects. First, there is no requirement for validation against objective or even external data in CPS to select the "best solution." As McLeod and Cropely (1989) described, "the "best" solution derived through Creative Problem Solving is always a winner; by failing to expose it to the test of experimental validation students are shielded from the real world of failure or partial success" (p. 168). Briefly, students are encouraged to "pop up" the ideas that they think are the best with internal check instead of external verification. Second, a scientific method needs to be cumulative through looping back to a previous step for subsequent experiments after accepting or rejecting hypotheses. However, CPS stops when the "best" solution has been accepted.

Scientific creativity.

Einstein and Infeld (1938) stated, "Physical concepts are free creation of human minds, and are not, however it may seem, uniquely determined by the external world" (p. 33). Although creativity is mentioned mostly in arts and humanities today, numerous famous scientists associated creativity with scientific discovery (Barrow, 2010). It is indubitable that science is an endeavor of creativity. Hadzigeorgiou et al. (2012) pointed out novelty and value are the two conditions or characteristics of scientific creativity. Barrett et al. (2014) added collaboration as a necessary component to scientific creativity. A representative example is the discovery of double-helix structure of DNA by the close collaboration between Watson and Crick. In fact, most remarkable scientific discoveries and achievements are the result of the collaboration among scientists or a group of scientists. Hadzigeorgiou et al. (2012) also view creativity as a mental ability emerging form a social context that is compatible with the social dimension of science. There is evidence that interactions among scientists play an important role in creativity and the creation of knowledge (Hadzigeorgiou et al., 2012; Feldman, Czikszentmihalyi, & Gardner, 1994; Latour & Woolgar, 1986; Simonton, 2004).

From the comparison that has been made between art and science, Hadzigeorgiou et al. (2012), identified two general abilities of scientific creativity, that is, imaginative and logical thinking. Hadzigeorgiou et al. (2012) also indicated both the necessity and the insufficiency of these intellectual abilities for generating novel ideas. Simon (1977) proposed that scientific creativity can be pursued in various problem spaces when solving problems. Similarly, Klahr and Dunbar (1988) put that scientific creativity includes two primary spaces: hypothesis space and experiment space. The hypothesis space involves the formation and evaluation of theory. New hypotheses derive from either prior knowledge or experimental data (Sak & Ayas, 2013). The experiment space involves the design of experimental and observational procedure that helps scientists to prove or disprove their hypotheses.

In science education, creativity is also regarded as an important aspect. The TIMSS survey (Beaton et al., 1996) reported that a majority of teachers in most countries believe creativity is important for success in school science. The National Science Education Standards requires that a scientifically literate person “be able to learn, reason, think creatively, make decisions, and solve problems (NRC, 1996, p. 1). To promote students’ creativity, critical thinking skills and opportunity to use new information in different situations should be included (Akcay, 2013); and a supportive environment, in which students can work in groups, is needed to produce creative products (Barrow, 2010). Besides that, National Advisory Committee on Creative and Cultural Education (NACCCE, 1999) made a distinction between teaching for creativity (creativity as a learning outcome) and creative teaching (creativity as a teaching characteristic). NACCCE (1999) defined creative teaching as the “teacher using imaginative approaches to make learning more interesting, exciting and effective” (p. 102).

Kind and Kind (2007) discussed the characteristics of “good” teaching in science education to compare it with “bad” traditional teaching. In Table 1, the “bad” traditional teaching is a more behaviorist process in which teachers are the center of classrooms, while students are passive receivers, their learning restricted toward a certain direction which is usually regarded as the only one best solution. One the other hand, the “good” creative teaching suggests an open-ended, student-centered, exploratory and group-based learning environment with hands-on activities in the laboratory or outdoors. Kind and Kind (2007) also claimed that “stereotypes of traditional and creative teaching are of little value, as good science teaching can be found by adopting a balanced approach between the two extremes rather than within one of them” (p. 5).

Table 1: *Contrasts Commonly Found in Science Education Literature Between Creative and Traditional Teaching (Kind & Kind, 2007, p. 4).*

Creative teaching		**Traditional teaching**
Student-oriented	v.	Teacher-oriented
Group/team work	v.	Individual work
Cooperative learning	v.	Individual learning
Explorative tasks	v.	Close-end tasks
Open-ended problems	v.	Closed problems
Open investigations	v.	"Recipe" work
Hands-on teaching	v.	Lectures
Outdoor activities	v.	Classroom activities
Project work	v.	Lectures
Issue-oriented	v.	Concept oriented
Teachers taking risks	v.	Teachers playing safe

Scientific creativity is compatible with the nature of science and also realistic in the context of school science education (Hadzigeorgiou et al., 2012). As one of the five components of the Science/Technology/Society (STS) movement (Yager & McCormack, 1989), creativity is facilitated by encouraging K-12 students to generate more questions, especially high quality questions within their daily lives, on science concepts and during science investigation (Yager & Roy, 1993). Kind and Kind (2007) introduced several theoretical perspectives accessible to teachers as a way to better and more effectively teach about creativity in NOS (e.g., Popper, 1959, 1963; Reichenback, 1938; Simonton, 2004). Nevertheless, there are also complexities in teaching about scientific creativity and the NOS. First, creativity contains many facets, such as intellectual abilities, field knowledge and knowledge about a field, thinking styles, personality (the willingness to take risks or overcome obstacles), motivation, environment, and confluence (compensation and superposition between different components) (Sternberg, 2006). Second, scientific creativity is unpredictable since scientific ideas usually burst forth (Hadzigeorgiou et al., 2012). Third, teachers must decide between giving student simple ways that may create misunderstandings and neglects of rational components, or a more authentic way that may be too difficult for understand (Kind & Kind, 2007). Although there is no obvious compromise, a reliable picture is presented as following suggested statements (Kind & Kind, 2007, p. 14):

- Scientific theories are creative products (ideas) made by scientists.
- Many scientists work on the same problems and new ideas (theories, laws) emerge by common effort.
- Most science theories develop over a long period in small steps.
- Some scientists are highly creative and make substantial contributions in their fields, but they always build on other people's ideas.
- All scientists must use their imagination when contributing to the development of science.
- Scientific theories are created in many different ways. The processes are sometimes highly creative and/or highly logic, rational and/or accidental.
- In science creativity and rationality always work together. Scientific creativity never works without rationality and strict empirical testing.

Along with the increasing focus on inquiry in K-12 science education, many teacher educators and researchers also suggest a positive effect on facilitating creativity through inquiry-based approach. In Chinese new science curriculum, one of the goals is explicit; "Through the process of scientific inquiry, (students will be able to) enhance the understanding of scientific inquiry, develop scientific inquiry ability, initially develop the habit of scientific inquiry, and enhance creativity and practical ability" (MOE, 2011). Kind and Kind (2007) consider that inquiry mimics scientists use of creativity. Taylor, Jones, Broadwell, and Oppewal (2008) argue that except science literacy, both science teachers and scientists "held strongly to a belief that students should experience the joyful creativity of doing open-ended science inquiry" (p. 1071). Barrow (2010) supported the use of inquiry to facilitate students' creativity through giving them opportunities for designing investigations, letting them work in small groups, and asking students to share their findings with peers. Barrow (2010) also indicated that the use of the four question strategy (see Cothron, Giese, and Rezba, 2006) allows students to be creative in the inquiry process and helps science teachers to address their frustrations about inquiry.

Chapter 3: Methods

Research Design

A mixed-methods approach was adopted to study the impact of the particular teaching approaches and developing a picture that was respectful for the particular culture context (Morse, 2003). A mixed-methods approach can refer to many things (Cohen, Manion, & Morrison, 2011). In this study, it refers to "the class of research where the researcher mixes or combines quantitative and qualitative research techniques, methods, approaches, concepts or language into a single study" (Jonson & Onwuegbuzie 2004, P.17). Mixed-methods approach is widely used in different disciplines (Creswell, Plano Clark, Gutmann, & Hanson, 2003). In education research, mixed-methods approach is evolving into a dominant design structure.

The reason to choose which research method is depended on research itself, especially research purposes and interests. Generally, qualitative methods might be used to understand and explain conclusions from quantitative methods. While using quantitative methods helps to express qualitative ideas precise and testable. As a combination of both quantitative and qualitative method, mixed-methods research contains methodological implications of critical realism (Zachariadis et al., 2013).

There are three main reasons for choosing mixed-methods in this study. First, mixed methods can help to build on a complete picture for better interpretation. McEvoy and Richards (2006) believed that a broader range of perspectives and experiences can assist to formulate explanation. Second, mixed methods can enable people to see through the appearance to perceive the essence. By deeply considering a phenomenon, mixed-methods approach helps to generate theory (McEvoy & Richards, 2006). Third, mixed methods further reinforce research findings

(McEvoy & Richards, 2006; Venkatesh et al., 2013) and offering more data for future discussions and research.

Setting

This study has been conducted at a high school in Wuhu, Anhui Province. Wuhu is a prefecture-level city with a population of approximately 3.6 million. Like in the United States, the major types of school in China are public and private. Public schools in China can also be classified as ordinary schools and key schools. A key school usually has more funding and teacher resources from regional government than ordinary school. However, both key school and ordinary school have over-size classroom (commonly, 50-80 students) due to insufficient budget. The participating school is one of the ten key schools in Anhui province. The class size in this school is around 60. There are about 3,000 students nested in grade 7, 8, and 9. Each grade contains 20 to 22 classes. In contrast to the class structure in American system, where students have each class in a different room with a different set of classmates, Chinese students remain in the same classroom all day, with teachers rotating in and out. Chinese education is built on "looping", in which the teachers of the students in the entering class will also follow their same students to the next grade level until graduation. The selected participating school follows the same class structure and “looping” process with other Chinese schools. The school hour is also different in China. Most Chinese primary and secondary schools have same fixed class periods of 40 to 45 minutes. The participating school starts at 7:10 and ends at 17:00. It means that the participating students stay at least 10 hours at school every day by counting a usually 40-minute period called extracurricular activities at school after 17:00.

Participants

Convenience sampling was used in this study. Two classes (120 students) were randomly picked from all the classes in 8th grade to participate. All the science teachers, including two physics teachers and one biology teacher, who taught these two classes participated in this study for gathering qualitative data. All three science teachers had a bachelor's degree, a middle school teaching license. One of the science teachers had more than 10 years of teaching experience while the other two had been teaching more than 5 years.

Instruments

A student survey (Appendix C) was used in this study to measure the extent to which the science teachers used reformed teaching methods described both in the Next Generation Science Standards (NGSS Lead States, 2013) and the New Curriculum Standards (MOE, 2001a). All the survey items were developed from established sources, such as the national surveys used by Horizon Research Incorporate (1997) and the TIMSS surveys (Beaton et al., 1996). The whole survey includes two parts. The first part is student demographic information which includes student ID number, gender, grade, age, "the only child" status, ethnic group, and socioeconomic status (SES). Among them, students' SES information is collected through a simple selection from four options of different ranges of their family annual household income. The second part of this survey is a five-level Likert scale, ranging from "never" to "always," questionnaire for investigating how frequently inquiry-oriented, reform-based activities are used in science classroom. Since this survey was for Chinese student, the author prepared a Chinese version (Appendix D) of the survey.

Torrance (1974) Tests of Creative Thinking (TTCT) is considered as the most widely used for measuring creativity. The TTCT has two equivalent versions, the Figural and Verbal

TTCT, and each version has two forms, Form A and Form B. In this research, the Verbal TTCT, either Form A or Form B, is used to measure students' creativity. The Verbal TTCT uses six word-based exercises to assess three mental characteristics: fluency, flexibility, and originality. The Verbal TTCT is appropriate for first grade students through adults by using grade-related norms for each of the grades and age-related norms from age six to eighteen years and beyond. A Norms – Technical Manual, a Manual for Scoring and Interpreting Results, and a scoring worksheet provided by the Scholastic Testing Service, Inc. were used with the Verbal TTCT.

Reformed Teaching Observation Protocol (RTOP; Sawada & Piburn, 2000) was used in this study. The RTOP provides an instrument for assessing curricular innovation and teaching strategies independently of student learning (Sawada et al., 2002). The RTOP (Appendix E) contains five parts. The first part is background information of the observed teacher. Second part is contextual background and activities including a brief description of the observed classroom and the events which may help in documenting the ratings. The rest three parts are in the form of five-level Likert scale, ranging from "never occurred" to "very descriptive." A totally 25 indicators are divided into three aspects: lesson design and implementation, content, and classroom culture. In this study, classroom observations have been conducted on a sample of classes to help triangulate findings. In addition, all data from the RTOP were used for descriptive purpose of reformed teaching in this study.

Semi-structured interview (Kvale & Brinkmann 2009) was also used in this study for drawing perspectives from science teachers. There are 20 primary questions include in this interview with probes and suggested further questions according to interviewee's responses. The whole interview questions are divided into 6 parts. The first 5 parts include learning theories, science education reform, NOS, scientific inquiry, and creativity. These parts associate with the structure of this study. The last part is closing the interview, in which the interviewer will answer questions from interviewees and thank for their participations. During the interview, a sound recorder was used to make sure that the researcher collected accurate audio data from interviewees' responses. The English version and Chinese version of the semi-structured interview protocol is in Appendix G and Appendix H respectively.

In addition, a video recorder was used for recording observations. Other instruments used in this study were computer software, SPSS and QDA Miner, for quantitative and qualitative analyses.

Data Collection

As a mixed-methods research, the data sources for examining the research questions will be separated into two categories, quantitative data and qualitative data. The quantitative data were extracted from the Verbal TTCT and the student survey. The Verbal TTCT was scored by the author who is holding the certificate of scoring Verbal TTCT. The student survey uses value "1" to represent "never" and increasingly using value "5" to represent "always". Those data were coded into different variables for the following statistical analysis.

The qualitative data were collected from both semi-structured interview and classroom observation. In the semi-structured interview, the audio information was recorded by a sound recorder under the permission from the interviewee. The classroom observation was conducted by a video recorder. The two classes participating in this research are observed. Totally 9 lessons were recorded.

At the beginning of this study, an assent form (Appendix A) was present to each student for their willingness of participation. A parent-guardian consent form (Appendix B) was provide to each participant’ parents or guardians for their permission. An oral consent (Appendix F) was presented to each teacher who gets interviewed. All data were recorded, represented, and analyzed by the author. All the data sources, such as student survey responses, the results of the Verbal TTCT, teacher interview records, and classroom observation records has been documented and locked. To ensure that the data collected from the semi-structured interview reflects the participant's perspective accurately, the section of the final report, which summarizes data for the individual participant, was sent to the participant for review, further input, corrections, and clarification.

Data Analysis

Demographic information and individual item data are included in tables as percentages for basic data information. To find the relationship between reformed teaching and students’ creativity, the first thing is to set up the variables. Creativity as an important objective in science education is used as the dependent variable of this study. Specifically, each student’ creativity is presented as the result of the Verbal TTCT, using the average standard score of fluency, flexibility, and originality. The independent variables include the extent of using inquiry-based teaching (the average score from Likert scale in student survey) and students’ demographic information.

The process of scoring Verbal TTCT included two parts. The first part was to score for fluency, flexibility, and originality in each activity. The second part included a combination of these three scores as standard scores which are normalized standard scores set with an average of 100 and standard deviation of 20 and percentile ranks which indicate the ranking of a student’s score when compared with scores of other students in the normative sample.

Fluency. The fluency score is regarded as the count of the number of relevant ideas. Basically, the scorer counted responses which met the requirements of the specific activity as the fluency score. Originality and flexibility would not be scored when a response did not receive fluency credit. Two or more distinct ideas within one sentence would be counted as two or more responses except for explain meanings and giving examples.

Flexibility. Flexibility is the quantity of different categories. To score this, the flexibility categories provided in the Verbal TTCT Manual for Scoring and Interpreting Results was used as reference for putting responses into certain categories. The score of flexibility is the number of different categories. However, no duplications receive credits. The scoring process of flexibility for the last activity differs from activities 1 through 5. In the last activity, flexibility is defined as a shift or change from one approach to another. Each shift or change will be counted one point.

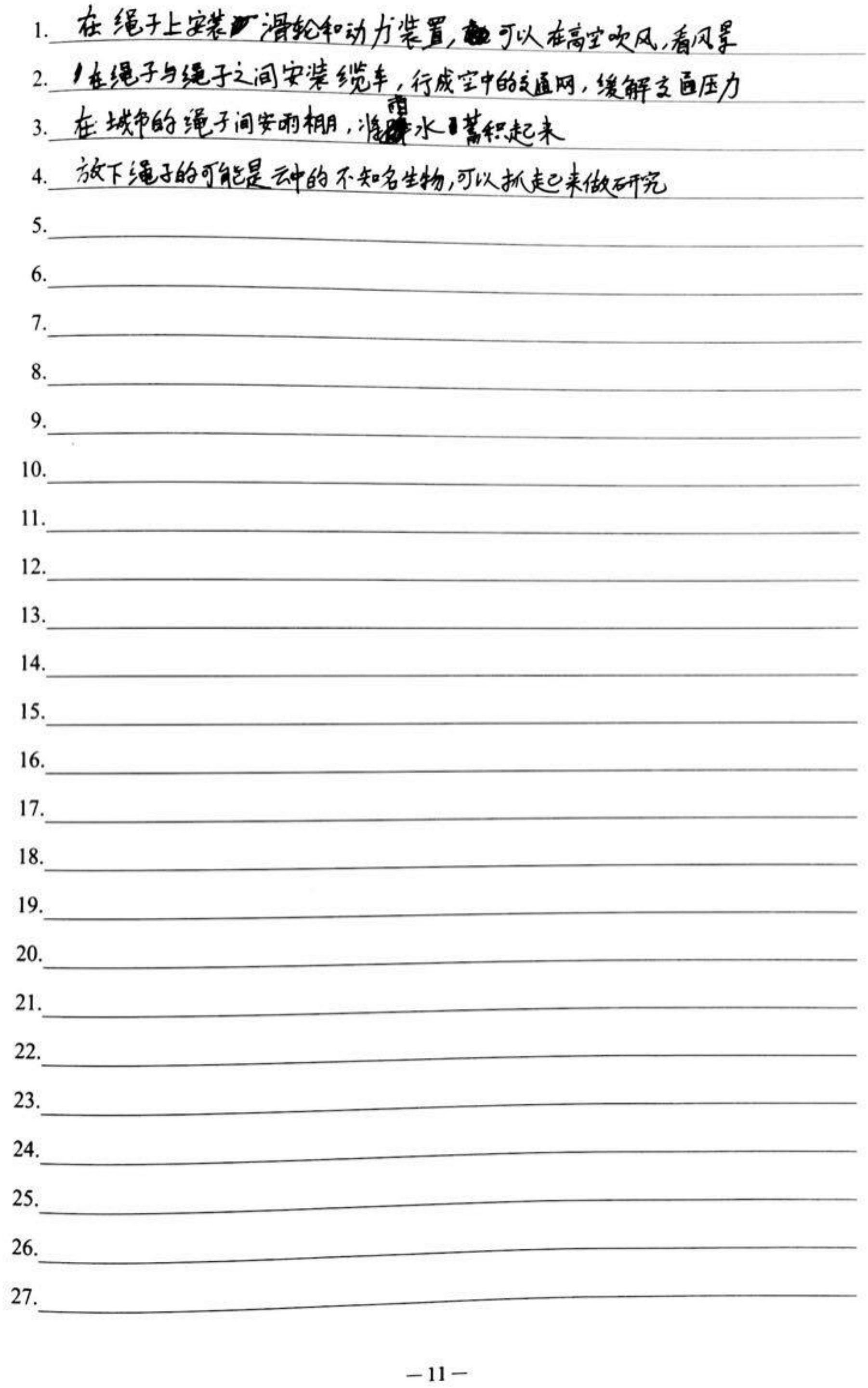
Originality. This score represents the ability of students to generate ideas that are away from the commonplace. The number of unusual responses were counted as the originality score. The scoring manual contains a zero-originality response list for each activity. The author scored each fluent response either zero point or one point based on whether this response is found on the zero-response list.

A scoring worksheet was used for recording the raw scores for each of the three parts (fluency, flexibility, originality). The standard score and percentile rank was obtained by locating the raw score in the relevant norms table which was either grade-related or age-related. The average standard score of the three Verbal scores was regarded as the overall indicator of student creativity in this study. The special percentile rank for this average standard score is also included in the norms table as national percentile for interpretation. The current study uses the United States national percentile norms table and the norms table of Taiwan area for an international comparison on creative thinking. The ratings of creative strength in this study shows in Table 2.

Table 2: *Rating of Creative Strength*

Weak	Below Average	Average	Above Average	Strong	Very Strong
0 – 16%	17 – 40%	41 – 60%	61 – 84%	85 – 96%	97 – 100%

Figure 4 and 5 exhibits two student's responses to the last activity in Verbal TTCT Form A. The English translation of relevant responses are presented in Table 3. In this activity, students were asked to generate hypotheses about an improbable situation about a picture in which clouds with strings attached. Figure 4 provides an example of student responses which received a low average standard score of 78 with the U.S. national percentile rank of 15, Taiwan percentile rank of 10. There were totally 4 relevant hypotheses in the response to this activity and none of them were in the zero-originality list. Then the student received 4 points as raw score for either fluency and originality. There are no flexibility credits for the first three hypotheses because of showing the same approach about setting up or installing things on or between the strings. One flexibility credit was received because a switch happened when the student wrote the fourth hypothesis as "I could be some unnamed creature that dropped the ropes. It can be captured and studied." Figure 5 shows an example of a student's response to the last activity with a high average standard score of 131 and the U.S. national percentile rank of 96, Taiwan percentile rank of 95. Generally, more relevant responses lead to a higher fluency score, more unusual responses according to the zero-originality response list lead to a higher originality score, and more mental leaps from one approach to another lead to a higher flexibility score.



1. 在绳子上安装滑轮和动力装置，可以在高空吹风，看风景
2. 在绳子与绳子之间安装缆车，行成空中的交通网，缓解交通压力
3. 在城市的绳子间安雨棚，将雨水蓄积起来
4. 放下绳子的可能是云中的不知名生物，可以抓起来做研究
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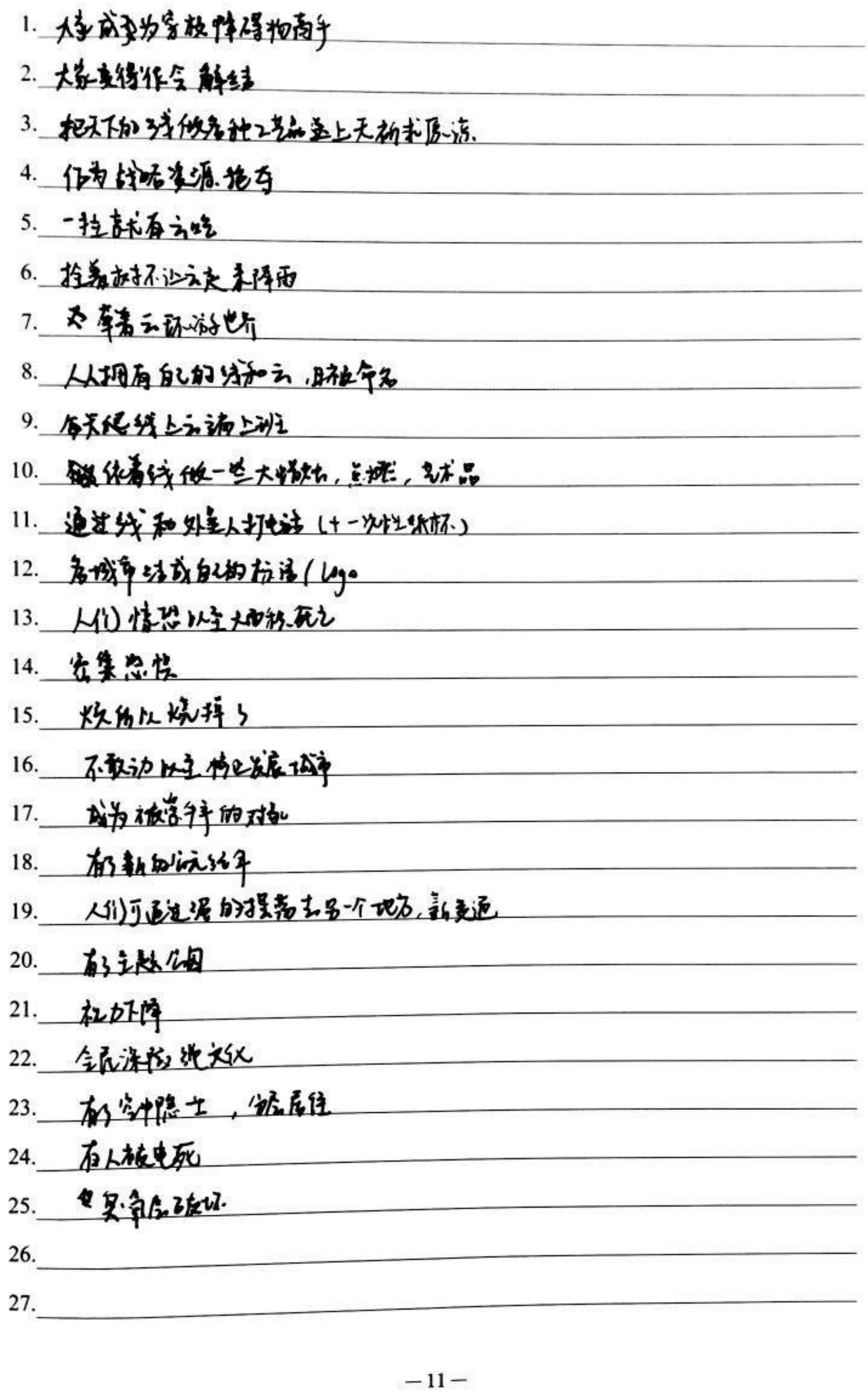
Figure 4. Example of Student's Verbal TTCT Response with Low Score


1. 大家成为穿梭障碍物高手
2. 大家变得很会解结
3. 把天下的线做各种工艺品送上天祈求原谅.
4. 作为战略资源.抢夺
5. 一拉就有云吃
6. 拴着放手不让云走来降雨
7. 天牵着云环游世界
8. 人人拥有自己的线和云,且被命名
9. 每天爬线上云端上班
10. 顺着线做一些大蜡烛,兰花,艺术品
11. 通过线和外星人打电话(十一次性纸杯)
12. 各城市造成自己的标语(logo
13. 人们惊恐以至大面积死亡
14. 密集恐惧
15. 炊烟从烧掉了
16. 不敢动以至慢慢发展城市
17. 成为被崇拜的对象
18. 有了新的玩线年
19. 人们可通过线的摆荡去另一个地方,新交通
20. 有了主题公园
21. 权力下降
22. 全民涨价 跳天仪
23. 有了空中隐士,空中居住
24. 有人被电死
25. 电灵 氧气层破坏.
26.
27.

—11—

Figure 5. Example of Student's Verbal TTCT Response with High Score

Table 3: *English Translation of Two Student's Responses to the Last Activity in Verbal TTCT Form A*

Low Score	High Score
1. Install pulleys and power units on the ropes to get some air and enjoy the scenery from up sky	1. Everyone becomes a master of parkour
2. A cable car is installed between the ropes to form a network of air traffic to relieve traffic pressure	2. Everyone knows how to untangle knots
3. Install rain sheds between the city ropes and store rainwater.	3. Use the strings to make handicrafts and send back to the sky and pray for forgiveness
4. The possibility of putting down the rope may be an unknown creature in the cloud, which can be captured and studied	4. Scramble as strategic resources
	5. There are clouds to eat when pull the strings
	6. Tie to a tree to keep the clouds from moving and to rain
	7. Take the clouds and travel around the world
	8. People will have their own clouds and will name them
	9. Go to work by climbing strings and taking the clouds
	10. Make some artworks such as big candles on the strings and light up
	11. Call the aliens through the strings (+paper cups)
	12. Each city has its own slogan/logo
	13. People are terrified and there is a mass death
	14. Trypophobia
	15. People burn them because they are annoying
	16. Stopping developing the city because the fear of touching
	17. Become an object of worship
	18. There is a new AD
	19. People can go to a different place through the strings and new traffic
	20. There is a new theme park
	21. Vision loss
	22. The whole country is stuck in a rope culture
	23. With the air hermit, stratified living
	24. Somebody's electrocuted
	25. Ozone depletion

Multiple linear regression has been conducted in this research. To run the regression, the dependent variable and all independent variables were put into the model for analysis by choosing stepwise method. In this way, the output can display not only the relationship between students' creativity and reformed teaching but also the impact of other factors, such as gender and SES, on students' creativity. Statistical significance level alpha = .05 was used in this analysis. Additionally, a scatter plot (Chambers, 1983) was conducted to pair up values of creative thinking and reformed teaching for revealing the relationship.

For the purpose efficiency, qualitative data analysis software, QDA Miner, was utilized for assisting coding, annotating, retrieving and reviewing textual data. Through this software, the data collected in the study can be seamlessly utilized in future qualitative or mixed methods research. Although some researchers argue that qualitative data analysis computer programs promoting a superficial view of grounded theory, overemphasizing coding, and "dehumanize" data analysis (i.e., Coffey, Holbrook & Atkinson, 1996; Charmaz, 2000; Lonkila, 1995), the author of this study believe that it is the mind of the researcher, which drives data analysis, not the tool itself (Williams, 2001; William, Lee, & Adams, 2002). Necessary translation (Chinese to English) was done for better coding and analyzing the data from semi-structured interview.

Trustworthiness

Validity and reliability.

Validity refers to the degree to which a study accurately reflects or assesses the specific concept or construct that the researcher is attempting to measure (Thorndike, 1997). For content-related and criterion-referenced validity, in this study, all items in the questionnaire are directly quoted from previous studies (Beaton et al., 1996; Horizon Research Incorporate, 1997; Huffman, Thomas, & Lawrenz, 2008) with minimum modification for the adjustment of Chinese students' understanding. The wording of the survey items is examined by author's academic advisor to make sure the survey questions are relevant to what are going to be measured. Since the survey questionnaire for this study is developed from existing resources, in which each item in the questionnaire is designed to address an important component of reform-based teaching with a factor analysis confirming a unique construct for each item to measure (Huffman, Thomas, & Lawrenz, 2008), construct-referenced validity is established.

To notice that this research includes translation from English to Chinese, additional examination of the validity of this survey has been conducted for the accuracy of translation into Mandarin Chinese. Several graduate students who are of fluency in both Mandarin and English has helped with the translation of questionnaire items. Some of them assisted the author for accurate and authentic Chinese terms of expression while the other are responsible for translating those items back into English for ensuring the translation by the author is accurate and all the translated items are functionally appropriate. For assessing student creative thinking, the Chinese version Torrance Tests of Creative Thinking – Verbal are directly purchased from the Psychological Publishing Co., Ltd in Taiwan which obtains the exclusive Chinese copyright.

Reliability refers to the accuracy and precision of a measurement procedure (Thorndike, 1997). This study uses Cronbach's Alpha coefficient to examine internal consistency of the questionnaire items. Calculating in the Statistical Package for Social Sciences (SPSS), the reform-based teaching questionnaire indicates a .82 value of Cronbach's Alpha coefficient as Table 3 illustrates, suggesting that the items in the reform-based teaching questionnaire have relatively high internal consistency by noting that a coefficient greater than or equal to .70 is considered as the minimum acceptable threshold of consistency in most social science research situations.

Table 4: *Cronbach's Alpha Coefficient*

Scale	Cronbach's Alpha	N of Items
Reform-based Teaching	.82	18

Although scoring TTCT doesn't need any special training, individuals specially trained and experienced in scoring TTCT are capable of reaching a very high degree of reliability. The author received a professional training and obtained the certificate for achieving inter – rater reliability in scoring the Torrance Tests of Creative Thinking – Verbal Forms A&B in Torrance Center for Creativity and Talent Development at the University of Georgia.

Credibility.

The corresponding qualitative term for this aspect of rigor is credibility, which Erlandson, Harris, Skipper, and Allen (1993) note, "is essentially its ability to communicate the various constructions of reality in a setting back to the persons who hold them in a form that will be affirmed by them" (p. 40). To insure credibility of this research findings, the author carefully and accurately describes every detail of data and findings with all the qualitative data processed in the author's native language. Triangulation (Guba & Lincoln, 1985) has also been promoted for higher credibility, in which data from different sources (semi-structured interview and classroom observation) have been collected and analyzed. Further input, correction, and clarification are processed as needed for accurately data interpretation and getting feedback from the participants.

Chapter 4: Results

Descriptive Statistics Findings

Demographics.

As a convenience sample, all student participants are from the same grade with a similar age. In this study 120 participating students were all middle school students studying in grade 8 in Wuhu, Anhui, China. The sample included 32 female participants (26.7%) and 88 male participants (73.3%), among which 103 participants (85.8%) were the single child in their families while 17 participants (14.2%) had siblings. All the 120 students (100%) who participated in the study are from the Han nationality. For their families' social economic status, 38 participants (31.7%) were unknown about the approximate annual income of their family; 4 participants (3.3%) were living in the families whose annual income was less than 12,000 yuan; 28 participants' families (23.3%) held the annual income that was between 12,000 yuan and 50,000 yuan; the rest 50 participants (41.7%) were included in the families with an annual household income that more than 50,000 yuan. The following tables 5, 6, 7, and 8, present the participants by gender, by single child, by ethnic group, and by family annual household income respectively.

Table 5: *Participants by Gender*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Female	32	26.7	26.7	26.7
	Male	88	73.3	73.3	100.0
	Total	120	100.0	100.0	

Table 6: *Participants by Single Child*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not Single Child	32	26.7	26.7	26.7
	Single Child	88	73.3	73.3	100.0
	Total	120	100.0	100.0	

Table 7: *Participants by Ethnic Group*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Han	120	100.0	100.0	100.0

Table 8: *Participants by Annual Household Income*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Unknown	38	31.7	31.7	31.7
	<12,000 yuan	4	3.3	3.3	35.0
	12,000 – 50,000 yuan	28	23.3	23.3	58.3
	>50,000 yuan	50	41.7	41.7	100.0
	Total	120	100.0	100.0	

Reformed science teaching.

The questionnaire including in the student survey is based on existing resources from previous studies (Beaton et al., 1996; Horizon Research Incorporate, 1997; Huffman, Thomas, & Lawrenz, 2008). This questionnaire contains 18 items aiming at addressing important components of reform-based teaching which is considering as the independent variable of this study to reveal the relationship between reformed science teaching and students' creativity. All student participants were asked to indicate the frequency of the activities for reform-based science classes they experience ranging from never (1), rarely (2), sometimes (3), often (4), or always (5). The frequency and percent of all responses to each questionnaire item are shown from Table 9 to Table 26.

Table 9: *Responses to Describe What You Know about A Topic before It Is Taught*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Never	13	10.8	10.8	10.8
	Rarely	20	16.7	16.7	27.5
	Sometimes	46	38.3	38.3	65.8
	Often	29	24.2	24.2	90.0
	Always	12	10.0	10.0	100.0
	Total	120	100.0	100.0	

Table 10: *Responses to Make Presentations That Help to Learn Science Concepts*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Never	48	40.0	40.0	40.0
	Rarely	34	28.3	28.3	68.3
	Sometimes	19	15.8	15.8	84.2
	Often	15	12.5	12.5	96.7
	Always	4	3.3	3.3	100.0
	Total	120	100.0	100.0	

Table 11: *Responses to Engage in Hands-on Science Activities*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Never	7	5.8	5.8	5.8
	Rarely	41	34.2	34.2	40.0
	Sometimes	51	42.5	42.5	82.5
	Often	16	13.3	13.3	95.8
	Always	5	4.2	4.2	100.0
	Total	120	100.0	100.0	

Table 12: *Responses to Participate in Discussions to Deepen Science Understanding*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Never	2	1.7	1.7	1.7
	Rarely	13	10.8	10.8	12.5
	Sometimes	20	16.7	16.7	29.2
	Often	43	35.8	35.8	65.0
	Always	42	35.0	35.0	100.0
	Total	120	100.0	100.0	

Table 13: *Responses to Choose Which Questions to Do or Which Ideas to Discuss*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Never	9	7.5	7.5	7.5
	Rarely	10	8.3	8.3	15.8
	Sometimes	27	22.5	22.5	38.3
	Often	33	27.5	27.5	65.8
	Always	41	34.2	34.2	100.0
	Total	120	100.0	100.0	

Table 14: *Responses to Share Ideas or Solve Problems with Each Other in Small Groups*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Never	10	8.3	8.3	8.3
	Rarely	20	16.7	16.7	25.0
	Sometimes	38	31.7	31.7	56.7
	Often	52	43.3	43.3	100.0
	Always	120	100.0	100.0	
	Total	10	8.3	8.3	8.3

Table 15: *Responses to Read Other (Non-Textbook) Science-Related Materials in Class*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Never	8	6.7	6.7	6.7
	Rarely	26	21.7	21.7	28.3
	Sometimes	25	20.8	20.8	49.2
	Often	32	26.7	26.7	75.8
	Always	29	24.2	24.2	100.0
	Total	120	100.0	100.0	

Table 16: *Responses to Work on Problems Related to Real World or Practical Issues*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Never	12	10.0	10.0	10.0
	Rarely	21	17.5	17.5	27.5
	Sometimes	44	36.7	36.7	64.2
	Often	28	23.3	23.3	87.5
	Always	15	12.5	12.5	100.0
	Total	120	100.0	100.0	

Table 17: *Responses to Make Hypothesis Based on Your Prior Experience and Knowledge*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Never	11	9.2	9.2	9.2
	Rarely	22	18.3	18.3	27.5
	Sometimes	36	30.0	30.0	57.5
	Often	29	24.2	24.2	81.7
	Always	22	18.3	18.3	100.0
	Total	120	100.0	100.0	

Table 18: *Responses to Design Your Own Experiment/Investigation*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Never	25	20.8	20.8	20.8
	Rarely	57	47.5	47.5	68.3
	Sometimes	27	22.5	22.5	90.8
	Often	9	7.5	7.5	98.3
	Always	2	1.7	1.7	100.0
	Total	120	100.0	100.0	

Table 19: *Responses to Collect, Organize, and Analyze Data*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Never	23	19.2	19.2	19.2
	Rarely	36	30.0	30.0	49.2
	Sometimes	38	31.7	31.7	80.8
	Often	17	14.2	14.2	95.0
	Always	6	5.0	5.0	100.0
	Total	120	100.0	100.0	

Table 20: *Responses to Draw Conclusions from Experiment/Investigation You Have Conducted*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Never	23	19.2	19.2	19.2
	Rarely	41	34.2	34.2	53.3
	Sometimes	33	27.5	27.5	80.8
	Often	12	10.0	10.0	90.8
	Always	11	9.2	9.2	100.0
	Total	120	100.0	100.0	

Table 21: *Responses to Prepare Written Science Reports*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Never	52	43.3	43.3	43.3
	Rarely	47	39.2	39.2	82.5
	Sometimes	15	12.5	12.5	95.0
	Often	6	5.0	5.0	100.0
	Always	52	43.3	43.3	43.3
	Total	120	100.0	100.0	

Table 22: *Responses to Write Reflections in A Notebook or Journal*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Never	20	16.7	16.7	16.7
	Rarely	23	19.2	19.2	35.8
	Sometimes	26	21.7	21.7	57.5
	Often	28	23.3	23.3	80.8
	Always	23	19.2	19.2	100.0
	Total	120	100.0	100.0	

Table 23: *Responses to Document and Evaluate Your Own Science Work*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Never	11	9.2	9.2	9.2
	Rarely	21	17.5	17.5	26.7
	Sometimes	32	26.7	26.7	53.3
	Often	25	20.8	20.8	74.2
	Always	31	25.8	25.8	100.0
	Total	120	100.0	100.0	

Table 24: *Responses to Think About What a Problem Means and Different Ways It Might Be Solved*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Never	3	2.5	2.5	2.5
	Rarely	13	10.8	10.8	13.3
	Sometimes	18	15.0	15.0	28.3
	Often	45	37.5	37.5	65.8
	Always	41	34.2	34.2	100.0
	Total	120	100.0	100.0	

Table 25: *Responses to Use Calculators or Computers to Assist Solving Science Problems*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Never	12	10.0	10.0	10.0
	Rarely	13	10.8	10.8	20.8
	Sometimes	28	23.3	23.3	44.2
	Often	32	26.7	26.7	70.8
	Always	35	29.2	29.2	100.0
	Total	120	100.0	100.0	

Table 26: *Responses to Receive Computer-Assisted Instruction (For Example: Simulations, Slide Show)*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Never	15	12.5	12.5	12.5
	Rarely	25	20.8	20.8	33.3
	Sometimes	30	25.0	25.0	58.3
	Often	25	20.8	20.8	79.2
	Always	25	20.8	20.8	100.0
	Total	120	100.0	100.0	

Students' responses to the survey questionnaire indicate that some items, such as "Make presentations that help to learn science concepts", "Design your own experiment/investigation", "Draw conclusions from experiment/investigation you have conducted", and "Prepare written science reports", are either never or rarely (once each semester) experienced by more than 65% students. Around 50% students participated in "Collect, organize, and analyze data", "Draw conclusions from experiment/investigation you have conducted", "Write reflections in a notebook or journal", and "Receive computer-assisted instruction (For example: simulations, slide show)" sometimes (once per month). More than 60% students engaged in other items from sometimes to always (everyday).

Table 27: *Statistics of Questionnaire Items by Gender*

Questionnaire Items	Scale Values					
	Male (*n* = 88)		Female (*n* = 32)		Overall (*n* = 120)	
	M	*SD*	*M*	*SD*	*M*	*SD*
Describe what you know about a topic before it is taught	3.19	1.17	2.69	.86	3.06	1.12
Make presentations that help to learn science concepts	2.10	1.17	2.13	1.18	2.11	1.17
Engage in hands-on science activities	2.78	.96	2.69	.74	2.76	.91
Participate in discussions to deepen science understanding	4.00	1.04	3.69	1.06	3.92	1.05
Choose which questions to do or which ideas to discuss	3.66	1.28	3.91	1.09	3.73	1.23
Share ideas or solve problems with each other in small groups	4.10	.97	4.09	.96	4.10	.96
Read other (non-textbook) science-related materials in class	3.44	1.22	3.28	1.35	3.40	1.25
Work on problems related to real world or practical issues	3.13	1.15	3.06	1.13	3.11	1.14

Make hypothesis based on your prior experience and knowledge	3.34	1.24	2.97	1.12	3.24	1.22
Design your own experiment/investigation	2.27	.92	2.06	.91	2.22	.92
Collect, organize, and analyze data	2.58	1.12	2.50	1.08	2.56	1.11
Draw conclusions from experiment/investigation you have conducted	2.69	1.22	2.19	1.00	2.56	1.18
Prepare written science reports	1.85	.98	1.81	1.06	1.84	1.00
Write reflections in a notebook or journal	3.00	1.38	3.34	1.31	3.09	1.37
Document and evaluate your own science work	3.27	1.30	3.63	1.24	3.37	1.29
Think about what a problem means and different ways it might be solved	3.90	1.12	3.88	.94	3.90	1.07
Use calculators or computers to assist solving science problems	3.56	1.32	3.50	1.22	3.54	1.29
Receive computer-assisted instruction (For example: simulations, slide show)	3.24	1.27	2.97	1.45	3.17	1.32
Average reformed science teaching	3.12	.56	3.02	.58	3.09	.57

From Table 27, descriptive statistics of reformed science teaching shows a medium frequency of reform-based teaching activities that experienced by students with an average score 3.09, SD = .57. When illustrated by gender, male students' average score (*M* = 3.12, *SD* = .56) is slightly higher than female students' average score (*M* = 3.02, *SD* = .58). Figure 4 illustrated the nearly normal distribution of the overall reform-based teaching activities in science class that experienced by students with the normal distribution curve.

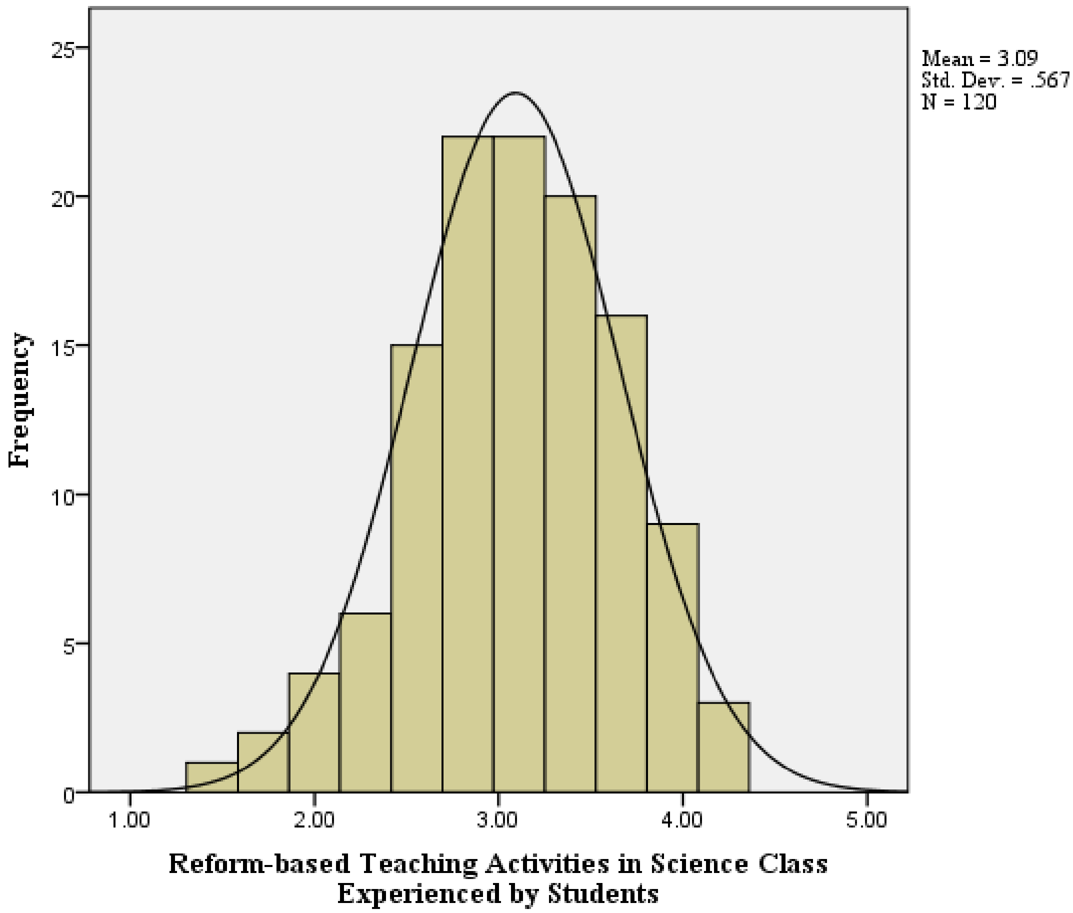


Figure 6. Distribution of Reformed Science Teaching

Creative thinking.

Student participations' creativity level were evaluated with Torrance Test of Creative Thinking – Verbal. Form A and Form B were randomly assigned to every student participant. Each student's Verbal TTCT average standard score which is the average of individual standard score of fluency, flexibility, and originality, was collected as the dependent variable of this study for investigating the relationship with reformed science teaching. Table 28, 29, and 30 provides descriptive information of sub-scores of Verbal TTCT including Fluency (*M* = 99.49, *SD* =

14.32), Originality (*M* = 108.07, *SD* = 13.14), and Flexibility (*M* = 97.51, *SD* = 15.29). Table 31 includes the descriptive statistics of students' creativity with a mean of 101.69, SD = 12.41.

Table 28: Statistics of Fluency

Valid N	Minimum	Maximum	Mean	Std. Deviation
120	73.00	155.00	99.49	14.32

Table 29: *Statistics of Originality*

Valid N	Minimum	Maximum	Mean	Std. Deviation
120	70.00	139.00	108.07	13.14

Table 30: *Statistics of Flexibility*

Valid N	Minimum	Maximum	Mean	Std. Deviation
120	56.00	139.00	97.51	15.29

Table 31: *Statistics of Student Creative Thinking*

Valid N	Minimum	Maximum	Mean	Std. Deviation
120	72.00	140.67	101.69	12.42

Referring to the national percentile ranks that including in the Torrance Tests of Creative Thinking Norms – Technical Manual for Verbal Forms A and B (Scholastic Testing Service, 2008), an average standard score equals to 102 and the U.S. national percentile rank is 56 (53 for Taiwan), which expressed the creative thinking level of testing sample was higher than 56% (53%

for Taiwan) of its population. It indicates the participants' creative strength is on average (see Table 2). The standard score of Fluency, Originality, and Flexibility is 99, 108, and 98 with U.S. national percentile ranks equal to 47, 65, and 46, and Taiwan percentile rank equal to 48, 65, and 46 respectively. The histogram of student creative thinking shows a shape of normal distribution (Figure 5).

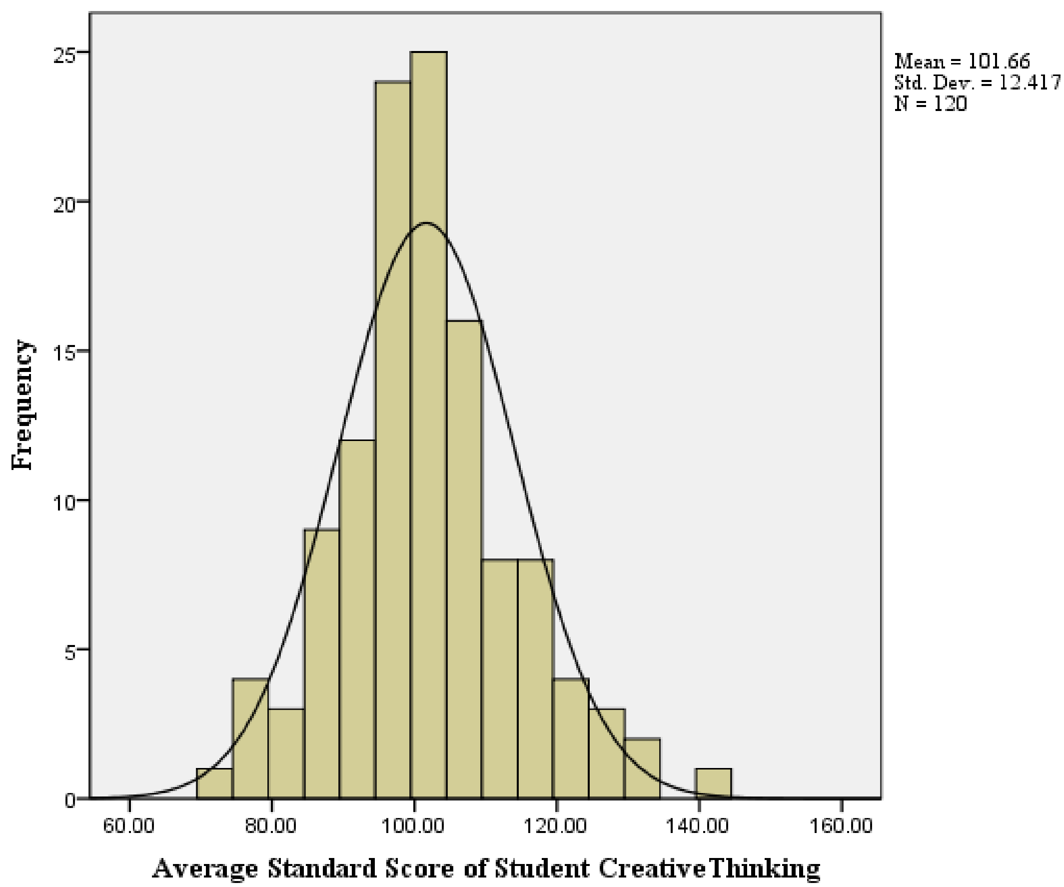


Figure 7. Distribution of Student Creative Thinking

The descriptive statistics of students' Verbal TTCT results by gender are presented in Table 32. Male students (*M* = 98.80, *SD* = 14.38) score 2.61 lower than female students (*M* = 101.41, *SD* = 14.20) in Fluency. There is a similar difference in Originality in which females (*M* = 110.03, *SD* = 11.84) are 2.68 higher than males (*M* = 107.35, *SD* = 13.58). An obvious difference is shown that female students (*M* = 104.28, *SD* = 11.85) score 5.27 higher than males (*M* = 100.70, *SD* = 12.55) in Flexibility. It means that female students are more capable of shifting from one thinking approach to another. In addition, female students' minimum scores of Fluency, Originality, and Flexibility are higher than male students' while the male students' maximum scores of the three parts are higher than females'.

Table 32: *Statistics of Student Verbal TTCT by Gender*

	Standard Scores							
Verbal TTCT	Male (*n* = 88)				Female (*n* = 32)			
	Min	Max	M	SD	Min	Max	M	SD
Fluency	73.00	155.00	98.80	14.38	77.00	133.00	101.41	14.20
Originality	70.00	139.00	107.35	13.58	86.00	137.00	110.03	11.84
Flexibility	56.00	139.00	96.11	15.65	78.00	134.00	101.38	13.74
Average	72.00	141.00	100.70	12.55	86.00	131.00	104.28	11.85

Inferential Statistics Findings

Preface.

The main purpose of this study was to indicate the relationship between reformed science teaching and students' creativity. Reformed science teaching as a crucial independent variable was collected and analyzed from student survey which included demographic information (gender, age, grade, single child, ethnic group, and annual household income) and a questionnaire containing 18 items for evaluating reform-based teaching activities that student experienced in their science classes. The average standard score from the Verbal Torrance Test of Creative Thinking was regarded as the dependent variable for its importance to the debate of creativity of Chinese students.

Reformed science teaching and students' creativity.

Since this study chose a convenience sample with same grade, similar age, and same ethnic group, multiple liner regression analysis using stepwise method was conducted for investigating the relationship among different variables after controlling grade, age, and ethnic group. The results of the regression analysis in Table 33, 34, and 35 demonstrated a significantly statistical relationship between reformed science teaching and students' creativity at a .05 alpha level.

Table 33: *Variance in the Regression Model*

					Change Statistics				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
1	.475	.225	.219	10.975	.225	34.339	1	118	<.001
2	.502	.252	.240	10.827	.027	4.239	1	117	.042

Note. Model 1 predictors: Reformed Science Teaching. Model 2 predictors: Reformed Science Teaching, Gender.

Table 34: *Analysis of Variance for Creative Thinking*

Model	df	Sum of Squares	Mean Square	F	p
1	1	4136.035	4136.035	34.339	<.001
2	2	4632.924	2316.462	19.760	.042

Note. Model 1 predictors: Reformed Science Teaching. Model 2 predictors: Reformed Science Teaching, Gender. Significant at p<.05

Table 35: *Coefficients of the Regression Model*

	Model	Estimate	Standard Error	t	p
1	(Constant)	69.489	5.558	12.452	<.001
	Reformed Science Teaching	10.404	1.775	5.860	<.001
2	(Constant)	72.021	5.641	12.767	<.001
	Reformed Science Teaching	10.679	1.757	6.079	<.001
	Gender	-4.615	2.242	-2.059	.042

Note. Dependent Variable: Creative Thinking. Significant at p<.05.

Table 33 shows the percent of variability in the dependent variable that can be accounted for by all the predictors together. The change in R^2 from .225 to .252 evaluates the increase of predictive power that is added to the model Analysis of Variance for Creative Thinking the addition of students' gender.

Table 34 and 35 indicate that the overall model is significant to predict students' TTCT verbal scores from reform-based teaching activities and genders, $F(2, 117) = 19.760$, $p = .042$. The R-square of the model was .240, which meant that of 24.0% of the variance on students' creativity could be explained by this model. All the parameters were statistically significant to the model at $\alpha = .05$ level. Specifically, for gender, female students scored 4.615 higher than male students on average. Other variables, such as single child (*M* = .86, *SD* = .350, *t* = .371, *p* = .711), and family annual household (*M* = 1.75, *SD* = 1.292, *t* = .906, *p* = .367), are excluded from the model. Figure 8 provides the visual display of the relationship between reformed science teaching and student creative thinking without considering student gender.

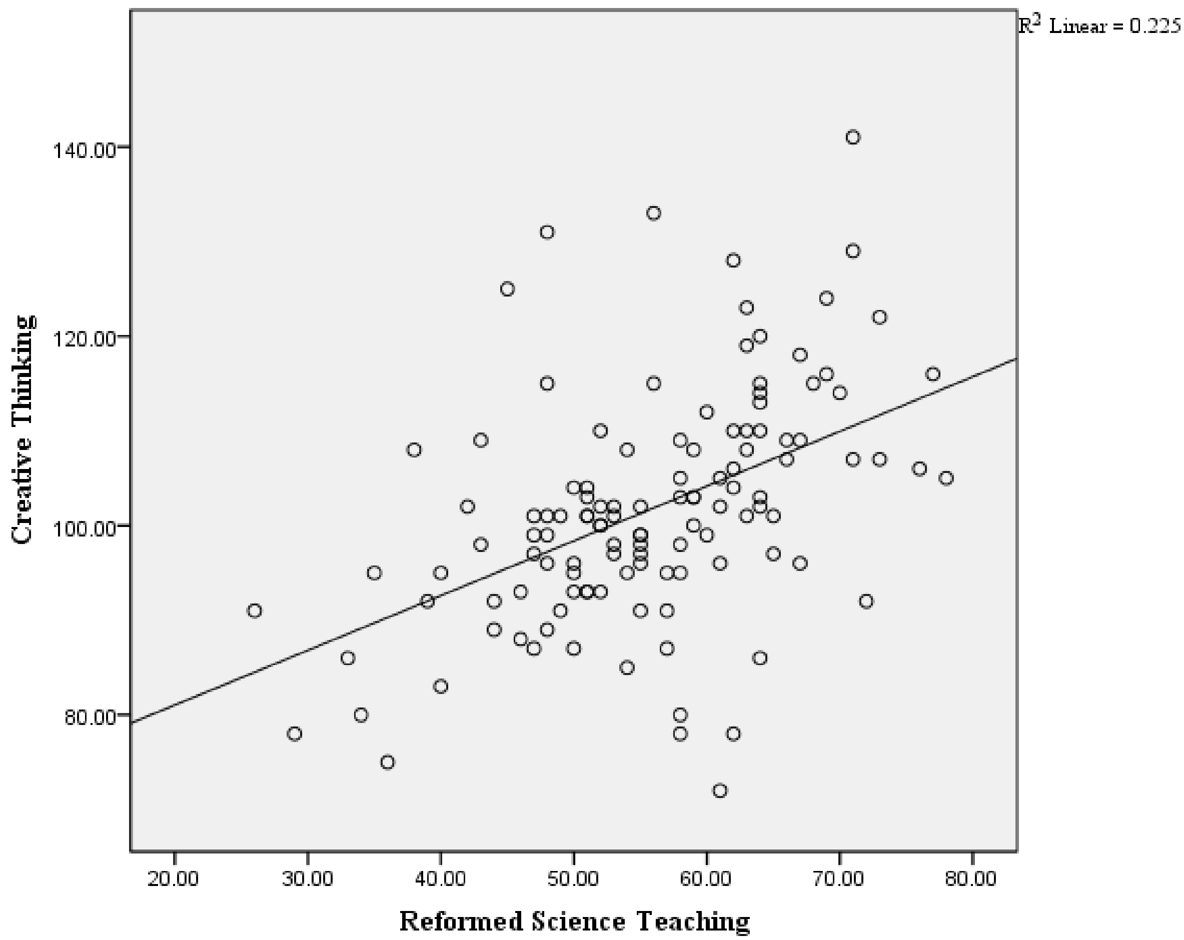


Figure 8. Relationship between Reformed Teaching and Students' creativity.

Classroom Observation

To address one of the research questions that “What is the extent that inquiry-based approach is applied in the observed science classroom”, Reformed Teaching Observation Protocol (RTOP; Sawada & Piburn, 2000) was used in this study for collecting qualitative data to better demonstrate the extent of inquiry-oriented standards-based teaching practices in observed science classes. Each of the two participating classes was observed for five new class lessons (45 minutes each lesson). With the assistance of a video recorder, more details of class events could be precisely caught and interpreted for analysis.

Generally, all the 9 science lessons, including 6 physics lessons and 3 biology lessons, showed a positive result of inquiry-oriented reform-based instruction with an average score of 2.13 in RTOP with the rating of “0” denoted that no evidence for the indicator was observed; the rating of “1” denoted that seldom evidence for the indicator was observed; the rating “2” denoted that some evidence was observed; the rating “3” denoted that the indicator was descriptive for the observed class; the rating “4” denoted that the indicator was very descriptive. The frequency of each rating was tabulated (Table 36).

Table 36: *Summary of Ratings on RTOP*

Indicator	Percentage of lessons on RTOP (*n* = 10)				
	0	1	2	3	4
The instructional strategies and activities respected students' prior knowledge and the preconception inherent therein.	—	—	—	22.2	77.8
The lesson was designed to engage students as members of a learning community.	44.4	44.4	11.1	—	—
In this lesson, student exploration preceded formal presentation.	88.9	11.1	—	—	—
This lesson encouraged students to seek and value alternative modes of investigation or of problem solving.	—	—	44.4	55.6	—
The focus and direction of the lesson was often determined by ideas originating with students.	33.3	22.2	22.2	22.2	—
The lesson involved fundamental concepts of the subject.	—	—	—	22.2	77.8
The lesson promoted strongly coherent conceptual understanding.	—	—	—	11.1	88.9
The teacher had a solid grasp of the subject matter content inherent in the lesson.	—	—	—	66.7	33.3
Elements of abstraction (i.e., symbolic representations, theory building) when it was important to do so.	—	22.2	—	33.3	44.4
Connections with other content disciplines and/or real word phenomena were explore and valued.	—	44.4	22.2	33.3	—
Students used a variety of means (models, drawings, graphs, concrete materials, manipulatives, etc.) to represent phenomena.	—	55.6	22.2	22.2	—
Students made predictions, estimations and /or hypotheses and devised means for testing them	—	22.2	33.3	22.2	22.2
Students were actively engaged in thought-provoking activity that often involved the critical assessment of procedures.	33.3	11.1	44.4	11.1	—
Students were reflective about their learning.	44.4	44.4	11.1	—	—
Intellectual rigor, constructive criticism, and the challenging of ideas were valued.	22.2	33.3	22.2	22.2	—
Student were involved in the communication of their ideas to others using a variety of means and media.	88.9	11.1	—	—	—

The teacher's questions triggered divergent modes of thinking.	—	—	44.4	22.2	33.3
There was a high proportion of student talk and a significant amount of it occurred between and among students.	22.2	44.4	22.2	11.1	—
Student questions and comments often determined the focus and direction of classroom discourse.	77.8	22.2	—	—	—
There was a climate of respect for what others had to say.	33.3	44.4	11.1	11.1	—
Active participation of students was encouraged and valued.	—	11.1	11.1	55.6	22.2
Students were encouraged to generate conjectures, alternative solution strategies, and ways of interpreting evidence.	—	—	—	33.3	66.7
In general, the teacher was patient with students.	—	—	—	22.2	77.8
The teacher acted as a resource person, working to support and enhance student investigations.	—	—	22.2	66.7	11.1
The metaphor "teacher as listener" was very characteristic of this classroom	11.1	55.6	22.2	11.1	—

RTOP, Reformed Teaching Observation Protocol

Results found that the following indicators were observed as "descriptive" or "very descriptive" in more than half of the lessons: "The instructional strategies and activities respected students' prior knowledge and the preconception inherent therein"; "This lesson encouraged students to seek and value alternative modes of investigation or of problem solving"; "The lesson involved fundamental concepts of the subject"; "The lesson promoted strongly coherent conceptual understanding"; "The teacher had a solid grasp of the subject matter content inherent in the lesson"; "Elements of abstraction (i.e., symbolic representations, theory building) when it was important to do so"; "The teacher's questions triggered divergent modes of thinking"; "Active participation of students was encouraged and valued"; "Students were encouraged to generate conjectures, alternative solution strategies, and ways of interpreting evidence"; "In general the teacher was patient with students"; and "The teacher acted as a resource person, working to support and enhance student investigations.” However, indicators, like “The lesson was designed to engage students as members of a learning community”, “In this lesson, student exploration preceded formal presentation”, “The focus and direction of the lesson was often determined by ideas originating with students”, “Students used a variety of means (models, drawings, graphs, concrete materials, manipulatives, etc.) to represent phenomena”, “Students were reflective about their learning”, “Intellectual rigor, constructive criticism, and the challenging of ideas were valued”, “Student were involved in the communication of their ideas to others using a variety of means and media”, “There was a high proportion of student talk and a significant amount of it occurred between and among students”, “Student questions and comments often determined the focus and direction of classroom discourse”, “There was a climate of respect for what others had to say”, and “The metaphor “teacher as listener” was very characteristic of this classroom,” are either “never occurred” or “seldom occurred” in most (>50%) observed lessons. Among them, more than 70% lessons didn't show any sign of the following indicators: “In this lesson, student exploration preceded formal presentation”; “Student were involved in the communication of their ideas to others using a variety of means and media”; and “Student questions and comments often determined the focus and direction of classroom discourse.

Three vignettes are presented to help to get closer looks and real-world descriptions of the classes the author observed. For easy comparison, the author selected three lessons from each participating science teacher for vignettes. Two of physics lessons share similar contents in which different circuits are investigated while the vignette for biology lesson focus on photosynthesis. The first vignette indicates a less reformed but more practice-based class which involves an experienced physics teacher with high reputation of teaching. The second vignette shows a more reformed class in which a young physics teacher who is trying to improve her teaching with inquiry skills. The third vignette also shows a more reform-based teaching approach in which computer technology are utilized. All the teacher's names displayed in this study are substitute names for the protection of participants' privacy.

Vignette 1.

Mr. Chen[1] is an experienced physics teacher who has been teaching for more than 10 years, including both middle school and high school level. There are usually more than 50 students in his class and he often teaches key classes. Mr. Chen is regarded as a high reputation teacher with humorous and professional elaboration.

The topic of observed class was Investigating the Characteristics of Current and Voltage in Series and Parallel Circuits. A first glance at the physical environment of the physics laboratory where this lesson is taught indicates a restriction on student-centered approach. The physics laboratory is designed and arranged by the school, including the space, furniture, materials and their settings. There are fixed tables of two with sockets on sides lined up as a regular classroom in this school. The table in the lab is larger than a regular classroom desk for the convenience of operating experimental materials. In front of the class room, there is a podium, a blackboard, and a projector. Small cabinets are on the back wall for storage and sinks with faucets are under the cabinets. Materials are usually prepared in another room called science preparation room where different experiment materials are reserved and prepared for science classes.

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[1] This is not a real name.

At the beginning, Mr. Chen announced the start of the class. All students stood up and bowed to him and greeted him together respectfully. The students in this class were relatively quiet during the whole lesson. Every student seemed focusing on what the teacher was saying. Mr. Chen spent 7 to 8 minutes to review the concepts of current, voltage, and resistance, and show his students what an ammeter, a voltmeter, a switch, and a light bulb looks like and how to draw them in a circuit diagram. It is not hard to notice that most students were concentrated while some students started to play with the materials which had placed on their table for the lesson.

After distributing handouts, Mr. Chen asked his students to read the handouts carefully and finish the warming up questions at the first page of those handouts. The questions were all fill in the black with hypotheses and given data calculations. Students were paired based on their seats and offered two batteries, two light bulbs, a voltmeter, an ammeter, a switch, and several wires on each table. In the next 15 minutes, students were following the steps on their handouts to connect wires with other materials in series and parallel circuits. Then they were asked to observe the luminous intensity of light bulbs and record the readings from the ammeter and voltmeter in their circuits. Every student was encouraged to think about an open-ended question according to what they found, "Do you find your data is in line with your calculation? Explain your reasons." Students could discuss with their partners and Mr. Chen was patient with any raised hands for the help during this section. Sometimes, Mr. Chen asked for the silence of the whole class for reminding some key points to assist his students.

At the end of the class, Mr. Chen randomly asked three students to stand up and sharing their thoughts. He made a summary of the lesson today and reminded his students the importance of working on their workbook for enhancing their understanding about what they had learned.

Vignette 2.

Miss Hu[2] is a young physics teacher who has been teaching for nearly three years. Miss Hu is energetic with all her passion on teaching science in this school. During an occasional chat before observing her class, Miss Hu expressed her strong will of improving her teaching with more inquiry-based approaches and she also introduced some of her efforts of studying online resources of teaching inquiries. Miss Hu is also very popular with students as a caring and warmhearted person.

The science lab Miss Hu had for her lesson is the same one that Mr. Chen used. The two classes shared similar classroom setting except that Miss Hu did not put an experiment set on every table. Instead, she put a set on every other table and intended to group her students into four rather than pairing up, so she asked her students to move their chairs for four-people groups. Miss Hu's class was easily recognized as a more student-centered class based on many details. For example, she arrived the science lab early and welcomed every student before class and she was more like a listener and willing to give praise for encouragement.

After standing up and bowing to the teacher, Miss Hu started her lesson by asking for volunteers to share what they had learned before on series circuits and parallel circuits. Volunteers were invited to draw a series and a parallel circuit on the blackboard and explain their drawings. Miss Hu encouraged different voices and was very attentive to other students' reactions. After a short sum up, Miss Hu started to distribute her handouts which were organized differently comparing to Mr. Chen's class. The handout contains three parts. The first part is "Try to Guess", in which students are asked to make hypotheses on the light intensity in six different circuits and give out their reasons. The second part is "Try to Do", in which students

[2] This is a real name.

are going to use provided materials to connect each circuit for investigation. The last part in the handout is “Try to think”, in which students rethink their hypotheses based on what they find in this experiment and share to others.

The whole time with the handouts were a little noisy but students were with high enthusiasm and well engaged. During this time, Miss Hu walked into her students and listened to their discussions and sometimes she asked question, like “why do you choose…” and “can you explain…”, to help generating more ideas. When most students were done with the investigation, each group was asked to choose one representative to demonstrate the difference between their hypotheses and what they found in the experiment.

After a conclusion of the lesson, the class was about to dismiss. Miss Hu showed her students a quick example of current flowing in either a series circuit and a parallel circuit and assigned the homework.

Vignette 3.

Mr. Zhou[3], as a “creative teacher”, is popular among students for showing amazing videos and interesting animations during class. Mr. Zhou always believes that “cool” technologies can help grasp students’ attentions and interests. He holds a bachelor’s degrees of biology teacher education and his thesis is about the important role of computer technology in teaching biology.

Mr. Zhou’s class was given in a biology lab with a similar setting of the physics lab that Mr. Chen and Miss Hu had except for a sink in the middle of two connected tables and the microscope on each table.

[3] This is not a real name.

The lesson topic is photosynthesis. The whole process of Mr. Zhou's teaching is like Miss Hu's. At the beginning, after greeting and bowing to each other, Mr. Zhou start to ask questions for reviewing the content knowledge of cells from previous lessons. He asked every student to take out a blank paper and start to draw a plant cell with interior structure. After reviewing the function of chloroplast, Mr. Zhou asked his students to make hypothesis about the way plants getting food. Some students guessed that plants suck food from the fertile soil. One student emphasized the source of food from watering. Many other students mentioned photosynthesis and the sun.

After a short discussion, Mr. Zhou asked for three volunteers selecting useful elements for photosynthesis in the relevant animation on his computer. Different selections were encouraged when students raised their hands for adding. The animation would not run until essential elements were selected.

Followed by a video about the evolution of plants from blue-green algae to today's diversity of plants, "thinking stage" was started by discussing scenarios such as "what will happen if using up solar energy" and "the effect of haze on green plant". The homework for this lesson includes finishing practice problems at the end of current textbook chapter.

Semi-Structured Interview

Results of the semi-structured interviews indicate the participating science teachers' beliefs and attitudes toward reform-based teaching. For "learning theories", all the three science teachers emphasized the importance of practice, such as homework or extra workbooks. They believed that learning after class was as crucial as it happened during class, or even more significant because students spent more time at home every day comparing to school time.

> I think exercises is very important to learning, or in another word “practice”. You know, every workday, students may only have one science lesson which only last for 45 minutes. This is not enough for students to digest and absorb what they get from our teachers . . . The best way of learning, in my point of view, should be like this: Students listen carefully during class and catch up with the teacher. After that, they practice through homework and other exercises and bring out any questions or confusions to the teacher for solutions. This process should be done after class.

One physics teacher reported the importance of student thinking because he believed that students would not learn or effectively learn something without a process of thinking.

> Besides, I believe that every student should have certain time to think about the knowledge they are going to learn. From my experience, passive learner always feels a lot of burden. Even one is regarded as a hardworking student who practice a lot but always lack of a process of thinking, I mean “ju yi fan san” (draw inferences about other cases from one instance), he or she will easily fail in tests. Personally, I encourage my students to be a thinker and ask questions for better understanding . . . In all, I think one can never actually learn through repeated exercise without an active mind activity.

All the three science teachers were familiar with current science education reform. They all mentioned nature of science and inquiry-based approach. The author was informed that scientific inquiry and scientific inquiry skills are required to apply in current science class to accord with the requirement of New Curriculum Standard. However, the teachers reported several challenges for the adaption of reformed science teaching. One of the two physics teacher who had been teaching for more than 10 years demonstrated the unnecessity of switching teaching styles.

> Well I do know that reformed science teaching methods are effective for students to really "do science" instead of simply "calculate science", because I believe that physics knowledge in middle school level should be more life-based. I know you may say that I keep asking students to practice more and find extra workbook to finish. This is what I must do because I don't want them to fail in exams. Here is the paradox. Even though more inquiries are added to our curricula and exams, I think it is not necessary to wholly switch your teaching style. You can still let them practice on inquiry-related questions rather than inquiry itself. I feel this way is more efficient.

The other teachers expressed the challenge of using inquiry-based approach due to the lack of sufficient training and the difficulty of time management.

> I know I should do it (reformed science teaching) and I tried a lot. I tried to have more activities for my students and tried to reduce the lecture time for better guiding my students to find answers by themselves as I read in some journal articles, however, I am not sure whether what I did is correct. What I am going to say is that I think I need someone who is professional in reform-based teaching, an expert, to help me figure out where I did wrong and what I can improve. You know, simply watching video record of an example class is not sufficient. I hope someone with authentic knowledge can walk into my classroom.

> Well if I keep doing inquiry in my class, you will see I will definitely end up with leaving so much stuffs not be taught. For example, in every experiment class, I have to keep using indicative language or even direct instructions to lead them to the result. Otherwise, there will be a big mess with the bell ring and class over . . . Our teachers' syllabi contain too much contents and the teaching progresses are monitoring by our school. I think I

> probably need the help to coordinate the teaching contents and classroom activities, such as inquiry.

Despite the challenges, some similarities of the way using reform-based approach were reported among the science teachers. Computer simulation, problem investigation, and group project are the three most common reformed way of instruction. The biology teacher informed a preference of using drawing and diagram in his teaching and encourage his students to use. All the teachers frequently used questioning strategies during class to provoke students' thoughts connecting to what they had learned before.

> I think to realize reformed science teaching is a process in which teachers should firstly learned it, then practice it with assistance or trainings, and finally get used to it and embrace it. Merely saying "get rid of traditional approach" is not smart and appropriate because traditional instruction does help our students more especially with their basic science and math skills. You cannot deny that Chinese students are xue ba (students with excellent grades) compared to any students in other countries.

Every participating science teacher express the meaning of creativity as either "to have something new" or "to have something different". All of them stated the importance of being a creative student.

> Although standards kill creativity, with the New Curriculum Standards, teachers like us have more straightforward objectives to cultivate students' creativity. In my class, you can obviously notice that a creative kid is more willing to generate different ideas and solutions. He can always synthesize what he learned or experienced before and make

> very impressive hypotheses . . . Those kids are always active in my class and very interpersonal. So, I think being creative is great.

The biology teacher also mentioned the benefit for teachers to become more creative. He believed that being a popular teacher among students would help to attract their attentions for better learning experiences.

> Be a creative teacher means you are also popular with your students. Students like different learning activities. They initially want something new and interesting rather than a same way of knowledge delivering. You know they are easy to get tired with a boring person. And everyone knows that if a student will probably learn better having a teacher he likes.

This teacher introduced the way he used to intentionally foster students' creativity – take-home project. Basically, he asked student to group and pick up a subject-related problem he prepared to investigate. At the end of the semester, the results of take-home projects will be graded and counted as regular scores combining with the final exam scores as final grades. All the teachers informed that they had not experienced relevant training of cultivating students' creativity; no one be aware of assessing students' creative thinking abilities. A teacher participant asked:

> Since the reform-based approach helps foster creativity, why would we teachers need to particularly assess students' creativity? Furthermore, there are no standards!

Chapter 5: Discussion

Overview of the Study

The study was designed in the context of calls for using reformed science teaching in K-12 science class in both the United States and China (see MOE, 2001a; NGSS Lead States, 2013) The Next Generation Science Standards encourage a more inquiry-oriented reform-based approach than traditional instruction. In addition, creativity as an important component of current reform documents for social programs (Sternberg & Lubart, 1996) and for personal learning and academic achievement (Garnham & Oakhill, 1994). Recent curriculum reforms in many countries emphasize creativity (see Burnard, 2006; Ferrari, Cachia, & Punie, 2009; Hui & Lau, 2010; Kaufman & Sternberg, 2006; Le Metais, 2003). The main purpose of this study was to examine the relationship between reformed science teaching and students' creativity. This study also aimed to understand teachers' beliefs of the reform process (Beck, Czemiak, & Lumpe, 2000; Gregoire, 2003; Sarason, 1996). For the interest of this study, several research questions were put forward:

1. What is the relationship between reformed science teaching and students' creativity?
2. To what extent is inquiry-based teaching used in the observed science classrooms?
3. What are teachers' beliefs in applying an inquiry-based teaching approach?
4. To what extent do middle school science students display creativity?

The research sample included 120 student participants from two classes in a key middle school in Wuhu, Anhui province. 3 teacher participants included 2 physics teachers and 1 biology teacher who taught the two participating classes. A student survey including a five-point Likert questionnaire was developed and utilized for gathering the data of reform-based teaching. The results from Torrance Tests of Creative Thinking – Verbal were analyzed to explicitly indicate the participating students' creative thinking level. This study also gained an insight into real classrooms in China and interpreted the way reformed science teaching was implemented. Teachers' beliefs were also analyzed for further address research questions.

The results from descriptive statistics and multiple regression indicated a statistically significant relationship between reform-based teaching and students' creativity. Some signs have shown that the observed Chinese teachers to some extent used inquiry-based approach while they presented several challenges for applying it during the semi-structured interview. The results from the Verbal TTCT illustrated an average standard score ($M=101.66$. $SD=12.41$) with the U.S. national percentile rank of 56 and Taiwan percentile rank of 53.

Findings by Research Questions

Research Question 1: What is the relationship between reformed science teaching and students' creativity and does gender difference significantly contribute to this relationship?

Hypothesis 1: There is a significant positive relationship between reformed science teaching and students' creativity in this study and gender difference significantly contribute to this relationship.

The primary purpose of this study was to figure out the relationship between reformed science teaching and students' creativity. As reviewed previously, several research studies on scientific creativity were conducted in China (e.g. Hu & Han, 2015; Hu et al., 2004; Lu & Yang, 2010) with no indication of the relationship. Bills' (1971) empirical intervention study found no significant effect of using inquiry science to improve students' creativity as a gloomy response to promote reform-based inquiry-oriented teaching. The findings from multiple linear regression provided data to fill the gap in current literatures on the relationship between students' creativity and reform-based teaching.

The current findings revealed a significant relationship ($F(2, 117) = 19.760, p < .001$) between reformed science teaching and students' creativity by suggesting a linear model for predicting students' creativity ($\alpha = .05$). Student gender was added to this model for higher predictive power, which also has indicated that girls outperform boys on average in all the three creative abilities, fluency, flexibility and originality. Other predictors such as single child ($p = .711$) and family annual household income ($p = .367$) were not significant to current model for predicting students' creativity. This means that whether students have siblings and the amount of their family annual household do not help in understanding the variance in their creative thinking. In addition, the result from the student survey showed a medium level ($M = 3.09. SD = .57$) of participation in reformed science approach. Generally, students experienced the reform-based activities in the student survey nearly once per month. The positive relationship found in this study indicated that higher students' creativity level was associated with higher reform-based approach in science classes. The different results from what Bills (1971) found may due to several reasons. For instance, Bills' study is a quasi-experimental study in which the experimental group was trained on divergent thinking through inquiry tasks. The negative result, as Kind and Kind (2007) concluded, is because "either training does not develop creativity or that creativity developed in the science tasks does not transfer to the testing tasks" (p. 11). However, the result of current study does not mean that the development of students' creativity was due to the implementation of reformed science teaching since this relationship was not causal. The relationship provided evidence for the notion that higher students' creativity was apparent in classes that used more reform-based teaching. Considering the effect of teaching and the role of students as learners, the results are in line with Barrow's (2010) standpoint and supported the content in the science education standards (MOE, 2011; NGSS Lead States, 2013) to enhance students' creativity through inquiry as a pioneer study.

Research Question 2: To what extent is inquiry-based approach used in the observed science classroom?

Hypothesis 2: In the observed science classes, teachers show certain signs of facilitating scientific inquiry.

The findings from classroom observation explained the extent that reformed teaching was used in the observed science classes. From the summary of RTOP ratings, all the observed science teachers presented either descriptive or very descriptive sign of using instructional strategies and activities which respected students' prior knowledge and preconception. In one physics lesson about Newton's First Law of Motion, the teacher asked students to imagine that "if there are no fictions, what will happen to our daily life" at the beginning of class. Ten examples were encouraged for sharing with the whole class. Most answers were about the difficulty of running and the easiness of sliding on the ground. However, an argument about whether a moving train would stop when the friction on the ground disappeared dominated the class. Different viewpoints were presented: some students argued that the train would stop because of the huge weight; other student held different point of view that it would keep moving since there was nothing to "drag" it to stop. One student mentioned the condition that if the engine still on, the train would not stop anyhow. Since lesson preview was encouraged by every Chinese teacher for the efficiency of learning, the teacher took notes of every argument and led the discussion by connecting with students' life experiences, such as ice skating.

The two vignettes compared a less reformed science class and a more reformed one. The teacher who taught the more reformed class shows apparent signs of facilitating scientific inquiry. First, her class was more student-centered and she was more like a listener during the whole class instead of traditional lecture delivering. Second, she encouraged her students to make hypotheses and test their hypotheses rather than directly gave them answers and solutions. Finally, she facilitated a cooperative learning environment in which students work in groups, feel free to discuss, and exchange their ideas. Although the other teacher taught a less reformed class in which practice solving problems were emphasized, he promoted his students to work in pairs answering open-ended questions and sharing with the whole class. However, the hands-on activity in the less reformed class is more like a verification compared to an inquiry itself.

Classroom observations generally showed that the capacity of these science teachers in which they led students to learn from the fundamental concepts to more difficult and complicated theories. High ratings on the indicators "The lesson involved fundamental concepts of the subject", "The lesson promoted strongly coherent conceptual understanding", and "The teacher had a solid grasp of the subject matter content inherent in the lesson" implied that the observed teachers obtained solid subject knowledge and emphasized on the coherence of conceptual comprehension. However, lower rating indicators indicated that there were more room to improve for reform-based teaching on communicative interactions and student/teacher relationships. The communication of students' ideas was monotonous in either group discussion or whole class discussion. Using a variety of media for students to communicate never occurred in the entire observation. The phenomenon can be explained by the conflict of a more traditional instruction and a more reformed instruction. In traditional Chinese class, talking with classmates during class is regarded as a disrespectful behavior by students who are supposed to keep quiet and focus on the teacher’s instruction. The influence from the tradition in some degree restrains students’ motivation of communicating in class.

Based on the observations of classes, questions by students were advocated and encouraged from teachers. The teacher sometimes praised representative questions which were held by many students and spent much time on the development and expansion of relevant knowledge. In a lesson about the balance of two forces, after the concept of “hyper gravity” and “hypo gravity” was described by the teacher by taking the ascending and descending period of elevators as an example for provoking high-order thinking of unbalance of gravity and support force from elevators. A student brought up an irrelevant question, “Can a person avoid death if he jumps when the free-fall elevator hit the ground in an accident?” The physics teacher praised the student and started to encourage all the students to investigate this question and find supported materials. He also informed his students that they would learn how to use calculations in high school physics learning.

To sum up, the observed lessons align with the hypothesis that in the observed science classes, teachers show certain signs of facilitating scientific inquiry. Generally, the observed teachers focused on provoking high-level thinking and were professional at promoting strong conceptual understanding. Alternative solution strategies were advocated and encouraged for the training of divergent thinking. On the other hand, insufficient evidences were shown for a student-centered instruction. Few students obtained the opportunity of using various kinds of media and making formal presentations. Student reflections about their learning were usually after class instead of in class. The communicative interactions caught by the author were mainly in the form of questioning. From the observation, the science teachers used more lectures for instruction than hands-on activities. More than half of the lesson period, teachers were “speakers” rather than “listeners”.

Research Question 3: What are teachers’ beliefs about using an inquiry-based teaching approach?

Hypothesis 3: Teachers generally believe the advantage of inquiry-based teaching. They mostly understand relevant concepts and are willing to apply them in their teaching.

The result from the semi-structured interview supported the hypothesis that science teachers are familiar with NOS and inquiry-based teaching. They also believe that students will benefit from inquiry-based approach. However, the observed science lessons were still more teacher-centered rather than student-centered because of a large proportion of lecturing.

First, one teacher demonstrated the unnecessity of switching teaching styles. This teacher believed that learning middle school physics should base on life experience. However, considering the pressure of tests and exams, more practice instead of inquiries were used for teaching efficiency for pass exams. Meanwhile, inquiries were usually presented as another practice form in workbooks with fixed questions instead of open-ended questions. This form would also be adapted in paper-and-pencil tests. This point of view was in line with the traditional approach which held a behaviorist idea of learning. In fact, the response given by the science teacher implied not only the unnecessity of switching teaching from practice-oriented style to inquiry-oriented style but also the belief that traditional teaching methods helped students to grasp basic knowledge and skills more efficiently.

Second, the teachers also referred to the need of training for fully conducting a reformed science class. Due to the lack of authentic instruction and constructive suggestion, there are many difficulties for pre-service and post-service science teacher in China to engage in inquiry-based science curriculum reform (Bai & Wang, 2009). The relevant research on science teacher education in China is more descriptive. Few studies proposed a systematic training plan for science teacher education in China. The current science teacher education in China was advocated to use the experience of western countries such as the United States and United Kingdom for reference (Li, 2011). The lack of corresponding standards of science teacher preparation became a huge obstacle to its development. As the interviewed teacher stated, the need to have in-class training was apparently essential.

Third, having a reformed science class was time-consuming. All the science teachers explained the required teaching content they had to cover during class kept them increasing inquiry time. Usually, teaching content-related problem-solving skills is regarded as necessary teaching proportion in each lesson. All the teacher complained that if they tried to add more inquiry time, they would be left far behind in teaching progress and facing a huge pressure from the school leaders and colleagues. It is understandable that in China every science teacher may teach a class containing 50-60 or even more students so that some reform-based activities, for instance hands-on activities, may easily end up with mess and chaos when classroom and time management skills are not acquired and utilized professionally by those teachers.

It is not hard to notice a paradox between statistical findings and teacher interviews. Student surveys generally indicated a positive result of reform-based approach while the semi-structured interviews presented many negative attitudes and objective difficulties. In fact, this situation happened because of the unwillingness of opposing national and school policy of adapting inquiry-oriented reform-based approach. Seen from the outside, every science teacher was trying to engage inquiries in his class but they may still be confused with how to do and even what to do according to either subjectively insufficient preparation or objectively lack of professional training.

Research Question 4: To what extent do middle school science students display creativity?

Hypothesis 4: Chinese students do have creativity for generating novel and useful ideas.

The interviews with teachers included questions about science teachers' understanding of creativity. The teachers did not receive any form of gifted education or specially training on cultivating students' creativity and they showed no sign of actively teaching for creativity or assessing students' creativity in class. Despite all this, the results of Verbal TTCT indicated a medium level creative thinking of student participants with a mean of 101.66 and SD = 12.41. The average standard score of 102 in the Verbal TTCT and the creative thinking level of participating students was higher than 56% of the U.S. population and 53% of Taiwan population.

Classroom observations also showed indications of students' creativity. Previous literature (Barrett et al., 2014; Hadzigeorgiou et al., 2012) stated that novelty, value, and collaboration were three necessary components to scientific creativity. The characteristics of novelty and value can be simply explained as having some new and useful ideas which were reflected by the performance of questioning. Collaboration includes the interaction among students and between teachers and students. All the participating science teachers encouraged students to ask questions and generate alternative solutions. However, the in-class questions usually appeared after the teacher gave a hint because arbitrarily interrupt a teacher's instruction was regarded as a misbehavior and extremely impolite. The traditional Chinese culture of "Zun Shi Zhong Dao" which means "honor the teacher and respect his teaching" somehow restricted student's active performance during class. The similar situation occurred in the interaction between students and the teacher. Although there were certain signs of students' creativity in the observed classes, many others happened after class.

The findings support the idea that Chinese students are not short of creativity at all. At least, Chinese students' creativity are at the average level comparing to averages in the United States. criticizing Chinese students for lack of creativity is not warranted. The current data indicate that Chinese students can generate various and original ideas. However, it is easy to connect the phenomenon that Chinese students study hard for exams and high-stakes tests, such as the National College Entrance Examination (NCEE), and the traditional teaching in China with the inherent thought of an absence of creativity. In fact, current reform in Chinese education is promoting reformed science teaching and inquiry-based approaches, in which students' creativity is highly valued. On the other hand, students' creativity may be cultivated after class or after school in which way people may not notice.

Limitations of the Study

There are several limitations in this study. First, this study was designed with mixed research methods to gather both quantitative and qualitative data to better understanding the findings. However, there is a debate regarding whether it is even appropriate to combine multiple methods (Denzin and Lincoln 1994; Guba 1987). Symonds and Gorard (2008) stated that most studies claiming to be "mixed methods" are two separate investigations, and either quantitative part or qualitative part in a mixed-methods research is not exhaustive. It is that authors belief that both methods add value to the study, but both have limitations.

Second, the study mainly relied on self-report information. Subjects might either over-report or under-report their perceptions regarding personal variables. Some students may over-report in the survey by counting the activities they take out of class. For example, they may think that the discussions they take during the break between two classes (usually 10-15 minutes in Chinese schools) can also count. Other students may under-report in the survey because of the negative attitude towards their teachers.

Third, the setting of this study contains its own limitation. The population was restricted to a single Chinese public middle school. Therefore, results of the study may not be generalized to other population (elementary or high school students) or schools (e.g., public schools or private schools). Meanwhile, considering the structure of Chinese classes, which has students remain in the same classroom all day and teachers rotate in and out, and the separated science subjects, such as physics and biology, the influence of a science teacher's instruction on students cannot be separated from other science teachers. This situation also increases the difficulty to the comparison between Chinese students and students from other countries. In fact, the different school hours between China and other countries, such as the U.S., lead to the ambiguity of the portion of creative ability generated in school or at home.

Conclusion and Directions for Future Research

Reform-based teaching and students' creative thinking were investigated in the present study for developing the relationship between reformed science teaching and students' creativity. The main purpose of this study was to contribute to research literature with a data-based support. Other research purpose included investigating the extent of current science education reform and students' creativity in China. All the four hypotheses in this study were accepted based on the findings. There was a positive relationship between reformed teaching and students' creativity ($F(2, 117) = 19.760, p<.001$). Gender as a significant predictor ($p = .042$) implied that girls scored 4.615 higher than boys on average in creativity. Classroom observation generally indicated that the participating teachers were skillful at promoting strong conceptual understanding and provoking high-level thinking. Nonetheless, the evidence of student-centered instruction was not very descriptive in the observed lessons. The semi-structured interviews with participating teachers showed a positive attitude toward inquiry-based teaching but also revealed several challenges and hesitancy about using inquiry science. Finally, the findings from the Verbal TTCT and classroom observation supported that Chinese students had levels of creativity that were typical of students in the United States and Taiwan.

One limitation of current study is merely using the results from Torrance Tests of Creative Thinking to represent students' creativity. Guilford/Torrance's creative abilities (fluency, flexibility, originality, and elaboration) mainly focus on divergent thinking which is only one form of higher-order thinking. In fact, higher-order thinking involves critical thinking, logical thinking, reflective thinking, metacognitive thinking, and problem solving as the learning of complex judgment skills. According to Bloom's (1956) taxonomy, higher levels learning is based on lower levels. It supports that students cannot engage in higher-order thinking until they master the lower level skills, such as cognitive strategies, comprehension, concept classification, discrimination, routing rule, simple analysis, and simple application. Future study should look at different types of higher order thinking skills of students instead of using a single form for judgement. Meanwhile, focusing on the bridges that help students to reach higher levels of thinking from lower order thinking is necessary and meaningful for providing teaching strategies based on current science education reform.

The major research interest of this study was to investigate the relationship between reformed science teaching and students' creativity to contribute to the research literature. The findings indicated a positive relationship between the two variables. Considering the limitation of sample size and convenience sampling, further study is suggested using participants from various schools and grades. Replicated studies should be conducted for further address the limitations in this study. Meanwhile, the positive relationship provided theoretical support for further research on the effect of reform-based teaching on students' creativity. Although Bills' (1971) quasi-experimental study found that there was no significant effect of using inquiry science to increase students' creativity, reform documents included creativity as one of the important learning outcomes through inquiry-based approach. The Bills (1971) study was conducted over 40 years ago and instruction in China has changed. Besides, many educators and researchers have been advocating using reformed approach to foster students' creativity. Further research on the effect are needed to investigate this question.

Teachers' beliefs in the current study presented a generally positive attitude toward inquiry-based teaching however with challenges and hesitancy about using inquiry in practice. This finding provided internal perspective on the implementation of current science education reform in China and what might be required to improve school's policy and management of promoting inquiry. Future research should focus on the limitations of applying inquiries in class and study more latent obstacles to an effective teacher education model for inquiry-based teaching in China.

Although the current study has found that Chinese students' creativity was at the average level with an average standard score of 102 and the U.S. national percentile rank of 56. According to Torrance (1974), fluency refers to the ability to produce quantities of ideas; flexibility is the ability to create different categories of ideas and take different approaches to solve a problem; originality is regarded as the ability to generate new and unique ideas that others are not likely to generate. The study generated a brief view of student Fluency, Originality, and Flexibility, among which, Chinese students hold higher Originality scores than American students while slightly lower Fluency and Flexibility scores. Similar situation happened when comparing to Taiwan students. For future study on Chinese students' creativity, the score of fluency, flexibility, and originality should be analyzed respectively for elaborating students' creative thinking and further produced specific and effective measures to cultivate students' creativity.

Since boys and girls performed differently in the creativity test in this study, further study should include gender as an important variable for investigating student creativity. In China, more boys than girls select science to learn in high school while more girls choose liberal arts. Some research (He et al., 2013) found that male superiority in creative thinking exists in Mainland China, which is different from the result in current study. The reason causes the gender difference in creativity may somehow influence science curriculum and its instructional strategies. Therefore, the gender difference on developing student creativity in an inquiry-based teaching should be studied more.

Future research is also suggested to include culture as an essential variable which may influence either reformed teaching or students' creativity. For example, the traditional culture of "Zun Shi Zhong Dao" as a good moral code has been planted deeply in every Chinese student's mind. It may limit student performance on interaction during class and encourage more communications after class. Future research should add culture to analysis and interpret culture-related influence. Such research could help the field better understand both inquiry science teaching and creativity in such a way that can help all students learn science.

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Appendix A

STUDENT ASSENT

My name is Chenglin Wu. I am interested learning about the relationship between your views of teaching and creativity. If you decide you will be in my study, you will complete a short survey and test for creative thinking.

There are no risks to you in this study. The creative thinking test itself provides you an opportunity to practice your creativity. Although other parts of this study will not benefit you directly, it will be helpful for better promoting educational reform and contributing to further relevant research.

Other people will not know if you are in my study. I will combine results together with other students, so no one can tell what results came from you. When I tell other people about my research, I will not use your name, so no one can tell who I am talking about.

Your parents or guardian must say it’s OK for you to be in the study. After they decide, you get to choose if you want to do it too. If you don’t want to be in the study, it is OK. If you want to be in the study now and change your mind later, that’s OK. You can stop at any time.

If you don't feel like answering any questions, you don't have to, and you can stop speaking with me anytime and that will be OK. I will be happy to answer any questions you may have now or when we are talking together. Do you want to take part in this study?

Appendix B

INFORMED CONSENT STATEMENT

THE RELATIONSHIP BETWEEN REFORMED TEACHING AND STUDENTS' CREATIVITY IN A CHINESE MIDDLE SCHOOL

INTRODUCTION

The Department of Curriculum and Teaching at the University of Kansas supports the practice of protection for human subjects participating in research. The following information is provided for you to decide whether you wish to participate in the present study. You may refuse to sign this form and not participate in this study. You should be aware that even if you agree to participate, you are free to withdraw your child at any time. If you do withdraw from this study, it will not affect your or your child's relationship with this unit, the services it may provide to you or your child, or the University of Kansas.

PURPOSE OF THE STUDY

The main purpose of current study is to explore the relationship between reform-based science teaching and student creative thinking. The current study also interests in indicating the extent of applying inquiry-based approach, teachers' attitudes on reformed teaching, and student creative thinking level.

PROCEDURES

In this study, the participants will be asked to fill out a survey and finish a test of creative thinking. The survey will take about 15 minutes and the test will last 45 minutes.

According to the purpose of this research, videotaping will be conducted for classroom observation. It means this study will involve audio and visual recording which may include your child's information. You can have taping stopped at any time due to any reason.

Only the researcher himself will transcribe the recordings and only the researcher himself can access to the recordings.

All the materials and electronic recording which including participants' personal information will be either locked in a cabinet or saved in an encrypted flash drive, and will be destroyed or deleted when the study is finished.

RISKS

No mental, physical, social or economic risks are posed to participants in this study.

BENEFITS

The creative thinking test itself provides participants an opportunity to practice their creativity. Although other parts of this study will not benefit participants directly, it will be helpful for better promoting educational reform and contributing to further relevant research.

PAYMENT TO PARTICIPANTS

Since this study is depended on willingness, there is no payment to participants. However, monetary compensation will be offered as class fund for your child's class.

PARTICIPANT CONFIDENTIALITY

Your child's name will not be associated in any publication or presentation with the information collected about your child or with the research findings from this study. Instead, the researcher(s) will use a study number or a pseudonym rather than your child's name. Your child's identifiable information will not be shared unless (a) it is required by law or university policy, or (b) you give written permission.

Permission granted on this date to use and disclose your information remains in effect indefinitely. By signing this form, you give permission for the use and disclosure of your child's information, excluding your child's name, for purposes of this study at any time in the future.

REFUSAL TO SIGN CONSENT AND AUTHORIZATION

You are not required to sign this Consent and Authorization form and you may refuse to do so without affecting your right to any services you or your child are receiving or may receive from the University of Kansas or to participate in any programs or events of the University of Kansas. However, if you refuse to sign, your child cannot participate in this study.

CANCELLING THIS CONSENT AND AUTHORIZATION

You may withdraw your consent to have your child participate in this study at any time. You also have the right to cancel your permission to use and disclose information collected about you and your child, in writing, at any time, by sending your written request to: Chenglin Wu, 2300 Wakarusa Dr. Apt P-2 Lawrence, KS 66047.

If you cancel permission to use your information, the researchers will stop collecting additional information about you. However, the research team may use and disclose information that was gathered before they received your cancellation, as described above.

QUESTIONS ABOUT PARTICIPATION

Questions about procedures should be directed to the researcher listed at the end of this consent form.

PARTICIPANT CERTIFICATION:

I have read this Consent and Authorization form. I have had the opportunity to ask, and I have received answers to, any questions I had regarding the study. I understand that if I have any additional questions about my child's rights as a research participant, I may call (785) 864-7429, write to the Human Subjects Committee Lawrence Campus (HSCL), University of Kansas, 2385 Irving Hill Road, Lawrence, Kansas 66045-7568, or email irb@ku.edu.

I agree to allow my child to take part in this study as a research participant. By my signature I affirm that I am at least 18 years old and that I have received a copy of this Consent and Authorization form.

_______________________________ _____________________

Type/Print Participant's Name Date

____

Parent/Guardian Signature

Researcher Contact Information

Chenglin Wu

PhD candidate

University of Kansas

2300 Wakarusa Dr. Apt P-6

Lawrence, KS 66047

785-979-4229

Appendix C

Student Science Class Survey

Directions: Please read each item carefully and answer thoughtfully based on your experiences during the current school year. Remember that this is not a test, and there are no “right” or “wrong” answers. Thank you for your help.

About yourself:

1. Student ID Number: __________________

2. Are you: O Male O Female

3. What grade are you currently in? __________

4. How old are you? __________

5. Are you the single child in your family? O Yes O No

6. Which ethnic group do you belong to? O Han O Minority groups

7. What is your family annual household income (approximately)?

   - O Less than ¥12,000
   - O ¥12,000 - ¥50,000
   - O More than ¥50,000
   - O Unknown

About your class:

How often do you and other students take part in the following activities in your science class?
(Darken one circle on each line.)

	Never	Rarely (once each Semester)	Some-Times (once a month)	Often (once a week)	Always (everyday)
8. Describe what you know about a topic before it is taught……………….	○	○	○	○	○
9. Make presentations that help to learn science concepts………………….	○	○	○	○	○
10. Engage in hands-on science activities…………	○	○	○	○	○
11. Participate in discussions to deepen science understanding……….……...	○	○	○	○	○
12. Choose which questions to do or which ideas to discuss…………………………	○	○	○	○	○
13. Share ideas or solve problems with each other in small groups ………………………….	○	○	○	○	○
14. Read other (non-textbook) science-related materials in class…………………….	○	○	○	○	○
15. Work on problems related to real world or practical issues………………	○	○	○	○	○
16. Make hypothesis based on your prior experience and knowledge ……….	○	○	○	○	○
17. Design your own experiment/investigation………	○	○	○	○	○
18. Collect, organize, and analyze data…………………	○	○	○	○	○
19. Draw conclusions from experiment/investigation you have conducted...	○	○	○	○	○
20. Prepare written science reports………………………	○	○	○	○	○
21. Write reflections in a notebook or journal……………	○	○	○	○	○
22. Document and evaluate your own science work………	○	○	○	○	○
23. Think about what a problem means and different ways it might be solved……………………………………	○	○	○	○	○
24. Use calculators or computers to assist solving science problems………...	○	○	○	○	○
25. Receive computer-assisted instruction (For example: simulations, slide show) …………………………	○	○	○	○	○

Appendix D

学生科学课调查

使用说明：请根据您在本学年的经历仔细阅读并认真回答每项问题。请记住这并不是一次测验，并没有“正确”或“错误”答案。感谢您的帮助。

关于你自己：

1. 学生号：____________________

2. 性别：　　○ 男　　○ 女

3. 所在年级：____________

4. 年龄：____________

5. 是否独生子女　　○ 是　　○ 否

6. 民族　　○ 汉族　　○ 少数民族

7. 家庭年收入（大致）：

   ○ 少于 12,000 元

   ○ 12,000 - 50,000 元

   ○ 多于 50,000 元

   ○ 不知道

关于你的课程：

在你的科学课中，你和其他同学多久会参与一次以下的活动？

（每一行填涂一个圆圈）

		从不	很少 (一学期一次)	有时 (一月一次)	经常 (一周一次)	总是 (每天)
8.	在内容没被教授之前描述你对此所知道的………	○	○	○	○	○
9.	做演示报告来帮助学习科学概念…………………	○	○	○	○	○
10.	参与到动手的科学活动中…………………………	○	○	○	○	○
11.	参与讨论来加深科学理解……………................	○	○	○	○	○
12.	选择需要解决的的问题或者需要讨论的想法…….	○	○	○	○	○
13.	在小组中与别人一起分享想法或者解决问题 ……	○	○	○	○	○
14.	在课堂中阅读其它（非课本）关于科学的材料…	○	○	○	○	○
15.	解决现实世界的或者实际的问题…………………	○	○	○	○	○
16.	根据你之前的经历或者问题做出假设 …………..	○	○	○	○	○
17.	设计你自己的实验/调查………………………….	○	○	○	○	○
18.	收集整理并分析数据……………………………	○	○	○	○	○
19.	从你做的实验/调查中得出结论..........................	○	○	○	○	○
20.	准备并撰写科学报告……………………………..………………..	○	○	○	○	○
21.	在笔记本或日志中记录得到的反馈…………..	○	○	○	○	○
22.	整理并评估你自己的科学作业…………………	○	○	○	○	○
23.	思考问题的含义以及不同的解答方法…………	○	○	○	○	○
24.	使用计算器或电脑来帮助解决科学问题……….	○	○	○	○	○
25.	计算机辅助教学 (例如: 模拟, 演示文稿)………	○	○	○	○	○

Appendix E

Reformed Teaching Observation Protocol (RTOP)

Daiyo Sawada External Evaluator

Michael Piburn Internal Evaluator

and

Kathleen Falconer, Jeff Turley, Russell Benford and Irene Bloom
Evaluation Facilitation Group (EFG)

Technical Report No. IN00-1
Arizona Collaborative for Excellence in the Preparation of Teachers
Arizona State University

I. BACKGROUND INFORMATION

Name of teacher ____________________ Announced Observation? ____________________ (yes, no, or explain)

Location of class ____ (district, school, room)

Years of Teaching ____________________ Teaching Certification ____________________ (K-8 or 7-12)

Subject observed ____________________ Grade level ____________________

Observer ____________________ Date of observation ____________________

Start time ____________________ End time ____________________

II. CONTEXTUAL BACKGROUND AND ACTIVITIES

In the space provided below please give a brief description of the lesson observed, the classroom setting in which the lesson took place (space, seating arrangements, etc.), and any relevant details about the students (number, gender, ethnicity) and teacher that you think are important. Use diagrams if they seem appropriate.

Record here events which may help in documenting the ratings.

Time	Description of Events

III. LESSON DESIGN AND IMPLEMENTATION

		Never Occurred				Very Descriptive
1)	The instructional strategies and activities respected students' prior knowledge and the preconceptions inherent therein.	0	1	2	3	4
2)	The lesson was designed to engage students as members of a learning community.	0	1	2	3	4
3)	In this lesson, student exploration preceded formal presentation.	0	1	2	3	4
4)	This lesson encouraged students to seek and value alternative modes of investigation or of problem solving.	0	1	2	3	4
5)	The focus and direction of the lesson was often determined by ideas originating with students.	0	1	2	3	4

IV. CONTENT

Propositional knowledge

6)	The lesson involved fundamental concepts of the subject.	0	1	2	3	4
7)	The lesson promoted strongly coherent conceptual understanding.	0	1	2	3	4
8)	The teacher had a solid grasp of the subject matter content inherent in the lesson.	0	1	2	3	4
9)	Elements of abstraction (i.e., symbolic representations, theory building) were encouraged when it was important to do so.	0	1	2	3	4
10)	Connections with other content disciplines and/or real world phenomena were explored and valued.	0	1	2	3	4

Procedural Knowledge

11)	Students used a variety of means (models, drawings, graphs, concrete materials, manipulatives, etc.) to represent phenomena.	0	1	2	3	4
12)	Students made predictions, estimations and/or hypotheses and devised means for testing them.	0	1	2	3	4
13)	Students were actively engaged in thought-provoking activity that often involved the critical assessment of procedures.	0	1	2	3	4
14)	Students were reflective about their learning.	0	1	2	3	4
15)	Intellectual rigor, constructive criticism, and the challenging of ideas were valued.	0	1	2	3	4

Continue recording salient events here.

Time	Description of Events

V. CLASSROOM CULTURE

Communicative Interactions		Never Occurred				Very Descriptive
16)	Students were involved in the communication of their ideas to others using a variety of means and media.	0	1	2	3	4
17)	The teacher's questions triggered divergent modes of thinking.	0	1	2	3	4
18)	There was a high proportion of student talk and a significant amount of it occurred between and among students.	0	1	2	3	4
19)	Student questions and comments often determined the focus and direction of classroom discourse.	0	1	2	3	4
20)	There was a climate of respect for what others had to say.	0	1	2	3	4
Student/Teacher Relationships						
21)	Active participation of students was encouraged and valued.	0	1	2	3	4
22)	Students were encouraged to generate conjectures, alternative solution strategies, and ways of interpreting evidence.	0	1	2	3	4
23)	In general the teacher was patient with students.	0	1	2	3	4
24)	The teacher acted as a resource person, working to support and enhance student investigations.	0	1	2	3	4
25)	The metaphor "teacher as listener" was very characteristic of this classroom.	0	1	2	3	4

Additional comments you may wish to make about this lesson.

Appendix F

ORAL CONSENT

As a doctoral student in the University of Kansas's Department of Curriculum and Teaching, I, Chenglin Wu, am conducting a research project about the relationship between reformed teaching and student creative thinking. I would like to (ask you a few survey questions) (interview you) (ask you to be in a focus group) to obtain your views on current reform in science education. Your participation is expected to take about 30 minutes. You have no obligation to participate and you may discontinue your involvement at any time.

Your participation should cause no more discomfort than you would experience in your everyday life. Although participation may not benefit you directly, the information obtained from the study will help us gain a better understanding of the way to promote reform in science teaching and to improve students' creativity. Your identifiable information will not be shared unless (a) it is required by law or university policy, or (b) you give written permission.

**It is possible, however, with internet communications, that through intent or accident someone other than the intended recipient may hear your response.*

***This interview will be recorded. Recording is (not) required to participate. You may stop taping at any time. The recordings will be transcribed by me. Only I and my advisor will have access to recordings which will be stored in a locked cabinet and will be destroyed when the study is finished.*

Participation in the interview indicates your willingness to take part in this study and that you are at least 18 years old. Should you have any questions about this project or your participation in it you may ask me or my advisor, Dr. Huffman at the Department of Curriculum and Teaching. If you have any questions about your rights as a research participant, you may call the Human Subjects Protection Office at (785) 864-7429 or email irb@ku.edu.

Appendix G

Science Teacher Semi-Structured Interview

Name: _____________

Date of Interview: ______________ **Time:** from **__________** to **___________**

(PART 1) LEARNING THEORIES

1. What does "learning" mean to you?

(How will student acquire knowledge?)

2. Do you believe that students are capable to construct knowledge by themselves?

(Do you believe that students can learn new knowledge based on their prior knowledge and experience?)

3. Do you think in which way your student can learn best?

Learning environment, learning habit, Factors that will influence student learning etc.

(PART 2) SCIENCE EDUCATION REFORM

4. Please tell me what you know about current education reform in science.

Difference you found that between current one and former ones, new standards, and key components

5. Can you indicate that how this reform influences your teaching?

Determine your teaching habit? Change your teaching habit?

6. How do you apply reformed-based curriculum in your class?

Talk about Instruction and assessment

(PART 3) NATURE OF SCIENCE

7. In current science reform documents, nature of science is emphasized as an important element for science teaching and learning. Would you please explain that what is nature of science?

Define nature of science

8. Do you think it is necessary to include idea of nature of science into science teaching?

If necessary, please demonstrate the necessity.

If not, please explain the reason.

9. Do you introduce nature of science to your student? How?

If yes, describe the way you use

(PART 4) SCIENTIFIC INQUIRY

10. As I know (as you said) scientific inquiry is also a very important component in current science education reform. Can you tell me what does inquiry means to you?

Inquiry methods and inquiry itself

11. Why is inquiry important to science class?

Goals, objectives, and performances

12. How do you include inquiry in your class?

(What kind of activities you use or will use in your class? How often?)

13. How do you assess inquiry?

Informally: performance assessments, such as questions, observation, and group project

Formally: paper-pencil assessments, such as unit test, middle and final exam

14. Is there anything that interferes you to fully apply inquiry-based approach in your class?

External influence: school, policy, testing system, timing, budget….

Internal influence: personal emotion, attitude, and perspective towards change

15. Can you give out some suggestions to promote inquiry in science class?

For application: efficient resources and supports; classroom structure and setting

For preparation: teacher training program; teacher evaluating system

(PART 5) CREATIVITY

16. What does creativity means to you?

Concept and expression

17. Do you think creativity is important to students? Why?

From student learning & human development

18. Many people criticize that Chinese students are lack of creativity. People also blame this to the traditional education (idea and method) in China. Do you agree with them?

If yes, please explain why traditional education in China negatively influence students' creativity.

If no, please tell me what do you think is truly strangling Chinese students' creativity.

19. How do you foster students' creativity in your class?

(How do you motivate your student in science learning?)

Instructional strategies you use

20. Do you assess students' creative abilities?

If yes, how? If no, why?

(PART 6) CLOSING THE INTERVIEW

Thank you very much for your participation. Do you have any questions for me?

Appendix H

科学教师半结构式访谈

姓名: ______________

访谈日期: _______________ **时间:** 开始__________ 结束 ____________

（第一部分）学习理论

1. 对你来说 "学习" 的意思是什么?

（学生如何获得知识?）

2. 你相信学生能够自我构建知识吗？

（你相信学生有能力基于先前的知识和经验学习新的知识么？）

3. 你觉得学生如何才能最好的学习?

学习环境，学习习惯，影响学生学习的因素等等

（第二部分）科学教育改革

4. 请告诉我你关于目前科学教育改革的认识。

目前的改革与以往的改革的不同点，以及关键部分

5. 你能说明一下当前改革如何影响你的教学吗？

决定你的教学习惯？改变你的教学习惯？

6. 你如何在你的课堂上实现改革化的课程？

谈谈教学和评估

（第三部分）科学本质

7. 在当前的科学改革文件中，科学本质被强调为对于教学和学习的一个重要的元素。你能解释一下什么是科学本质吗？

定义科学本质

8. 你觉得在科学教学中加入科学本质这个理念是必要的吗？

如果必要，请叙述必要性。

如果不必要，请解释原因。

9. 你向学生介绍科学本质吗？如何介绍？

如果介绍的话，描述你用的方式

（第四部分）科学探究

10. 据我所知（据你所说）科学探究是当前科学教育改革中非常关键的部分。你能告诉我探究对于你来说意味着什么吗？

探究方法和探究本身

11. 为什么探究对于科学课十分重要？

目标，目的，以及表现

12. 你怎样将探究融入到你的课上呢？

（在你的课上，你正在使用或将要使用哪些教学活动？多久使用一次？）

13. 你如何测试探究？

非正式：对学生表现的测试， 比如问题，观察，以及小组项目

正式：纸笔测试，比如单元测试，期中和期末测试

14. 有什么是阻碍探究式教学的？

外在影响：学校，政策，考试系统，时间，预算……

内在影响：对于改变的个人情绪，态度，以及观点

15. 你能给出一些对于在科学课上促进探究的建议吗？

对于应用：充足的资源和支持；教室的结构和设置

对于准备：教师培训项目；教师评价体系

（第五部分）创造力

16. 创造力对于你来说是什么？

概念以及表现

17. 你觉得创造力对学生来说重要吗？为什么？

从学生学习以及人类发展来说

18. 很多人批评中学学生缺乏创造力。人们也把这归咎于中国传统的教育（理念和方式）。你同意这样的看法么？

如果同意，请说明传统教育对学生创造力负面影响的原因

如果不同意，请告诉我你觉得什么是真正扼杀中国学生创造力的原因

19. 在你的课上你如何培养学生的创造力？

(你如何激发学生学习科学的积极性?)

你所用的教学策略

20. 你测试学生的创造能力吗？

如果测试，请说明方式。如果不测试，请说明原因。

（第六部分）结束访谈

非常感谢你的参与。你还有什么问题需要问我吗？