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Comparing US and Chinese High-School Physics Teaching in Terms of the Use of Inquiry

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COMPARING U.S. AND CHINESE HIGH-SCHOOL PHYSICS TEACHING

IN TERMS OF THE USE OF INQUIRY

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By

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I HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER MY SUPERVISION BY Lingbo Qian ENTITLED Comparing US and Chinese High-School Physics Teaching in Terms of the Use of Inquiry BE ACCEPTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF Master of Science.

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ABSTRACT

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Inquiry based teaching has been widespread in the United States as well as in China in the last two decades. It was implemented by many teachers and shown to be effective in both countries. This study examines the extent to which inquiry-based teaching in high-school physics is practiced in US and China through the use of lesson observations and a survey. Nineteen lessons taught by 19 teachers (9 US and 10 Chinese) were observed (N=19). Results show that both US and Chinese teachers know well about the inquiry-based teaching. However, in practice, little inquiry-based teaching was observed in the two countries by different reasons: many of US physics lessons lack rigorous content, while many Chinese lessons failed to include student-centered instruction. Implications of the findings to improve teacher education in both countries are discussed.

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I. INTRODUCTION

Last decade saw an increased emphasis on the use of inquiry activities in science education in the United States. Many policy documents, curricular materials and programs were developed based on the idea that inquiry should be a guiding principle in K-12 science education (AAAS, 1994; National Research Council, 1996). In the National Science Education Standards (NSES), it is said: "Learning science is something that students do, not something that is done to them"(P20). NSES call for inquiry is central to science learning. When engaging in inquiry, students describe objects and events, ask questions, construct explanations, test those explanations against current scientific knowledge, and communicate their ideas to others. In this way, students actively develop their understanding of science by combining scientific knowledge with reasoning and critical thinking skills.

In the physics education community, new instructional strategies were proposed to adapt inquiry into classroom and to achieve higher levels of student conceptual understanding both at the high school level and college introductory physics level (Karen, 2008; Daniela, 2009; Mazur, 1997; Sokoloff 1997; Sokoloff 2001; Aubrecht, 2005). Peer instruction is one of such strategies proposed by Eric Mazur (Mazur, 1997) for college introductory physics course. By engaging in peer instruction, students made predictions about the questions, communicate their idea with peers, arranged their thoughts by discussing them, and finally test them. These are all the elements of the inquiry-based teaching (NRC, 1996). Mazur(1997) showed that this instructional strategy increased students' engagement in class. Mazur's study also showed that after discussion, the percentage of students who submitted the correct answer increased from 50% to 70%, and the percentage of students who were confident in answering to the question correctly increased from 12% to 47%. Peer instruction was also implemented successfully in high schools (Karen, 2008). In Karen's research, improvements in student understanding were made when the Peer Instruction method was used; with the test group showing a 40% normalized gain in comparison to a 24% gain achieved by the control group. Another example of an inquiry-based approach which is shown to be both effective and efficient is a series called Interactive Lecture Demonstrations (ILDs) by Sokoloff and Thornton (Sokoloff 1997; Sokoloff 2001). During the ILD students are asked to predict the result and draw a conclusion about the experiment that is presented in class. Their study shows that students' performance in the content knowledge test (Force and Motion Conceptual Evaluation [FMCE]) improved from less than 20% to around 80%. Resent study showed that inquiry-based instruction than other Peer Instruction and ILDs also had a statistically significant improvement on student conceptual understanding of physics compared to traditional ways of teaching both in high school and college introductory physics classes (Paul, 2006; Yeounsoo, 2006; Todd, 2010).

Compared to the United States, China has a short history of inquiry education. However, Department of Science Education puts a strong emphasis on it since the beginning of 21 century. In the high school National Physics Education Standards of China [NPES]

(People's Education Press， 2003), which is reformed in 2003, scientific inquiry is required as guidelines of learning and teaching. It's said in NPES "scientific inquiry is not only one of the objectives of learning but also the method of teaching" (P2). The aim for implementing scientific inquiry is to focus on inquiry processes of learning concepts instead of emphasizing acquisition and accumulation of knowledge; students are expected to actively construct knowledge instead of accepting content passively. In this way, students develop their understanding of science by combining scientific knowledge with reasoning and thinking skills. Incidentally, the Chinese Standards describe content of Chinese high-school physics that is not only compatible with the US high-school level but also extended to include college introductory physics level in US.

After NPES was published, a number of Chinese teachers and educators have been trying to translate the idea of scientific inquiry described in NPES into classroom practice. The new wave of literature in high school physics education recommends a number of ways to encourage students to find questions, inspire students design an experiment, and guide students for making conclusions (Zhang, 2002; Feng,2011; Han, 2011; Zhu, 2011; Chen, 2011). Also research results showed statistically that the inquiry-based teaching improves students' performance on conceptual understanding (Pan, 2011). The results of Pan's experimental research design showed that by implementing inquiry-based teaching for half year, the test group increased the scores from 70 to 86.1, which shows a larger gain compared to the control group with the scores changing from70.5 to 71.

From the above, we can see that inquiry-based teaching is highly supported by researchers and policy makers; also it has been shown to be effective, especially on students' conceptual learning. However, in US, despite the positive effect on student achievement, survey results by Withee (2005) indicated that physics teachers of high school don't feel that the inquiry-based teaching methods are comprehensive enough to be used in different situations, such as different requirements for the courses, different levels of students, and even different number of students. A teacher in Thomas's survey complained that:"I personally don't feel that any one of [the inquiry-based methods] is comprehensive enough in all situations." Another study (Sadaghiani, 2008) showed that students in college introductory physics courses did not appreciate the self-discovery aspect of the inquiry approach and characterized the inquiry learning process as difficult and unpleasant. One of the students in Sadaghiani's research complained that" I think that not all of the class should be learning by inquiry and that we need a good portion of lecture. People learn in different ways and I need some lecture and teacher explanation, not my blind ideas going into an exercise."

Difficulty of implementing inquired-based teaching is also happening in China in high school (Yang, 2011; Wang, 2011; Zhu, 2011). It is claimed that inquiry-based teaching is time consuming and its effects would not show up quickly. It seems high school students do not appreciate the benefit of conducting investigations and they complain the longer time they have to spend on investigations. One of the reasons of the unpopularity of inquiry-based learning in China may be the fact that students have to face a very competitive college entrance exam; each year only about 10% of students could go to college. In order to get a good grade on the exam, problem solving skill is highly valued and strongly emphasized in high-school physics classes in China. This situation presents a big obstacle when teachers want to implement inquiry-based teaching. In addition, some research studies (Wang, 2011; Zhu, 2011) described that Chinese high-school physics teachers have the following difficulties when they want to implement inquiry-based teaching: a) teachers cannot control the time very well, which causes the inquiry process too long and tedious; b) teachers let the students do the experiments on their own, which tends to make student get lost during the process; and c) teachers ask lots of questions as a part of inquiry-based teaching, which keeps students too busy in answering to questions and gets few things done in the class.

In summary, scientific inquiry is highly emphasized in education in both US and China. Educators and teachers from these two countries talk about the importance of inquiry-based instruction, and they made great efforts in developing inquiry-based teaching methods (Karen, 2008; Daniela, 2009; Han, 2011; Zhu, 2011). Furthermore, some researches (Todd, 2010; Takahashi 2009; Pan, 2011) showed that inquiry-based teaching has a statistically improvement on student's conceptual learning. However, in classroom practices, teachers and students in both countries are complaining about the inquiry-based teaching approach (Withee, 2005; Sadaghiani, 2008; Yang, 2011; Wang, 2011; Zhu, 2011). The problem this paper addresses is these complaints about inquiry-based teaching in physics education in USA and China. China is different from US in many respects. Since high-school physics education communities in both of these two countries are facing problems of implementing inquiry-based teaching, it would be interesting to compare the situation to see if we would be able to gain insight in the picture of physics education for both countries. The question naturally arises is whether there are ways to solve the problems that teachers of these two countries are complaining during implementation. It would be necessary first to see what extent to which inquiry-based teaching is taking place in these two countries. We also want to ask what alternative ways of teaching inquiry-based physics lessons are available in both of the countries.

PURPOSE OF THE STUDY

The purpose of the study is to gain insight into the problem of how to improve inquiry-based teaching in high-school physics by comparing US high-school physics teachers' thoughts and practices in terms of inquiry-based teaching with those of Chinese teachers. By understanding what high-school physics teachers are actually thinking about and practicing inquiry-based teaching, it may be possible to better understand teachers' and students' complaints from teachers' point of view. Moreover, by understanding the connections between teachers' thoughts and practice, it may be possible to find out what needs to be done to improve inquiry-based teaching in the US and China.

A cross-cultural comparison offers a potential for providing effective tools to analyze inquiry-based teaching in each country regardless of the difference within (Stigler， 1999; Diane, 2002). Teaching is a cultural activity; looking across cultures is one of the best ways to see beyond the blinders and sharpen our view of ourselves (Stigler，1999). Moreover, differences in pedagogical flow, such as assumptions about learning, the status of teachers, high levels of commitment from parents and children, amount of time spent in school, reflect differences in the ways in which physics is taught in different countries(Diane, 2001). By conducting a cross-cultural study, it is expected that the problems for inquiry-based teaching can be more clearly identified in both US and China.

Based on this expectation, the following research questions are put forward:

1. What are American high-school physics teachers' thoughts and practices in terms of inquiry-based approach?

2. What are Chinese high-school physics teachers' thoughts and practices in terms of inquiry-based approach?

3. What are the differences and similarities between US lessons and Chinese lessons in terms of the use of inquiry in teaching high school physics?

This study will take a closer look at US and Chinese physics teaching. Teachers' thoughts about the use of inquiry will be measured through a survey instrument, and the practice will be examined through classroom observations.

SIGNIFICANCE OF THE STUDY

Can Chinese teachers suggest some strategies for inquiry-based teaching to US teachers or vise versa? This study informs physics teachers in the United States and China how teachers of these two counties think about and practice inquiry-based teaching similarly and differently. By comparing US and Chinese teachers in terms of their thoughts and practice of the use of inquiry, the study reveals what is taken for granted as inquiry-based teaching in each place. This study further provides US and Chinese high-school physics teachers with alternative ways of teaching physics through inquiry.

Further, teaching is different in different culture (Stigler, 1999; Diane, 2002). Lots of studies about inquiry-based teaching in the United States have been conducted (Karen, 2008; Daniela, 2009; Aubrecht, 2006). A number of studies about inquiry-based teaching in China have also been conducted (Chen, 2011; Miao, 2011; Feng, 2011). However, no cross-cultural study that focuses on the use of inquiry on the two countries has been conducted. By understanding Chinese physics teaching in comparison with American teaching, it may be possible to suggest a different point of view of inquiry-based teaching in these two countries. Furthermore, Chinese education is generally thought to produce highly trained workers. It is thought to be more uniform and task-driven, whereas American education is more individualized and values creativity. It is of great interest to compare physics education between these two very different countries (Zhao, 2012).

II LITERATURE REVIEW

DEFINITION OF INQUIRY-BASED TEACHING IN THE UNITED STATE

In National Science Education Standards (NSES) (NRC, 1996), it is said "Scientific inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work"(P23). When it refers to learning, NSES define that inquiry is "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"(P23). It can be seen that inquiry is referred to as a way of knowing how scientists work and how they find the explanations of their work about our natural world. We can envision that the content we learn in our textbooks about science is the accumulation of the scientists' work. When referred to learning, inquiry is regarded as a process through which students need to learn the content. When learning some new content, it is most recommended that students go through the steps of understanding natural phenomena as scientists would do.

More specifically, NSES (NRC, 1996) describe that: " inquiry is a multifaceted activity that involves several steps such as making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results"(P23). This description defines the specific steps students should do for inquiry learning. This approach calls for students' active participation in the development of scientific knowledge, and teacher plays a role as a facilitator. In inquiry-based teaching, it is the students who construct the knowledge and the lessons are the places where students are provided with opportunities for their own learning of scientific knowledge.

INSTRUCTIONAL STRATEGIES THAT AMERICAN PHYSICS TEACHERS USE IN TERMS OF SCIENTIFIC INQUIRY

One of the assumptions on which the NSES (NRC, 1996) for science teaching are grounded is the notion that "What students learn is greatly influenced by how they are taught"(P28). The decisions about content and activities that teachers make about teaching affect the knowledge that students develop. Teachers' instruction and the selection of assessments also affect the understanding and abilities that students develop. The habits of mind that teachers demonstrate and nurture among their students wittingly and unwittingly affect the attitudes that students develop (NRC, 1996). Science teaching is a complex activity and teachers play an important role in shaping the actual situation in science education.

As one of the fields in science, physics education community experienced a surge of popularity to new ways of achieving higher levels of student conceptual understanding through inquiry approach (Karen, 2008; Daniela, 2009; Mazur, 1997; Sokoloff 1997; Sokoloff 2001; Aubrecht, 2005). Educators and teachers proposed new instructional strategies to adapt inquiry into classroom both at the high school level and college introductory physics level. Some of the instructional strategies and their effects are described in the following sections to show the variety of the approaches. Although the focus of this research study is on inquiry-based teaching in general, the instructional strategies developed in physics education research community in the US demonstrate how traditional ways of teaching physics would need to be changed. It would be worth describing these strategies in a little more detail in order to illustrate the magnitude of the movement toward inquiry-based teaching in physics education research community in US.

Peer instruction is one of the inquiry-based teaching strategies for college introductory physics (Mazur, 1997). Peer Institution helps students in their own learning during lecture and focuses their attention on underlying concepts. Lectures are interspersed with conceptual questions, called *ConcepTests.* They are challenging multiple-choice questions about the material just covered in the class. They are designed to expose students to common difficulties in understanding the material. The students are given one to two minutes to think about the question and formulate their own answers; then students answer the questions at their seats by either holding up a colored card showing their answer or by using a device that collects and displays the collective response on a projection screen. After checking the answer, they then spend two to three minutes discussing their answers in groups of three to four, attempting to reach consensus on the correct answer. This process helps students think through the arguments being developed, and enables them to assess their understanding of the concepts before they leave the classroom. Peer Instruction actively engages students in their own learning. When discussing with the concept questions, students have the opportunity to make sense of the physical concepts and correct their misunderstanding of the material they may have. Peer Instruction also provides students with a chance to present their own idea, and confidence about what they have constructed. In this process, students have opportunities to learn the key ideas of physics from one another.

Karen (2008) showed that Peer Instruction (PI) was implemented successfully in a high school (Karen, 2008). Ten separate classes of students attending algebra-based, introductory physics courses at a suburban high school and five different instructors participated in Karen's research. In the study, five groups of students received the traditional instruction and five groups of students received Peer Instruction. The content area was an introduction to forces and motion (Newton's laws). Force Concept Inventory (FCI) (David, 1992) was used in order to measure students' achievement through pre- and post-tests. Gains in conceptual understanding were reported as a normalized gain <g>, based on the percentage of correct pre- and post-test average scores. It was shown that improvements in student understanding were observed when the Peer Instruction method was used in physics; while the test group showed a 40% normalized gain, the control group showed 24% normalized gain. Another research about Peer Instruction was conducted by Fagen (Fagen, 2002). He created a survey to asked instructors, who were using Peer Instruction, about students' conceptual learning. 384 instructors in colleges and high schools, most of them in physics, responded to the survey. As a result, more than 108 PI users responded to the survey on the effectiveness of PI. In addition, instructors at 11 colleges and universities provided matched sets of pre- and post-test results on FCI. From these data the researchers determined the average normalized gain and it showed that PI courses had a class average gain of 0.39 ±0.09, which falls in the "medium-g" range between 0.3 and 0.7. The "medium-g" was defined by Hake (Hake, 1998) to indicate the medium size effect on the effectiveness of instruction, and in Hake's research none of the traditionally taught courses showed gains in this range. From these research studies, Peer Instruction was shown to have some positives effects on students' learning. However Peer Instruction only accounts for the increase of the interaction between students. There are other important elements in inquiry-based teaching. One of the important elements is to incorporate empirical observations as evidence. This element was well developed in the instructional model called Interactive Lecture Demonstrations (ILDs) which will be explained in the next section.

ILDs have been co-developed by Ron Thornton at Tufts University and David Sokoloff of the University of Oregon (Sokoloff, 1997). These demonstrations focus on fundamental conceptual issues and take up a few lecture periods during a semester. A typical ILD is structured as follows: 1) Professor describes the experiment, or carries it out without recording data; 2) Students record their predictions on the outcome of the experiment on a Prediction Sheet; 3) Peer discussion follows, with the students discussing their predictions in small groups; 4) Professor engages class, soliciting predictions and highlighting common predictions; 5) Students record their final prediction on the Prediction Sheet; 6) The experiment is run. Real data is collected and plotted by the computer, with the results displayed graphically for all to see; 7) Professor engages class, discussing what students say about their predictions and focusing in particular on any common misconceptions. Students record the results on a Results Sheet, which they keep; 8) Professor discusses variations of the experiment and similar physical situations based on the same underlying concepts. By participating in all of the 8 steps, students would be able to develop their own understanding of the phenomena by making a prediction about the experiment, discussing their thoughts with peers, testing their prediction, and finally making a conclusion based on an empirical result.

Sokoloff (Sokoloff, 1997) studied student understanding of dynamics in a traditional course and compared the results with those obtained in a course with ILDs. 200 students in a non-calculus-based general physics lecture course participated in the research. Students met 2 times a week. The class was separated in 4 sections, two of them have traditional instruction as a control group, the other two having ILDs as a test group. The results showed 10% of the students understood the concept before instruction. This rose to about 20% after instruction in a traditional lecture course, compared with at least 80% in a course involving ILDs. Catherine (Crouch, 2004) performed a study in a 133-student introductory physics course for premedical students. A series of seven demonstrations were presented during the class meeting on the test group for12 weeks, while the control group met at the same time by having traditional lecture. As the result of his implementation of ILDs, he stated that "Learning is enhanced, however by increasing student engagement; students who predict the demonstration outcome before seeing it, however, display significantly greater understanding." Also results showed that the average percentage of correct responses increased from 61% with no demo group to 82% with interactive demo group. ILDS demonstrated positive effects on students' learning, but this instructional strategy pays attention on students' performance only during the class time. Just-In-Time Teaching (JiTT) examines students' thoughts before they come into the class.

Original module of JiTT was developed by Laura Guertin, Carol Ormand, Gregor Novak, and Andy Gavrin at Indiana University-Purdue University Indianapolis (*Gregor* 1999). Just-in-Time Teaching focuses on improving student learning through the use of brief web-based questions (JiTT exercises) delivered before a class meeting. The components of the process are as follows: 1) before each lecture, carefully chosen WarmUp questions are assigned and made available on the web. The questions concern a topic that has not yet been considered in class and that will be addressed in the lecture and class discussions and activities. 2) Students are expected to do the reading and consider the questions carefully, providing their best answers. They are graded for effort, not correctness. The student responses are due a few hours before class. 3) The instructor looks at the student response before lecture, estimates the frequency of the different responses, and selects certain responses to put on transparencies and include them as part of the in-class discussion and activities. 4) The class discussion and activities are built around the WarmUp questions and student responses. 5) At the end of a topic, a tricky question known as puzzle is put on the web for students to answer. With this method, students use their prior knowledge to solve the problem before class. Their thoughts are discussed and the correct way of understanding the problem is presented by teacher in class, and their understanding is tested by the puzzle after class.

To measure the effect of JiTT on student's learning and understanding of concepts, a research study was conducted by Sarah (Formica, 2010) with 222 students in introductory physics courses, which focused on Newtonian concepts. The Force Concept Inventory (FCI) was used to determine if students' beliefs about Newtonian mechanics were transformed from Aristotelian beliefs to Newtonian thinking (using Newtonian's theory, which means Newton's three laws of motion, to explain the problem instead of Aristotelian's beliefs, which believe that motion continues so long as there is only an applied force to an object). The results showed that the JiTT group had a gain of 37.6%± 2.0% while the Non-JiTT group had a gain of 17.9% ±2.5%. The results indicated that the JiTT teaching method enabled students to better understand Newtonian concepts and compel them to eradicate many of their Aristotelian beliefs. Also when the researchers studied further to check how students answered the questions in a particular group of concept-related questions, they found that 32% of the students in JiTT group were able to transform into Newtonian thinkers, while only 6.5% of the students in Non-JiTT group learned to think from a Newtonian perspective on the questions.

All of the instructional strategies mentioned above are implemented in lecture-type classes where only one instructor helps students to learn. It would be hard to pay attention on individuals. Tutorials in Physics that will be explained next are an instructional strategy that uses tutors to help students on an individual basis.

Tutorials in Introductory Physics were developed at the University of Washington, Seattle, Washington, by McDermott, Shaffer, and the Physics Education Research Group (McDermott, 2002) to provide a structure that promotes active mental engagement of students in the process of learning physics. The tutorials comprise an integrated system of pretests, worksheets, and homework assignments. The tutorial sequence begins with a pretest. These are usually on material already presented in lecture but not yet covered in tutorial. The pretests help students identify what they do and do not understand about the material and what they are expected to learn in the upcoming tutorial. They also inform the instructors about the level of student understanding. During a tutorial session, students work together on worksheets that provide the structure for these sessions. The worksheets consist of carefully sequenced tasks and questions. The questions here were chosen based on findings on students' common misunderstanding of physical concepts, and the questions were designed in such a way that they can guide students through the reasoning necessary to construct concepts and to apply them in real-world situations. Students are expected to construct physics knowledge for themselves through discussions with their classmates and with tutorial instructors. The tutorial instructors do not lecture but ask questions that are designed to help students find their own answers. The tutorial homework reinforces and extends what is covered in the worksheets. For the tutorials to be most effective, it is important that course examinations include qualitative questions that emphasize the concepts and reasoning skills developed in the tutorials.

A research study for implementing tutorials in an introductory physics course was conducted at United States Air Force Academy by Mauk (Mauk, 2005). They used the tutorials to teach induced current and magnetic force. Four instructors participated in the study. Each of them taught a section with approximately 20 students. The researchers also set a control group with the same instructors and around the same number of students to compare the results. For those who had the tutorials, the correct responses to four relevant questions were obtained from 60.9%, 66.5%, 56.7%, and 27.4% of students respectively for each of the questions, while 35.9%, 50.2%, 46.5%, and 14.7% of students in the control group had the correct answers. These results indicate that tutorials provided students with a better opportunity for acquiring the concepts. In addition, the researchers showed that the students in the control group more frequently failed to write an explanation for their answers. This result may indicate that the tutorial students were more comfortable with the language of physics and demonstrated growth in writing about physics.

PROBLEMS FOR IMPLEMENTING INQUIRY-BASED TEACHING IN THE UNITED STATE

Although results indicated that inquiry-based teaching approach have some positive effects on student achievement, teachers express their complaints about inquiry-based teaching. A survey was administered by Withee (Withee, 2005) to five science and math educators at Southern Illinois University Edwardsville. The survey examined three major themes: views on conceptual change, views on inquiry, and inquiry in practice. Survey data showed that the educators have similar answers to the first theme, in which all the instructors agreed that conceptual change include four steps: 1) There must be dissatisfaction with existing concepts; 2) A new concept must be intelligible; 3) A new concept must be initially plausible; 4) A new concept should suggest further exploration. Survey data also showed that have two kinds of view about the second theme: inquiry by discovery and inquiry by accommodation respectively. Accommodation here means conceptual change; it includes four conditions: a) dissatisfaction with existing concepts, b) the new concept must be intelligible, c) the new concept must be initially plausible, and d) the new concept should suggest further exploration. However when referring to the practice, the results indicated that the educators didn't feel that the inquiry-based teaching approach are comprehensive enough to use in all situations, which means that when teaching in a specific situation, teachers feel it difficult to follow the inquiry-based teaching approach. One instructor stated "I personally don't feel that any one of [the inquiry-based approach] is comprehensive enough to use in all situations." It seems that there are many uncertain factors when implementing the inquiry-based teaching approach in the classroom even though the educator comprehends the theory of inquiry well.

Another study was implemented by Sadaghiani in college introductory physics course (Sadaghiani, 2008), The course focused on the topics of *Properties of Matter* and *Heat & Temperature* using the *Physics by Inquiry* textbook. There were 15 students in the class. A three-item open-ended assessment tool was administered on the fourth week of the quarter in order to gain understanding on the students' experience. The items were asking: (1) what is helping you learn the material in this class; (2) what makes learning hard in this class; and, (3) what other suggestions you have in order to improve your experience in this class. Some of the students' responses follow:

> */ think that not all of the classes should be learning by inquiry and that we need a good portion of lecture. People learn in different ways and I need some lecture and teacher explanation, not my blind ideas going into an exercise* (Sadaghiani, 2008).
>
> *Not lecturing before we start the experiments makes it hard to understand what it is we are supposed to be finding* (Sadaghiani, 2008).
>
> *The things make learning hard is that the teacher doesn't lecture, also if the concepts of what we are learning are not demonstrated to me prior to doing the section, it is a lot harder* (Sadaghiani, 2008).

Students collectively suggested that they *"need more lectures"* and that the instructor should tell them *"what they need to know."* The findings indicate that there are students who do not like the self-discovery aspect of the inquiry-based curriculum. This finding was based on qualitative research. However, it still shows that there were problems for implementing inquiry-based teaching in classroom.

SUMMARY OF INQUIRY-BASED TEACHING IN THE UINTED STATE

In US, NSES give us the definition of scientific inquiry and highly recommend it in science education. Based on the strong emphasis on implementing inquiry in classroom, educators and teachers developed new teaching strategies in physics education (Mazur, 1997; Sokoloff, 1997; Novak 1999; McDermott, 2002). Furthermore, research studies showed that these inquiry-based teaching strategies improve student's conceptual learning comparing to traditional ways of teaching physics (Karen, 2008; Fagen, 2002; Sokoloff, 1997; Crouch, 2004; Formica, 2010; Mauk, 2005). However despite the positive effect, the literature suggests that both teachers and students express some problems during classroom practices (Withee, 2005; Sadaghiani, 2008).

DEFINITION OF INQUIRY-BASED TEACHING IN CHINA

In the National High school Physics Education Standards of China [NPES] (People's Education Press，2003), which was reformed in 2003, scientific inquiry is required to be included in lessons as guidelines of learning and teaching. It’s said in NPES “scientific inquiry is not only one of the objectives of learning but also the method of teaching.” The NPES describe scientific inquiry with six elements:

1）Identifying questions: it asks students to be able to find questions about physics from natural phenomenon in daily life and experiment; present the question by verbal and written forms; understand the scientific meaning of finding and asking questions.

2）Making predictions: it requires students be able to propose predictions based on their experience and prior knowledge; speculate the direction of inquiry and possible result of the experiment; understand the importance of making predictions.

3）Designing investigation: it requires students be able to experience the process of designing an experiment based on what is available; consider factors that affect the results and control variables; understand the function of designing investigation.

4）Conducting an experiment and collecting data: it requires students be able to get data by observing and doing an experiment; collect information from public resources; operate some common equipment and get the right data; understand the importance of conducting an experiment and collecting data.

5）Analyzing and formulating the experiment: it requires students be able to estimate the usefulness of the data; compare the data and information; conclude scientific principle from physics phenomenon and experiment；explain and describe results of the experiment; understand that analysis and formulation of experimental results is the necessary step of scientific inquiry.

6）Communicating and collaboration: it requires students be able to write an experiment report; present opinion accurately; insist the principle and respect others; have group spirit; understand the importance of communication and collaboration.

From the descriptions in the Standards, it becomes evident that physics education in China calls for inquiry-based teaching with a similar approach to the United State. The NPES’s six steps: identifying questions, making predictions, designing investigation, conducting experiment and collecting data, analyzing and formulating the experiment, communicating and collaboration, are all covered in the NSES in United State (NRC, 1996). So inquiry-based teaching is also highly recommended in Chinese high-school physics education.

INSTRUCTIONAL STRATEGIES THAT CHINESE PHYSICS TEACHERS USE IN TERMS OF SCIENTIFIC INQUIRY

After the NPES was reformed, teachers and educators realized the importance of scientific inquiry. In the physics education community, a new wave of ideas of implementing scientific inquiry has been tried by teachers and educators (Zhang, 2002; Feng, 2011; Han, 2011; Zhu, 2011; Chen, 2011). Unlike the physics educators in the United State, teachers and educators in China did not propose some specific instructional strategies based on inquiry, but they put forward a series of suggestions on inquiry-based teaching.

Based on his own teaching experience, Feng (2011) argue that inquiry-based teaching is a new teaching approach that needs to respect students' personality, to inspire students' enthusiasm for learning, and to encourage students to take part in autonomous learning activity with multiple methods. In order to implement this new approach, he proposed four conditions: (a) the environment of inquiry should be liberal and democratic; (b) the question of inquiry should be connected to real life; (c) the content of inquiry should be chosen carefully; (d) the result of inquiry should be open and resilient. These four elements proposed by Feng are consistent with the idea of scientific inquiry in China and drawn from the situation in China.

A number of teachers proposed more specific steps of inquiry-based teaching (Zhu, 2011; Chen, 2011; Miao, 2011; Han, 2011). Zhu states that the first step is to create a circumstance, in which students are able to find questions, ask questions, and enjoy learning physics (Zhu, 2011). Same argument can be found in other studies (Chen, 2011; Miao, 2011). Chen and Miao argue that how to provide the circumstance is an important part of inquiry-based teaching. They also argue that teachers should guide students to ask questions so that teachers can lead students to gain the knowledge on the content. Next step is to use experiments which include both experimental demonstrations by teacher and hands-on experiments by students (Chen, 2011). It was argued that every physics concept is built on experiments and letting students experience the process of finding a physics concept can raise the enthusiasm to learn and help students understand the concept more effectively (Miao, 2011). Third, in the traditional teaching method, teacher typically provides all the information, tells the conclusion, and asks students to remember it. Instead, during inquiry-based teaching, Miao (2011) recommends, teacher should guide students to use different ways of figuring out the question and use multiple representations to explain what they found. Teacher can ask questions like "how" and "why" to lead students to gain the content knowledge that they are supposed to learn in class (Zhu, 2011). In the last step, cooperation and communication among students are emphasized strongly in scientific inquiry. During this phase, students learn how to explain their own thoughts precisely and learn to listen to others (Miao, 2011). This also helps students learn the content with different points of view (Zhu, 2011; Han, 2011).

From the steps Chinese teachers and educators suggest, it could be concluded that when implementing inquiry-based teaching, teacher acts as a facilitator; they guide students to explore the knowledge and encourage them to grasp the concept by themselves. They also should let students think, conclude, and communicate. Raising the level of enthusiasm of learning physics and acquiring the knowledge through scientific inquiry is also important.

Compare to US, there are only few papers that talk about the results of implementing inquiry-based teaching (Pan, 2011). In Pan's study, there were ten high school physics classes in China taught by five different teachers. It was conducted for half year. Before the study, the teachers were trained for the inquiry-based teaching approach, such as the main elements of the notion and some suggestion of inquiry-based teaching. In the study, five classes were taught by inquiry-based teaching, and five classed taught by traditional instruction. Each of the classes had approximately 40 students. Pre-test results showed that there was no statistically significant difference between the test classes and control classes. However, after a half year of implementation, the post-test showed that the percentage of students who were interested in learning physics increased to 81% comparing to 42.6% in the control classes . In addition, the regular final test in the high school showed that the average score of the experiment groups that had inquiry-based teaching in Pan’s research increased from 70 to 86.1, while the control group showed little change from 70.5 to 71.4. Pan’s research showed effectiveness of scientific inquiry during the classroom practices in China.

PROBLEMS FOR IMPLEMENTING INQUIRY-BASED APPROACH IN CHINA

Compared to the United States, China has a large population. Colleges cannot accept all the high school students. Actually only around 10% of students can be admitted to colleges, and the only criteria for the college admission is the scores on the college entrance exams that high school students take after three years' of study. It is a keen competition. In order to earn a high score on the exam, not just students but also parents, teachers, and even administrators pay a lot of attention on problem solving skills. Students are generally more concerned with getting a good grade on the college entrance exam instead of cultivating their own scientific literacy skills and knowledge. A teacher who could help students improve problem solving skill is considered to be a good teacher. Inquiry-based teaching asks students to grasp the knowledge by themselves (NPES), which needs time and students' vitality to experience the process of learning. However the college entrance exam requires lots of time and effort on students for training problem solving skill, which becomes an obstacle for teachers to implement inquiry-based teaching.

On the other hand, when teachers are implementing inquiry-based teaching, there are some problems in high-school physics classes (Yang, 2011; Zhu, 2011; Jia, 2011; Wang, 2011) all these authors did not show evidence of problems, but they made some arguments based on their experiences. Yang said in his article that lots of people including teachers and students consider scientific inquiry as a very hard method that not everyone can achieve, and that this kind of thoughts at first diminish the self-confidence of teaching or learning of scientific inquiry. Wang (2011) and Zhu (2011) independently concluded that some of the following problems happened during the practices of scientific inquiry: (1) Teachers sometimes exaggerate the advantages of scientific inquiry too much, and ask students to conduct inquiry activities completely by themselves. It often happens that students don't have the abilities to complete the whole process and achieve the goals at the appropriate level. As the result, the class becomes tedious and students get lost in what they were doing (Wang, 2011). (2) Some teachers think that asking questions is a good way of inquiry-based teaching. Asking questions is for teachers to guide students to follow the inquiry steps and construct the knowledge required on the curriculum. However, some teachers consider that asking lots of questions is an inquiry-based teaching approach, and no conceptual development and logic present behead the questions. It turned out that students are just busy with answering the questions and do not have a chance to build the concept. (Zhu, 2011; Wang, 2011). (3) Some teachers think that experiments are the key part of scientific inquiry, but instead of letting students to generate predictions and design the steps of the experiment, teachers just told them what to do and what is expected. This is not inquiry. What's more, some teachers consider multimedia presentation could replace hands-on experiments, so they show a lot of videos and consider their methods as inquiry-based teaching. These teachers expect that students can make a progress on learning by just looking at experiment performed by teacher or showed in videos (Zhu, 2011). From the obstacle these papers described, it seems that many of Chinese teachers lack full understanding of inquiry-based teaching; they usually emphasize one aspect in the classroom, and consider that they were doing inquiry-based teaching. However it always turned out to be no effective.

SUMMARY OF INQUIRY-BASED TEACHING IN CHINA

Compare to the United State, China has a short history of inquiry-based education, but Department of Science Education puts a high emphasis on it. Lots of teachers and educators have been trying to translate the idea of scientific inquiry described in NPES into classroom practice (Zhang, 2002; Feng, 2011; Han, 2011; Zhu, 2011; Chen, 2011). Also some research results show that the inquiry-based teaching improve Chinese students' performance on conceptual understanding (Pan, 2011). However, with high pressure of college entrance exam, and lack of profound and full-scale understanding of inquiry-based teaching, it has been indicated that teachers do not implement inquiry-based teaching in an effective way (Yang, 2011; Wang, 2011; Zhu, 2011).

CROSS-CULTURAL COMPARISONS

Cross-Cultural comparison studies, such as Trends in International Mathematics and Science Study [TIMSS] (NCES, 2006), have played an important role in identifying critical factors impacting student achievement and in improving education system and teaching instruction.

Teaching is a cultural activity

Stigler and Hiebert (Stigler，1999) argue in their book, "The Teaching Gap" that "people within a culture share a mental picture of what teaching is like"(P86). If we define this mental picture as a script, then "one of reasons classrooms run as smoothly as they do is that students and teachers have the same script in their heads: they know what to expect and what roles to play"(P87). So it can be said that teaching, like other cultural activities, is learned through informal participation in classroom activities over long periods of time. It is something one learns to do more by growing up in a culture than by studying it formally.

In Diane and Edgar's book "Learning from others" (2001), they argue that "different ways of engaging students with subject matter have evolved in different countries" (P146). They further explain that these differences as: "the emphasis and focus of lessons, the kinds of explanation given to students, the attempts to relate abstract subject matter to students' everyday experience, the degree of responsibility given to students to develop and monitor their own learning, the cognitive demands made of seemingly comparable groups of students and the ways in which concepts are introduced, developed and linked to others" (P146). The social and cultural features for each individual country are different, such as assumptions about learning, the status of teachers, the levels of commitment in education from parents and children, amount of time spent in school and so on. All of these differences strongly affect teaching activities. So teaching is a cultural activity (Stigler，1999).

Benefit of cross-cultural comparison

Scientific theories are universal. The theories and laws of physics in China are the same in the United State or elsewhere in the world. Despite the differences of teaching in different cultural, knowledge gained from studying the natural world in one country should be applicable in another country. Regardless of the cultural context, there should be common knowledge that physics teachers need to have in order to teach a class successfully through inquiry.

Stigler and Hiebert (Stigler，1999) argues in their book that "We often are blind to the most familiar aspects of our everyday environment, and teaching turns out to be one of these aspects. Looking across cultures is one of the best ways to see beyond the blinders and sharpen our view of ourselves (Px)". They implemented a cross-cultural comparison based on the videotaped lessons and questionnaire responses from teachers of eighth-grade mathematics. The videotapes include 100 lessons in Germany, 50 lessons in United State and 81 lessons in Japan. After the study they said in their book "we were amazed at how much teaching varied across cultures and how little it varied within cultures" (P11). In addition, they made some proposal to improve American education by comparing with Germany and Japan, such as “we must take a long-term view when we design initiatives for improving teaching" (P133). "Recruiting highly qualified teachers will not result in steady improvement as long as they continue to use the same scripts. It is the script that must be improved"(P134). John (2008) conducted a comparison of curricular breadth, depth, recurrence, and physics achievement of three countries by analyzing the data from the 1995 administration of TIMSS. His research showed that "Depth of curriculum is the only curricular variable that is closely related to physics achievement, so the U.S. Physics curriculum should add depth". These two studies suggest that cross-culture comparison offer a valuable opportunity to review critically one's own practices in the light of the wider international picture.

Obstacle for cross-cultural comparison

Conducting a cross-cultural comparison is not problem-free at all. As Diane and Edgar argued in their book (2001) that in international studies " Some of these difficulties, such as the high cost of international studies and the different ages at which pupils start formal schooling, can be overcome, or at the least be minimized, by adequate resourcing and research design. Others, such as ethnic, linguistic or other types of bias in test instruments or agreement about the variables between which correlations are to be sought, are both more subtle and more problematic"(P138). So a research study conducted in two countries certainly presents more technical challenges than conducting a research study in one country. For example，China and US use different languages. All the written materials have to be translated back and forth between Chinese and English. Furthermore the translation itself, whenever data are translated from Chinese to English or from English to Chinese, would include the risk of losing meanings contained in the document in the original language. Language barriers make the measurement across the culture particularly difficult. Appropriate precautions, such as paying attention on the meaning of some words when transiting between English and Chinese, asking participants to get more information about cultural custom, have to be made because we want to compare the cultural factors connected to the education without other interference from the culture.

SUMMARY OF CROSS-CULTURAL COMPARION

Teaching is a cultural activity. However, the scientific theories are global. Comparing the teaching instruction between different countries would offer an opportunity to find some characteristics in education for these countries, which cannot be found if we are just looking inside one culture. Although there are some obstacles like language for implementing a cross-cultural comparative study in two countries, it can provide meaningful views by taking some precautions. The present study focuses on cultural differences and similarities in inquiry-based teaching between US and China.

III METHOD

INTRODUCTION

In order to gain an insight into the use of inquiry-based teaching in the United Stated and China, this study measured two aspects in these two countries: teachers' practices and their thoughts on inquiry-based teaching. Teacher's practices were examined by classroom observations. During the observation, qualitative data were collected. They represented the extent to which inquiry-based teaching was used in classroom practice by teachers. Teacher's thoughts on inquiry-based teaching were examined by a survey instrument. The survey asked teachers' thoughts on inquiry-based teaching and the importance of some of the elements in scientific inquiry, such as making predictions, making connections to real life, students' reflection, communication among students and groups, and hands-on experiments. The survey also includes demographic questions, such as gender, age, years of teaching, academic degrees they hold and types of teaching certificate they have. The survey questions can help researchers to understand the inquiry-based teaching from teachers' perspective. It was important to collect data on both teachers' thoughts and practices of inquiry-based teaching, as these two aspects reflect the teachers' inner thoughts and what actually happened in classrooms. The two aspects provided researchers with better understanding of the use of inquiry-based teaching in US and China.

PARTICIPANTS

In order to measure teachers' practices and thoughts on inquiry-based teaching, data were collected from 9 American and 10 Chinese high school physics teachers through classroom observations and administration of a survey. American participants consisted of 9 full-time physics teachers in high schools from 7 different schools in the urban and suburban areas in Mid-west in the United States. American participants were first recruited through email requests that the researchers sent to the area teachers. Requests were sent via email to 15 American teachers, and eight teachers signed up for the site visits. The sample was a convenience-based sample, based on the fact that the researchers were able to visit the schools and the teachers agreed to participate in the research. One more teacher was recruited using a snowball sampling technique, where we asked existing participants to refer potential participants from among their acquaintances.

Chinese participants consisted of 10 full-time high-school physics teachers in 3 different schools in Zhejiang province. Chinese participants were recruited through phone calls. Requests were sent to 11 high-school physics teachers in Zhejiang. The Chinese sample was also a convenience-based sample. Ten Chinese teachers signed up for the site visits.

PROCEDURES

Classroom observations were used for examining teachers' practices of inquiry-based teaching. In order to obtain approval for conducting the research on human subjects, an application form was submitted to the Institution of Review Board at Wright State University for a review. Upon IRB approval, the data from American teachers were collected in late February and early March, and again in May, 2012. The data from Chinese teachers were collected in late March and early April, 2012. For every teacher who signs in site visit will receive an Informed Consent forms (See Appendix A).

A typical classroom observation was conducted to document the regular teaching of each participating teacher. The teacher selected the topic of the lessons to be observed. Field notes were taken by the researchers to help coding the extent to which the elements of inquiry-based teaching were used during the observed lesson. All of the lessons were videotaped with permission except 2 lessons in an American high school where the permission from the principal was not obtained. The video recording allowed researchers to further analyze the classroom data. The observation data were analyzed based on the instrument called Reformed Teaching Observation Protocol [RTOP] (Sawada, et al., 2000), and coded according to teachers' instruction based on inquiry oriented elements. More explanation of the rubric is presented in the Instrumentation section.

Each of the participants for observation was asked to fill out the survey (see Appendix B) that was developed to measure teachers' thoughts of inquiry-based teaching. The survey requests were sent via email to each teacher prior to the site visit. The electronic version of the survey was sent as an attachment to both American and Chinese participants. They were asked to finished the survey and submit their answers back to the researcher or printed out the form and answered the questions. The hard copies were given to the researcher when the site visit took place. Chinese-language version of the survey was used for Chinese participants.

INSTRUMENTATION

Classroom observations were analyzed using a rubric for inquiry-based teaching. The rubric is called the Reformed Teaching Observation Protocol (see Appendix B) (RTOP)

(Michael-2000). It was proposed by Evaluation Facilitation Group (EFG) of the Arizona Collaborative for the Excellence in the Preparation of Teachers (ACEPT). It was developed as an observation instrument to provide a standardized means for detecting the degree to which K-20 classroom instruction in mathematics or science is reformed. There are 25 items in RTOP and they were organized into five categories:1) Lesson design and implementation; 2) Content: propositional pedagogic knowledge; 3) Content: procedural pedagogic knowledge; 4) Classroom culture: communicative interactions; and 5) Classroom culture: student/teacher relationships. When using the RTOP, the lesson was coded with a number from 0 to 4 for each of the items to represent the extent to which how inquiry-based teaching is used. A lesson with a score of 4 for a specific item means that the inquiry elements of that particular item was fully implemented in that lesson, whereas a score of 0 means the elements didn't happened at all in the lesson.

The survey instrument was created by the researcher in order to measure teachers' thoughts on various aspects of inquiry-based teaching. There are 3 aspects about inquiry-based teaching that were included in the survey. The 3 aspects were selected from PTOR instrument by the researcher: 1) teacher's thoughts about teaching in general and inquiry-based teaching in particular, such as the use of prior knowledge, real word application, and reflection by students; 2) communication that happens in the classroom, including student-student interaction, student-teacher interaction, group-group talking, and whole class discussion; and 3) experiments, that consist of students' hands-on activities and teacher's demonstration. Each of the aspects was asked to the teachers both by describing their thoughts in words (open-response questions) and by rating the importance of the elements with numbers from 0 to 4. The demographic questions asked teachers about their age range, years of teaching, academic degrees they hold, and certified areas and levels for teaching.

DATA ANALYSIS

Classroom observations were coded using RTOP, indicating the extent to which teachers' practice of inquiry-based teaching was happening. Each lesson was coded through 25 items in the RTOP with the scale from 0 to 4. The total score that is the sum of the scores on 25 items ranges from 0 to 100 representing the overall performance of the teacher. A factor analysis was performed for the whole set of data that were collected from 19 teachers. The observational data were co-coded by an independent person and the inter-coder reliability was checked. The co-coder is university faculty in physics education who has been studying similar subject. Inter-coder reliability, which is the extent to which two or more independent coders agree on the coding of the content of interest with an application of the same coding scheme, was implemented to test the reliability of researcher's data. Factor analysis is used to analyze large numbers of dependent variables to detect certain aspects of the independent variables (called factors) affecting those dependent variables - without directly analyzing the independent variables. It was performed in this study to reveal characteristics of teachers' practice on inquiry-based teaching in two countries. The test of the significance were performed for the multiple categories appeared in the factor analysis to see if there were any significant difference between US data and Chinese data.

Descriptive statistics was also used when comparing observational data between US and China. Frequency counting was used to analyze some features happened in the classroom, such as how many questions were asked by students, and how many problems were solved by students during the class. By comparing these individual features, differences in teachers' practices between US and China were revealed.

The collected survey data were analyzed quantitatively and qualitatively. The statistical data analysis was performed through the use of SPSS. A factor analysis was performed to reveal characteristics of teachers' thoughts on inquiry-based teaching in two countries. A multivariate analysis of variance was used to see if there were statistically significant results between US and Chinese data. Words and phrases that were frequently mentioned in the open-response items were identified to find differences and similarities in teachers' practice of inquiry-based teaching in US and China.

IV RESULT

This study examined what extent inquiry-based teaching is valued in high-school physics education in the United States and China. Two components were measured in two countries: physics teachers' thoughts of inquiry-based teaching and practice of inquiry-based teaching in United States and China. Teachers' thoughts of inquiry-based teaching were measured by a survey instrument. Teachers' practice of inquiry-based teaching was measured qualitatively through classroom observation.

The survey results are presented first in this chapter to show high-school physics teachers' thoughts of inquiry-based teaching in both United Stated and China. Descriptive statistics for demographic data from 19 survey participants by country are presented in Table 4-1. Statistical analyses include factor analysis and multivariate analysis of variance. The former one reveals the main factors that affect teachers' thoughts of inquiry-based teaching, and the latter one presents the significant difference between American and Chinese teachers' thoughts of inquiry-based teaching. In addition, frequency counting is used to analyze the open-response questions, which also reflect teachers' thoughts about inquiry-based teaching.

The result of the classroom observation data are presented next. The descriptive data of each of the observed lessons are presented first in Table4-6. The table provides information on the lessons including students, time length, and contents. The description summaries what happened in the class. The inter-coder reliability was calculated. Factor analysis are used to reveal the main factors that affect teachers' practice of inquiry-based teaching, and tests of significance are presented to determine whether American teachers' teaching is statistically different from Chinese teaching on any of the categories of essential features of inquiry practice. In addition, frequency counting is used to further analyze some features of the lessons.

SURVEY RESULT

DEMOGRAPHIC DATA OF PARTICIPANTS

A total of 19 teachers participated in the survey including 9 American teachers and 10 Chinese teachers. Participants' demographic data were shown in table 4-1.

In the study, we had more male participants than female participants in both US and China; about 29% of the American participants were female and 20% of Chinese teachers were female. It is indicated in Table 4-1 that the age range of the participants was highest in the over 50 category in the US, while the 30s category was the highest in Chinese data. As for the number of years of teaching, we had more experienced teachers than new teachers in both US and China: there were 6 American teachers (66.7%) who have been teaching for more than 10 years and 2 American teachers (22.2%) have been teaching for 6-10 years; 3 Chinese teachers (30%) have been teaching for more than 10 years and 3 Chinese teachers (30%) have been teaching for 6-10 years.

Table 4-1

Percentage of US and Chinese Teachers in Survey by Demographic Category

Demographic Category			US Teachers	Chinese Teachers
Gender		Male	7	8
		Female	2	2
Age		20s	1	3
		30s	2	5
		40s	2	1
		50s and older	4	1
The number of years for teaching		Less than 1 year	0	2
		1-2 years	1	1
		3-5 years	0	0
		6-10 years	2	3
		More than 10 years	6	3
Highest academic degree earned	bachelor's	Physics only	0	4
		Other science	1	0
		Physics + Education	0	2
		Other science + Physics +Education	1	0
		Other science + Education	1	0
	master's	Physics only	0	1
		Physics + Education	0	3
		Other science + Physics + Education	3	0
		Other science + Education	2	0
	Doctor's	Chemistry	1	0
Certificate earned	grade : 7-12th	Other science + Physics	2	1
		Other science	1	0
		Physics only	0	9
	grade : 9-12th	Other science + Physics	5	0
		Other science	1	0

Table 4-1 also shows that there is a larger variation in the fields of degree that American teachers hold than Chinese teachers do. For example, three US teachers have academic degrees of other science areas (other science here means a science subject except physics, such as math, biology, or chemistry), physics and education; one of the US teachers received two bachelor's degrees for math/physics education and electrical engineering, and a master's degree for psychology. All of the Chinese teachers hold bachelor's degree or master's degree for physics or physics education. Also some of the American teachers hold a degree not in physics but a field that is related to physics, such as chemistry, engineering, and mathematics. The same pattern was found in the teaching certificate the participants have. American teachers have teaching certificates in multiple areas while all the Chinese teachers have a certificate in physics. For example, one of the US teachers has certificates to teach physics, physical science, and geology. Another US teacher has certificates to teach all sciences, all engineering, and AP Physics. Chinese teachers only have a certificate to teach physics, except for one teacher who has a certificate to teach math. Also some of the American teachers do not have the certificate to teach physics even though they were teaching physics.

RESULTS ON LIKERT-TYPE QUESTIONS

The survey included 15 Likert-type questions that were designed to measure teacher's thoughts of some main elements about inquiry-based teaching. The numerical values from 0 to 4 were given to each of the response options for the 15 Likert-type items in the survey to indicate the extent to which participants value the importance of each element, where “Not at all” = 0,”Very important” = 4, and the numbers between them represent the importance between “Not at all” and “Very important”.

Factor analysis

A factor analysis was performed for the whole set of data. The analysis identified 8 factors with eigenvalues greater than one. The matrix rotation converged in 38 iterations. However, the scree plot (Fig. 4-1) was not in an elbow shape and the results may need to be interpreted cautiously. Table 4-2 summarizes the result of factor analysis.

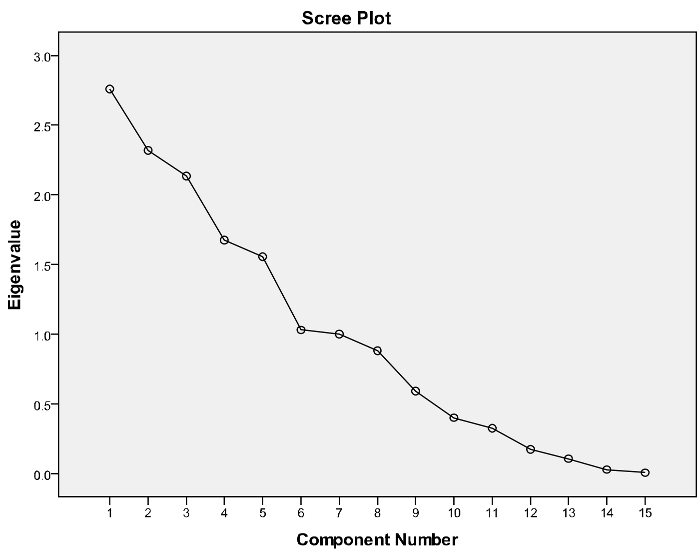

Figure 4-1 Scree Plot for the Factor Analysis of Survey Data

Each of the items was examined if it is loaded on one of the factors with a value of greater than .5. Some of the items loaded more than one factor with a value of greater than .5. In such a case, the item was identified to belong to the factor with the highest loading. It also happened that items grouped in one factor do not share a common characteristic; multiple characteristics were identified for the factor in such a case. For example, Factor 3 includes two items that are characterized as to indicate “Real world example/application”, “Challenging questions to students”. The first one is about application, while the second one concentrated on challenging questions to students. In addition, there are four factors (factors 4, 5, 6, and 7) that include only one unique item, like factor 4 that has one item about “Reflection by students”. The table shows the mean values and standard deviations for each factor by country.

Table4-2

Name of Factors and Mean Scores for the Items in Each Factor by Country

Factor	Name of the factor (items in the factor)	Mean score(SD)	
		US	China
Factor 1	Students-students and student-teacher interaction (Q 5.2, Q5.5, Q7.2)	2.77(0.4)	2.8(0.6)
Factor 2	Multiple representation students (Q3.6, Q5.3, Q5.4)	2.93(0.31)	3.07(0.38)
Factor 3	Real world application and Challenging questions to students (Q3.3)	3.3(0.0)	2.9(0.0)
Factor 4	Reflection by students (Q3.5)	3.1(0.78)	3.8(0.42)
Factor 5	Prior knowledge(Q3.1)	2.2 (0.97)	2.5 (1.51)
Factor 6	Solid grasp of the subject matter content by teacher (Q3.4)	3.67(0.5)	3.3(0.82)
Factor 7	Individual work (Q5.6)	2.9(0.78)	3.5(0.71)

The results of the factor analysis indicate that for most of the items teachers from United State and China have the similar thoughts. They both agreed, for example (in factor1), that student-teacher interaction, whole class discussion and demonstration by the teacher are important, the average score for each country are 2.77 (US) and 2.8 (China). When the average scores are compared, it can be seen that Chinese teachers think students' reflection is more important (Factor 4). The means value of item "Reflection by students" for Chinese data (3.8) is higher than that for American data (3.1). Also Table 4-2 indicates that Chinese teachers value higher about individual work (Factor7) than US teachers. The means value of the item in factor 7 "individual work" for Chinese data is 3.5, while American data is 2.9.

Multivariate analysis of variance

A multivariate analysis of variance was used to perform tests of significance. The independent variable was the country: US and China. The dependent variables were the 15 items in the survey. The tests of between-subjects were performed. The result showed that only one item is statistically significant, that is reflection by students with $p=0.027$ (the p-value is the probability of obtaining a test of statistical significance at least as extreme as the one that was actually observed, assuming that the null hypothesis is true), the mean value and standard deviations has been shown in table 4-3. The results of the tests of significance indicate that Chinese teachers valued the importance of students' reflection higher than American teachers do; the mean score for this item for Chinese teachers significantly higher than that for American data ($p<0.05$). In addition, the item for" individual work" shows a moderately statistically significant result with p=0.091, which indicates that Chinese teachers agreed with importance of individual work more strongly than American teachers do.

Table 4-3

P Value and Mean Score for Each Item in Survey by Country

Items	Mean score(SD)		P value
	US	China	
Q3.1	2.22(0.97)	2.50(1.51)	.644
Q3.2	2.11(0.93)	2.10(1.10)	.981
Q3.3	3.33(0.50)	2.90(1.287)	.357
Q3.4	3.67(0.50)	3.30(0.823)	.264
Q3.5	3.11(0.78)	3.80(0.422)	.027*
Q3.6	3.22(0.44)	3.50(0.527)	.233
Q3.7	3.33(1.12)	2.90(0.876)	.357
Q5.1	3.67(0.50)	3.70(0.675)	.905
Q5.2	3.22(0.67)	3.40(0.843)	.620
Q5.3	2.56(1.01)	2.80(0.919)	.588
Q5.4	3.00(0.50)	2.90(0.738)	.737
Q5.5	2.67(0.87)	2.20(1.033)	.304
Q5.6	2.89(0.78)	3.50(0.707)	.091
Q7.1	3.78(0.44)	3.90(0.316)	.493
Q7.2	2.44(1.24)	2.80(0.632)	.434

*Statistically significant(p<0.05)

OPEN-RESPONSE QUESTIONS

Four open-response questions were designed to measure teachers' thoughts of inquiry in physics teaching. The answers were summarized in Appendix D. Frequency counting was used to identify the elements that teachers referred frequently in each of the questions. Results were shown in the table 4-4.

The first question asked about the ideal and practical effective teaching methods. It is shown in table 4-4(a). Four main elements that were identified in teachers' answers for the ideal method were self-directedness, inquiry, experiment, and multiple methods. Five main elements that were identified in teachers' answers for the practical method were lecture, exercise, teacher's guide and combination or selected of lecture and inquiry-based approach. The numbers below show the frequency that teachers referred to the element in their answers. The results of the frequency counting indicate that both American and Chinese teachers consider inquiry as an ideal effective teaching method. The word "inquiry" was mentioned 5 times by teachers both in these two countries, and also has the highest frequency among other elements. Beside inquiry, both American teachers and Chinese teachers value the self-directedness, which is the second highest frequently referred word.

In addition, American teachers also include experiment and multiple methods as the ideal effective teaching method, while only one Chinese teacher regarded experiment as an ideal effective method and no Chinese teachers mentioned multiple methods. The result of Table 4-4(a) also showed that when it comes to the practical way, lecture was regarded as the effective method both by American teachers and Chinese teachers. The lecture was mentioned in teachers' answers 3 times both in USA and China. However, American

Table4-4

Frequency Counting for Open-response Questions

(a)

	What teaching method do you think is effective for student understanding of physics content? Please describe it in two ways: ideally and practically.								
	Ideal effective teaching method				Practical effective teaching method				
Elements	Self-directedness	Inquiry	Experiment	Multiple method	Combination	Lecture	Selective	Exercise	Teacher guide
US	2(22%)	5(56%)	2(22%)	2(22%)	3(33%)	3(33%)	1(11%)	0	0
China	3(30%)	5(50%)	1(10%)	0	0	3(30%)	0	1(10%)	1(10%)

(b)

	How would you describe inquiry-based teaching?						
Elements	Teacher guide/facilitate	Teacher cultivate	Self discovery/ infer	experiment	prediction	understanding (fully enforce get by own)	Students are main body
US	4(44%)	0	5(56%)	5(56%)	0	0	0
China	4(40%)	2(20%)	4(40%)	2(20%)	1(10%)	3(30%)	2(20%)

(c)

	How would you value the importance of students' active participation in discussion in your physics lesson? Please describe the reasons for your answer as well.					
Elements	Engaged/ involved	Understanding (fully/ enforce/ get by student self)	Process of learning	experience	Reflection of students	Others
US	4(44%)	2(22%)	0	1(11%)	0	1(11%)
China	0	5(50%)	2(20%)	2(20%)	2(20%)	3(30%)

(d)

	How would you value the importance of students' experiments and observations during your physics lesson? Please describe the reasons for your answer as well.				
Elements	Experience/practice real physics	understanding (fully/ enforce/ get by own)	Develop ability	interactive	others
US	2(22%)	5(56%)	1(11%)	0	2(22%)
China	3(30%)	3(30%)	1(10%)	2(20%)	1(10%)

teachers also take lab and lecture for the practical effective teaching method. The word "combination" was also referred 3 times by American teachers. On the other hand, no Chinese teachers consider combination as a practical way of teaching, while one Chinese teacher thinks exercise as a practical method and another teacher in China thinks teacher's guide as a practical way of teaching.

Table 4-4(b) shows the results of frequency counting for the question "How would you describe inquiry-based teaching?" Seven elements were identified in teachers' answers. The frequency counting revealed that both American teachers and Chinese teachers think inquiry-based teaching is a student self-discovery method, and teacher acts like a guide or facilitator, which are consistent with the description in the NSES (NRC, 1996). The frequency of the reference to the element in both US and China was high. Also American teachers describe experiment as an important element, which was mentioned by 5 American teachers, while only 2 Chinese teachers mentioned experiment. On the other hand, Chinese teachers described inquiry-based teaching with words like "predictions", "understanding (fully/enforce/get by student self)" and "Students are main body".

The third question asked about the importance of students' active participation in discussion, Table 4-4(c) shows the results of the frequency counting. Most American teachers think participation in discussion can make students engaged or involved in the class, while Chinese teachers think students can understand the concept better or by themselves by participating in discussion. It is shown in the table that the most frequently mentioned word in the American teachers' answers was "Engaged/ involved", and the word "understanding (fully/ enforce/ get by student-self)" was mentioned by Chinese teachers with most frequency. In addition, the results show that Chinese teachers also think active participation in discussion is a process of learning, and it can help students experience the content they have learned. Also teacher can get reflection from students through discussion.

The results of frequency counting for the last question show that both American teachers and Chinese teachers think students' experiments and experimental demonstrations by teachers can help students understand the concept better. They also think these two kinds of experiments give students the chance to experience the real physics and develop abilities to conduct experiments. More American teachers strongly agreed with the first point of view; there were 5 American teachers mentioned the word "understanding (fully/enforce/get by student-self)", while only 2 Chinese teachers use the word in their answers. In addition, this table shows that experiment performed by students or teachers can be a way of interaction for Chinese teachers. The word "interactive" was mentioned 2 times by Chinese teachers.

SUMMARY OF SURVEY RESULTS

American and Chinese teachers' thoughts of inquiry-based teaching were measured by a survey instrument that was created for this study. The responses of Likert-type questions indicated that there are not many differences between American and Chinese teachers about the thoughts of inquiry-based teaching, except for the items of students' reflection and individual work. Statistical analysis showed that Chinese teachers valued theses two elements higher than American teachers. The results of the frequency counting of open-response questions showed both American and Chinese teachers agreed that inquiry is an effective teaching method. However when referring to some elements in inquiry-based teaching, teachers from these two countries have some different opinions. For example, American teachers think discussion was used to engage students, while Chinese teachers consider discussion would help students get a better understanding.

OBSERVATION RESULTS

DESCRIPTIVE SUMMARY OF OBSERVED LESSONS

Observational data were collected from 19 lessons; nine lessons were collected from American teachers and 10 lessons were collected from Chinese teachers. The lessons were taught by the same teachers who participated in the survey. The researcher visited each of the participants' schools and observed lessons. Lessons were all videotaped with permission from principals of each school, except for 2 lessons from an American high school, where we cannot obtain permission from the principal.

Description of each of observed lessons are shown in Appendix E; Table 4-5 summarizes the content of the observed lessons. In general, American lessons had a long lesson time; two of them were 60 minutes, and others were 50 minutes. All Chinese lessons had 40 minutes lesson time. American lessons have a bigger variation on number of students and the gender ratio than Chinese lessons did. For example, in American classes, the smallest number of student was 5, and the biggest was 28, and the numbers between them were all different. Gender ratio in American classes was all different from each lesson, ranging from 4:1 (boys: girls) to 1:1, while in Chinese lessons, the numbers of students were all close to 45, and the gender ratio was close to 1:1. It should be also noted that in some American lessons, there were students in different grades, such as11th and 12th graders in one class and students in 10th and 11^{th} grades in another class. In Chinese lessons, they have always one grade in one lesson. The content of the observed lessons were different in two countries; the topics in American lessons were, for example, lenses in optic, parallel circuit in electricity, and pressure in mechanics, while in China, four lessons had the topic of universal gravitation. Other Chinese lessons cover such topics as motion of simple harmonic oscillation and theorem of kinetic energy.

Table 4-5

Summary of Content of the Observed Lessons

Observed US physics class				
	Grade	Number of Students(Boys/Girls)	Lesson Time Length	Content of the Lesson
US1	11th&12th	5(4:1)	60mins	Investigate how light travels with mirror
US2	10th&11th	14(2:12)	60mins	(1)Measure the current and voltage of a parallel circuits by adding more bulbs, (2)calculate the total resistant, (3)make connection between bulbs and total resistant
US3	11th&12th	28(1:1)	50mins	(1)conduction of the heat, and the formula of H;(2)convection of heat in a room;(3)Radiation
US4	10th	19(6:13)	50mins	(1)Pressure;(2)P=pgh, connect to a lot of exercise
US5	11th&12th	26(12:14)	50mins	Exercise about Snell's law and converging and diverging lens
US6	10th	23(10:13)	50mins	The current voltage resistant of the

				parallel circus, connect to many exercise
US7	10th	20(1:1)	50mins	(1)lectured the electric potential energy and charges; (2)students simulate the interact force between charges
US8	10th	15(6:9)	50mins	Exercise about dynamics and kinetics
US9		12(7:5)	50mins	(1)review the imaging principle of lens and mirror;(2) the principle of faculties composed by multiple lens of mirrors
C1	10th	45(22:23)	40mins	Consequence of universal gravitation: how to calculate the mass and density of earth and sun
C2	11th	48(1:1)	40mins	Definition of natural frequency and driver frequency; the connection between driver frequency and the frequency of forced oscillation; finally come out the idea of resonance.
C3	10th	43(23:20)	40mins	achievement of universal gravitation: how to calculate the mass and density of Minor Planet Center
C4	10th	42(22:20)	40mins	universal gravitation: prove that gravity is one kinds of universal gravitation; give the general idea of universal gravitation
C5	10th	47(23:24)	40mins	achievement of universal gravitation: how to calculate the mass and density of Minor Planet Center
C6	10th	44(1:1)	40mins	Learning the concept of energy conservation: the concept of conservation came from other conservation like quantity and mass, and the derivation of the energy conservation was from free fall.
C7	10th	47(23:24)	40mins	derivation of the equation of work-kinetic energy theorem based on some equations of dynamic theorem, such as $ax=v_f^2-v_i^2$
C8	11th	44(23:21)	40mins	motion of simple harmonic oscillation
C9	12th	50(1:1)	40mins	Exercise of the college entrance exam with the whole content in high school physics (students spend half of the class doing the exercise, then teacher explain

				them)
C10	12th	49(25:24)	40mins	Exercise of the college entrance exam with the whole content in high school physics (students did the exercise before the class, then teacher explain them)

RESULT OF OBSERVED LESSONS WITH RTOP CODING

Coding observed lessons

Classroom observations were coded by two coders using the rubric described in the method section, which indicates the extent to which classroom practice reflected inquiry. Each lesson was rated on the 25 items of the elements of inquiry-oriented classroom on the rubric.

Training the coder

The coders were first trained by three example videos provided on website (http://physicsed.buffalostate.edu/AZTEC/RTOP/RTOP_full/) the coders coded the example videos, and then compared the score coded by experts. After trained with three videos, the coders coded three observed lessons from American schools independently and compared the scores. Most of the score was in good agreement. The coders discussed about the disagreed items, and made sure that there would be no misunderstanding on the definitions of the words and the concepts of reformed based-teaching. All the 19 lessons were coded by two coders independently, one coder is fluent in Chinese, the other do not know Chinese, however translation and description of Chinese lessons were provided as much as possible.

Inter-coder reliability

Inter-coder correlations were calculated using the scores given by two coders. Pearson Correlation (The range of the Pearson Correlation may be between 0.0 and 1.0, the number will be high when there is little variation between the scores given to each item by the raters) was 0.756, showing high inter-coder reliability. Having shown high inter-coder reliability, one of the researchers' data was chosen to be used for further analyses. Obviously, the researcher who was able to observe all the lessons alive in the actual classrooms could collect more data than the other researcher who had only a limited view on the video-taped lessons for Chinese data

Factor analysis

A factor analysis was performed for the whole set of data. The analysis identified 8 factors with eigenvalues greater than one. The Scree plot is shown in Figure 4-2. It shows an elbow shape, which means the factors well explained the variation in the data.

By considering common features of the items grouped in the factors, each of the factors can be named as they are shown in Table4-6. Factor 1 was named as "Students' exploration and multiple ways to approach to physics concepts" because the items in the group (Q3, Q 4, Q7, Q9, Q12, Q22 and Q24) addressed the students' exploration and multiple ways to learn the content. For example, Q3, Q12 and Q24 valued students' exploration, investigation, predictions, and estimations made by students, and Q4, Q22 valued that students use multiple modes to investigate, solve problems, and generate alternative strategies and ways of interpreting evidence. Factor 2 was named as "rigorous content knowledge" because the three items (Q6, Q8 and Q18) in the group addressed the content of the lesson, teacher's solid grasp of the subject and teacher's way to teach the content. The rest of the factors were named in a similar way.

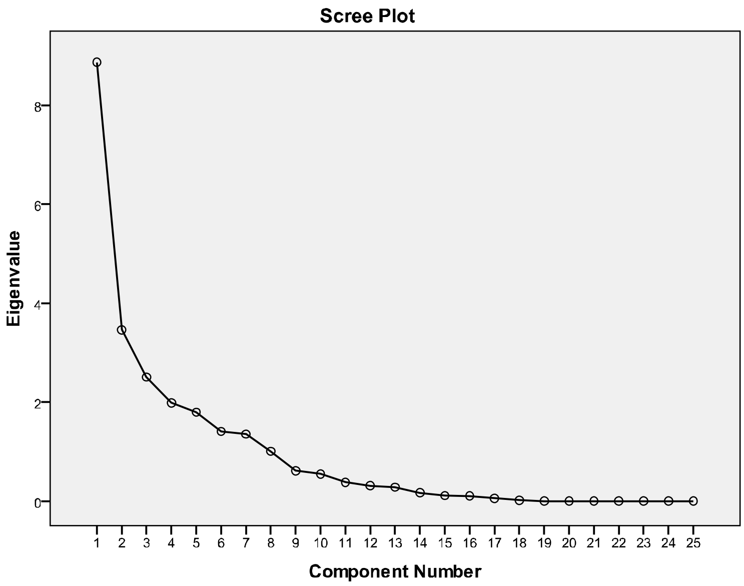

Figure 4-2 Scree Plot for the Factor Analysis

The numbers in Table 4-6 indicate the average numerical values (and standard deviations) for the items grouped in the factors. The negative sign in the table in Factor 3 means this factor had the opposite effect with the positive one. The asterisk (*) in the last column in Table 4-6 indicates that the difference between the US and China is statistically significant that factor.

The results of the factor analysis indicate that both American teachers and Chinese teachers did not score high on practice in terms of inquiry-based teaching (factors 1, 2, 5, 6, and 8). The mean scores for all of these factors were under 2 (full score is 4). This means that teachers included the inquiry elements, but the degree to which the particular element was used was not very high. For example, in factor 1 the mean score is 1.38 for US and 1.29 for China. One of the questions (Q3) in this factor is "In this lesson, student exploration preceded formal presentation." Some of the American lessons included student exploration. Student exploration preceded formal presentation in one of the lessons. In another lesson, teacher's presentation occupied almost of the class time, so it couldn't be given a score of more than 2; however for other six lessons in USA and all lessons in China, there was basically no exploration. Also for factor 8 "real world application", the mean scores are 1.89 for USA and 1.6 for China, which means teachers from both countries mentioned same real world application, but did not guide students to take further steps to use them. For example, in a US lesson teacher told students how to make the painting color use the three-primary color, but he didn't ask students to apply the knowledge. Also mentioning the real world by the teacher only happened once in this class. In a Chinese lesson, at the beginning of the class, the teacher introduced some examples oscillation phenomena in real life, and explained how they oscillated, but the lesson did not include students' use of knowledge to be presented as an example. It is also interesting to notice that real world application is a unique item in Factor 8, which means this item didn't share the characteristic with other items.

The analysis also reveals that American teachers pay more attention on students' presentation and interaction. The analysis showed that the mean value of the items in this factor for American data is significantly higher than that Chinese data ($p<0.05$). The result indicates that American teachers included students' presentation and interaction with a greater degree than Chinese teachers did. For example, three lessons in USA had a high amount of peer discussions; in one US lesson students were discussing within a group when they did the simulation. Also in some lessons in the USA students asked questions. No lesson in China had high amount of peer discussion and students' voices were heard only when teacher asked questions. It should be noticed that the p value for factor 2 was 0.082 ($p<0.1$), which indicates a moderately significant effect of the country for the factor. This result shows that Chinese teachers include more rigorous content knowledge than American teachers did. For example, in one of the US lessons, the teacher did not teach explicitly except for checking students' progress on the investigation work twice during the class time. Almost in all lessons in China teachers asked lots of questions and draw logical conclusions.

Test of significance

A multivariate analysis of variance was used to perform tests of significance. The independent variable was the country; USA and China. The dependent variables were 8 factors that were identified in the factor analysis. The numerical values of the items grouped in each factor were averaged for each lesson and used for the calculation. Tests of between-subjects effects were performed. The results of the tests were shown in the last column in Table 4-6, where the asterisk (*) indicates that the difference between the US and China is statistically significant that factor ($p<0.05$).The difference was statistically significant for factor 2.

Table 4-6

Name of Factors and Mean Scores for the Items in Each Factor by Country

Factor	Name of the factor (items grouped in the factor)	Mean Score(SD)		P value
		US	China	
Factor 1	Students' exploration and multiple ways to approach to physics concepts(Q3, Q 4, Q7, Q9, Q12, Q22, Q24)	1.38 (.88)	1.29(.76)	.803
Factor 2	rigorous Content knowledge(Q2, Q 6, Q8, Q11, Q17)	1.13(1.22)	1.88(.40)	.082
Factor 3	Students' presentation and interaction(Q5, Q15*, Q16, Q18)	.70(1.27)	-.70(1.01)	.016 *
Factor 4	Prior knowledge and Active participation (Q1,Q21)	2.56(.81)	2.6(.61)	.894
Factor 5	Climate of respect and patient (Q20,Q23)	1.78(.51)	1.75(.59)	.914
Factor 6	Students' question and teacher as a listener (Q19,Q25)	1.28(.36)	1.0(.62)	.259
Factor 7	thought-provoking activity and reflection(Q13,Q14*)	1.33(1.5)	1.7(1.34)	.580
Factor 8	Real world application(Q10)	1.89(0.6)	1.6(0.7)	.350

*Statistically significant ($p<0.05$)

RESULT OF FREQUENCY COUNTING OF OBSERVED LESSONS

Frequency counting were used to examine how often some activities such as students-students discussion, and question asked by teachers happened during the lesson. These activities were counted manually by the researcher through the observation of the videos. For the two lessons that had no video-tapes the frequency was counted by the observation note. Table 4-7 shows the results of frequency counting.

The results of frequency counting show that there are some differences between American and Chinese lessons. For example, student-student discussion happened more frequently in American lessons than Chinese lessons. Seven out of 9 American lessons had some kinds of student-student discussion. There were three lessons that had students' group/peer work, and students' discussion happened all the time during the class. Also there were two American lessons in which students discussed with peers randomly during teacher's lecture. Among the Chinese lessons only one lesson had students' discussion when teacher asked students did simulation for 10 minutes. The rest of the Chinese lessons included no student-student discussion at all. It was interesting to notice that, in two Chinese lessons, even teacher asked students to discuss, no students started discussion. In addition, the results of frequency counting showed that students in American lessons asked questions more frequently than Chinese students did. There were 8 American lessons in which students asked questions, while in China only five lessons involved students' questions. What's more, the numbers of questions asked by students were higher than Chinese students did; there were 4 questions asked by students in 2 American lessons and 3 questions asked in 2 American lessons. It was shown in the previous section that American teachers pay more attention on students' presentation and interaction. So this result of frequency counting is consistent with the result from factor analysis.

Table4-7

Frequency Counting of Observed lessons

Frequency counting items		US		China	
Students-students discussion	None	2	2	7	9
	Teacher asked but students didn't discuss	0		2	
	Teacher asked and students discussed	1	7	0	1
	Students discussed once	1		0	
	Students discussed randomly during the class	2		0	
	Students worked in a group/peer	3		1	
Numbers of questions asked by students	None	1	1	5	5
	1	1	8	2	5
	2	1		1	
	3	2		1	
	4	2		0	
	Asked Privately	2		1	
Numbers of problems solved	None	5	5	2	2
	1	0	4	2	8
	2	0		1	
	3	0		3	
	Exercise class	2		2	
	Students did homework at the end	2		0	
Numbers of questions asked by teacher	None	2	2	0	0
	1-10	3	7	3	10
	11-20	3		2	
	21-30	1		4	
	Above 30	0		1	

On the other hand, Chinese teachers were more likely to have students engage in solving problems during the lesson. The frequency counting shows that 8 lessons in China had problems solving time, while there were 4 lessons in USA. In most of the Chinese lessons, problem solving happened in the middle of the lesson, and the problems were connected to the content students had just learned, and the teacher took time to students to solve the problems. These elements were not included at all in American lessons. In American lessons problem solving happened at the end of the class as part of homework, and teacher would not draw a conclusion about the problems to develop a concept. When counting the numbers of questions asked by teachers, there are differences between American lessons and Chinese lessons. All the Chinese teachers asked questions during lecture, while there were two teachers in American lessons who didn't ask questions at all. In addition, there were five teachers in Chinese lessons who asked more than 20 questions, while there was only one teacher in American lessons who asked more than 20 questions. It was also interesting to note that when students answer to the questions asked by teachers, in most of the Chinese lessons individual students in the whole class answered the questions, while in American lessons, the answers were always given by several students.

SUMMARY OF OBSERVATION RESULTS

The observational data collected from 19 lessons indicate the degree to which the elements of inquiry were included in the lessons were not very high both in American lessons and Chinese lessons. The factor analysis showed that there is a statistically significant difference between US and Chinese lessons in one category. The American teachers provided more chances for students to talk with peers; this is consistent with the results obtained for the frequency counting. The frequency counting also showed that

Chinese lessons included problem solving during the class, and teachers explained them in the class.

The results found in the observational data indicate difference and similarities between American and Chinese lessons in high school physics. How these differences and similarities are related to teachers' thoughts of inquiry-based teaching is described in the next section.

V DISCUSSION

This study examined what high-school physics teachers in the US and China thinks and practice on inquiry-based teaching using a survey and classroom observations. Survey responses were collected from 9 American and 10 Chinese teachers. Classroom observation data were collected from the same teachers who responded to the survey. Differences and similarities between American and Chinese teachers were found in terms of their thoughts and practices about inquiry-based teaching. It was expected that discussions will shed light toward the understanding of the issues of increasing inquiry-based physics teaching at the high-school level in both countries.

In this chapter, discussions of each type of data take place first. The results from all of the data sources are combined to draw conclusions. The conclusions lead to a discussion of how this study informs the educational research communities about the use of inquiry-based teaching in the US and China. Lastly, limitations of this study are discussed.

DISCUSSIONS CONCERNING TO THE SURVEY RESULTS

Table 4-1 shows that demographic backgrounds for American and Chinese participants are different. Factor analysis on the survey data was used to show the pattern of teachers' thoughts based on the responses to Likert-type questions (see Table 4-2). Some differences in thoughts on inquiry-based teaching between American and Chinese teachers were revealed in the multivariate analysis based on Likert-type question data and frequency counting based on open-response data.

The survey results indicate that there are some similarities between American teachers' thoughts and Chinese teachers' thoughts on inquiry-based teaching. Likert-type questions show teachers from both countries highly value the elements of inquiry-based teaching such as student-teacher interaction, multiple representations to describe phenomenon by students, and student presentation of their findings. The results were consistent with the findings from open-response questions.

Open-response data, as a high percentage of both American and Chinese participants recommended inquiry-based teaching as an effective teaching method. Also they describe inquiry-based teaching as a students' self discovery process through teachers' guide. The findings suggest that the idea of inquiry-based teaching is well spread over both in American and Chinese high-school physics education communities.

Only one item showed a statistically significant difference between American teachers and Chinese teachers among the Likert-type questions. The result showed that Chinese teachers value the importance of the reflection by students more strongly than American teachers did. It also should be noticed that another item showed moderately high statistical significance ($p<0.1$); Chinese teachers consider individual work by students was important more than American teachers did.

Differences between American and Chinese teachers' thoughts on inquiry-based teaching also found upon open-responses questions. When referring to the practical ways of teaching, several American teachers suggested combined inquiry approach with lecture or these two methods would be selected depending on different situation. All Chinese teachers consider lecture as the only practical way of teaching, even though one of them mentioned teacher's guide as a practical way. Also, more American teachers recommend experiments as an inquiry-based teaching than Chinese did, and most of American teachers think discussion is important because it helps students be involved in the class.

It is interesting to notice that Chinese teachers mentioned the acquisition of knowledge by students more frequently than American teachers did. Many Chinese teachers describe inquiry-based teaching is a method that can help students get knowledge by themselves; they also think the importance of discussion lies in the fact that discussions can help students get knowledge through their own learning. When referring to the importance of experiment, most of the Chinese participants think experiments can help students to acquire knowledge by themselves.

DISCUSSION CONCERNING TO THE OBSERVATIONAL RESULTS

The observational data collected from 19 lessons were coded using the RTOP. The results indicate the extent to which classroom practice reflected the essential features of inquiry-based teaching. Table 4-6 shows that in general, American lessons had a longer lesson time and smaller number of students than Chinese lessons did. Description of the lessons show that there were three American lessons obviously different form Chinese lessons; in these three lessons, students did experiments and collected data by themselves, which could be considered to be students-centered lessons, while other six American lessons were similar with Chinese lessons, where teachers lectured during the lesson time.

The observation results indicate that there exist some statistically significant differences between American teachers' practice and Chinese teachers' practice on inquiry-based teaching. American teachers were more willing to have students make presentations and interact with peers (Factor 3). It was consistent with the findings of frequency counting, which shows that in American lessons more discussions between students happened, and also more questions were asked by students than in Chinese lessons.

It should be noticed that Chinese teachers pay more attention on rigorous content knowledge than American teachers did (Factor 2). It is not a statistically significant difference between these two countries, but it is still a moderately significant difference among other factors. Form frequency counting, it was also found that Chinese teachers were more willing to ask questions during the whole lesson process than American teachers. Also Chinese teachers were more likely to ask students to solve problems in class just after the teachers drew a conclusion about some content, while problem solving that was linked with the newly presented concept was less likely to be included in American lessons.

It is interesting to examine what factors were not statistically different between American and Chinese data. Generally speaking, teachers' practice on inquiry-based teaching in both countries did not include much of the elements that were emphasized in inquiry-based teaching. Both American teachers and Chinese teachers did not incorporate many chances for students to have exploration and allow students to have multiple ways to approach to physics concepts. Teachers generally did not create a good climate of respect for what others to say and teachers were not patient in both American and Chinese lessons.

Also teachers in both countries did not guide students to apply knowledge to real life or participant in thought-provoking activities.

DISCUSSION CONCERNING TO THE RELATIONSHIP BETWEEN TEACHERS' THOUGHTS ON INQUIRY-BASED TEACHING AND THEIR PRACTICE

There was consistency found between survey and observational data. Chinese teachers valued students' individual work more highly in survey responses than American teachers did. It was shown in many of the Chinese lessons that teachers offered time for students to engage in problem solving. On the other hand, American teachers mentioned experiment more frequent than Chinese teachers did in the survey responses. It was observed that in 9 American lessons there were 3 lessons that had students' hands-on experiment, while little experiment happened in Chinese lessons.

It was interesting to find that for the items that showed statistically significant difference there were no apparent relationship between teachers' thoughts on inquiry-based teaching and their practice. The survey data showed that Chinese teachers highly value students' reflection, while in practice; there were no obvious differences between Chinese lessons and American lessons in terms of the use of student reflection. In addition, more American teachers included students' presentations and interaction in practice. However, the survey data did not show any difference in teachers' thoughts about student presentations and interaction between Chinese and American teachers.

HOW DOES THE STUDY INFORM PHYSICS EDUCATION RESEARCH COMMUNITY?

This study carried out an in-depth analysis of high-school physics teachers' thoughts and practice on inquiry-based teaching in the United Stated and China through the use of a survey and classroom observations. Results obtained from all the data enabled the researcher to draw a picture of American and Chinese high-school physics teachers respectively in terms of what they think and practice on inquiry-based teaching. No such cross-cultural study on physics teaching in the US and China has been done before. This study revealed a number of important findings that have not been known to the physics education research community.

Need for the emphasis on rigorous content knowledge in teacher education programs in the US

This study showed that many American physics lessons were lack of conceptual development through questioning. Some American teacher did not ask critical questions during the class. The ultimate goal of inquiry-based teaching is a student-centered way of learning scientific concepts; students themselves should construct their knowledge through the activities, such as posing questions, planning investigation, doing experiment, collecting data. However it is also said in NSES (NRC, 1996) that "at all stages of inquiry, teachers guide, focus, challenge, and encourage student learning (P33)" and "teachers match their actions to the particular needs of the students, deciding when and how to guide-when to demand more rigorous grappling by the students, when to provide information, when to provide particular tools, and when to connect student with other sources (P33).” Teachers’ guidance to conceptual developments is important.

An effective way to improve the situation will be to emphasize the importance of the role of teacher in classroom. In inquiry-based teaching lesson, teacher has the responsibility to guild students to learn the content. It was also suggested that the lack of rigorous content knowledge might be attributed to some misunderstanding of inquiry-based teaching; in the first open-response question, it was shown that when describing the inquiry-based teaching, fewer teacher mentioned teachers’ guide. More emphasis on the fully understanding of inquiry-based teaching is also recommended.

Need for the emphasis on students’ discussion in China

This study showed that most of Chinese lessons did not include students’ discussion. It is said in NSES (NRC, 1996) that “when engaging in inquiry, students describe objects and events, ask questions, construct explanations, test those explanations against current scientific knowledge, and communicate their ideas to others (page number).” Communication with others is an important part of inquiry-based teaching. In addition, Hollander (2002) concluded in his study that “Discussions force students to search for their own answers, give students practice in expressing their own ideas, increase their appreciation for complexity and diversity, and develop their listening, cognitive, and critical skills”. It is indicated that discussions increases student learning.

One of the reasons for the lack of students’ discussion in Chinese lessons might be the Chinese tradition of classroom. Chen (2005) mentioned that “in traditional classroom, students were told to keep quiet, raise your hand when you want to answer teacher's questions." It seems that keeping quiet was valued as behavior for good students. An effective way to improve the situation will be to emphasize on the importance of students' discussion. Once teacher realize the importance of student discussion, they should further create an atmosphere for students to feel free to talk with others.

LIMITATIONS OF THE STUDY

The selection of the sample puts a larger limitation on this study. Both samples in the US and China were convenience-based samples; the American participants were all from Dayton area, and Chinese participants were all come from Zhejiang province. So neither the American, nor the Chinese sample represents all high-school physics in the country. The results obtained from the survey and observational data should be treated cautiously because of the small sample size (N=19). The number of samples was small for a statistical treatment. However, using the multiple techniques to analyze the data helps us avoid making incorrect statements. In addition, we had the consistency in the result from the multiple analyses. In spite of this limitation, the study is still meaningful.

Reliability of the qualitative data analyses may be threatened by the accuracy of data collection and coding. Chinese data were collected by the researcher alone in China. It would be ideal if multiple researchers who understand both Chinese and English collected and analyzed data independently and checked inter-rater reliability. However, it wasn't possible because of the financial and time limitations on the research. Instead, appropriate measures were taken in order to minimize researcher's bias; observational data were co-coded by a professor who has been studying inquiry-based teaching for a long time and explanations on the Chinese lessons were provided her in order to help her understand the content of the discussion that was carried in Chinese language. American lessons were observed live by two coders. The inter-coder reliability was checked and high consistency was obtained.

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Appendix A

Informed Consent Forms

CONSENT FOR PARTICIPATION IN RESEARCH

Comparing instruction of high school physics in terms of the use of inquiry between US and China

A. PURPOSE AND BACKGROUND

Lingbo Qian, a graduate student in the Department of Physics at Wright State University, is conducting a research study to help understand how high-school physics teachers' thoughts and practices about the use of inquiry are similar and different in US and China. I am being asked to participate in this study because I am a teacher teaching physics in a high school in the US or in China.

B. PROCEDURES

If I agree to be in the study, the following will happen:

1. As a participant of this study, I will be asked to have the researchers observe and video-tape one of my physics lessons. The video material will not be used for any purpose other than analysis of the research.

2. I will be asked to complete a questionnaire about my attitudes toward inquiry-based teaching. It should take approximately 15 minutes to complete the questionnaire.
3. The observation of my lesson will be done at my school and will take a total time of no more than one and half hours. The questionnaire can be completed at any time that is convenient for me.

C. RISKS/DISCOMFORTS

There are no known risks involved in being a participant in this study.

D. CONFIDENTIALITY

Any information about me obtained from this study will be kept strictly confidential and I will not be identified in any report or publication. Video-taped data will be reviewed only by researchers. All the data will be destroyed upon the completion of the research study.

E. BENEFITS

There will be no direct benefit to me from participating in this study. However, the information that I provide may help physics educators better understand how to increase inquiry-based teaching in the USA and China.

F. COSTS

There will be no costs to me as a result of taking part in this study.

G. PAYMENT

There are no monetary or material compensations for giving my permission for my materials to be used in this study.

H. QUESTIONS

If I have questions about this research study, I can contact the researcher, Lingbo Qian at 937-430-3591 or qian.5@wright.edu. If I have general questions about giving consent or my rights as a research participant in this research study, I can call the Wright State

University Institutional Review Board at 937-775-4462. I can also contact her faculty advisor Sachiko Tosa, an Assistant Professor of Physics at Wright State University for any questions I have regarding this study. She can be reached at 937-775-2760 or sachiko.tosa@wright.edu. If I would like a copy of the group (not individual) results of this study, I can contact Lingbo Qian. It is estimated that these results will be available on or after January 1, 2013.

I. CONSENT

I will be given a copy of this consent form to keep.

PARTICIPATION IN RESEARCH IS VOLUNTARY. I am free to decline to be in this study, or to withdraw from it at any point. My decision as to whether or not to participate in this study will have no influence on my present or future status as a teacher.

If I agree to participate I should sign below.

____________________ ____

Date Signature of Study Participant

____________________ ____

Date Signature of Person Obtaining Consent

Appendix B

Survey Instrument

This survey help researchers to understand how high-school AP physics teachers think about inquiry-based teaching. Please answer to the following questions.

1) What teaching method do you think is effective for student understanding of physics content? Please describe it in two ways: ideally and practically.

2) How would you describe inquiry-based teaching?

3) Please indicate the extent to which you feel the importance of each of the following items as an element of inquiry-based teaching by circling the appropriate number.

Not at all very important

1. Prior knowledge and preconception 0 1 2 3 4

2. Element of abstraction (i.e., mathematical formula) 0 1 2 3 4

3. Real world example/application 0 1 2 3 4

4. Solid grasp of the subject matter content by teacher 0 1 2 3 4

5. Reflection by students 0 1 2 3 4

6. Multiple representation (models, drawings, graphs, concrete materials, manipulative, etc.) to describe phenomenon by students. 0 1 2 3 4

7. Challenging questions to students 0 1 2 3 4

4) How would you value the importance of students' active participation in discussion in your physics lesson? Please describe the reasons for your answer as well.

5) Please indicate the extent to which you feel the importance of each of the following items as an element of inquiry-based teaching by circling the appropriate number.

1.	Student---student interaction	0 1 2 3 4
2.	Student---teacher interaction	0 1 2 3 4
3.	Student presentation	0 1 2 3 4
4.	Group---group talk	0 1 2 3 4
5.	Whole class discussion	0 1 2 3 4
6.	Individual work	0 1 2 3 4

6) How would you value the importance of students' experiments and observations during your physics lesson? Please describe the reasons for your answer as well.

7) Please indicate the extent to which you feel the importance of each of the following items as an element of inquiry-based teaching by circling the appropriate number.

1.	Hands-on activity	0 1 2 3 4
2.	Demonstration by the teacher	0 1 2 3 4

Demographic questions

Please provide the following information by marking × in the appropriate box.

8) Are you male or female?

☐ Male

☐ Female

9) How old are you?

☐ 20s

☐ 30s

☐ 40s

☐ 50s

☐ 60s

10) How many years have you been teaching?

4. Less than 1
5. 1-2years
6. 3-5years
7. 6-10years
8. More than 10 years

11) What are the academic degrees you earned during the course of your higher education

and what were the fields of study?

1st Degree: Field of study:

2st Degree: Field of study:

If you have more than 2 degrees, please indicate degree and field:

12) What area(s) and level(s) are you certified to teach?

Area: Level(s):

If you are certified to teach more than one area, please specify:

Thank you very much for completing the survey.

Your time and input are very much appreciated.

Appendix C

Reformed Teaching Observation Protocol

		RTOP items	score	Subtotal	Comments
Lesson Design and Implementation	1	The instructional strategies and activities respected students' prior knowledge and the preconceptions inherent therein.			
	2	The lesson was designed to engage students as members of a learning community.			
	3	In this lesson, student exploration preceded formal presentation.			
	4	This lesson encouraged students to seek and value alternative modes of investigation or of problem solving.			
	5	The focus and direction of the lesson was often determined by ideas originating with students.			
Content: Propositional knowledge	6	The lesson involved fundamental concepts of the subject.			
	7	The lesson promoted strongly coherent conceptual understanding.			
	8	The teacher had a solid grasp of the subject matter content inherent in the lesson.			
	9	Elements of abstraction (i.e., symbolic representations, theory building) were encouraged when it was important to do so.			
	10	Connections with other content disciplines and/or real world phenomena were explored and valued.			
Content: Prodecural knowledge	11	Students used a variety of means (models, drawings, graphs, concrete materials, manipulatives, etc.) to represent phenomena.			
	12	Students made predictions, estimations and/or hypotheses and devised means for testing them.			
	13	Students were actively engaged in thought-provoking activity that often involved the critical assessment of procedures.			
	14	Students were reflective about their learning.			
	15	Intellectual rigor, constructive criticism, and the challenging of ideas were valued.			
Classroom	1	Students were involved in the communication of			

Culture: Communicative interaction	16	their ideas to others using a variety of means and media.			
	17	The teacher's questions triggered divergent modes of thinking.			
	18	There was a high proportion of student talk and a significant amount of it occurred between and among students.			
	19	Student questions and comments often determined the focus and direction of classroom discourse.			
	20	There was a climate of respect for what others had to say.			
Classroom Culture: Student/teacher relationships	21	Active participation of students was encouraged and valued.			
	22	Students were encouraged to generate conjectures, alternative solution strategies, and ways of interpreting evidence.			
	23	In general the teacher was patient with students.			
	24	The teacher acted as a resource person, working to support and enhance student investigations.			
	25	The metaphor "teacher as listener" was very characteristic of this classroom.			

Appendix D

Responses of Open-response Questions in Survey

Questions	**What teaching method do you think is effective for student understanding of physics content? Please describe it in two ways: ideally and practically.**
UA1	Inquiry is great if students are self-directed. It does not work well if they are not. I think a combination of inquiry, exploration, and direct instruction.
UA2	Ideal: students are part of a guile inquiry process, design their own experiment, and develop molds. Practically: teacher may need to adjust approach
UA3	Ideally, students would ask questions, and the teacher would provide answers, in both a laboratory and a classroom. Most the learning would be due to the students' finding their own answers. Practically, there must be a certain amount of lecture, because students don't know what questions to ask. Also, not many of them are as self-motivated as would be need for the ideal situation.
UA4	Lecture demonstration helps students combine math + science knowledge; lab gives students a change to explore physics knowledge. Combination
UA5	It's my belief that students develop deeper understanding and confidence in their understanding when they discover concepts for themselves. Therefore, inquiry is ideally most effective for depth of understandings. Practically, it is often the case that students engaging in inquiry will "discover" things that aren't "textbook-true." Also, true inquiry is impractical in terms of the time it takes to work through concepts. Given all that we have to teach in a year, I have to be very selective in where I use true inquiry.
UA6	Ideally-Use multiple methods to develop scientific reasoning & content understanding. For the big ideas, inquiry activities, reflection, discussion, and practicing principles are very effective methods. Lecture is an effective method for quickly disseminating information. Web resources are great for independent learners. Practically- Time restraints; local, state and national policies distract from effective teaching. With the number of topics in the curriculum, lack of student retention of math and previous science content, and large class size, much time is spent on non-academic activities and lecture becomes the prevalent teaching method for its time efficiency and effectiveness for large class sizes and the 47 minute class periods we have on most days.
UA7	I like to use a variety of methods in class for my students. Variety and practice is

	key to a physics class. We have demos almost every day before, during, or after a lecture on a topic for 90% of our lectures. Along with demos, the students frequently participate in lab (approx: 1 per week, 2 per unit) to compliment their physics problems that we give them on paper or out of the book.
UA8	Inquiry based learning through projects is certainly the ideal but often time constraints, especially in an AP Physics class present practical problems.
UA9	ideally: inquiry; Practically: lecture with experimentation +problem solve
C1	inquiry and inspire
C2	ideally: inquiry method; Practically: teacher lectured method
C3	Ideally, students find and ask questions, and communicate; get the answer. Practically, Time restraints; national policies distract from effective teaching, large amount of student, these factors make the teaching out of inquiry.
C4	ideally: heuristic method; Practically: exercise training method
C5	ideally: students find the problem by themselves, discuss with teacher; Practically: teacher lectured method
C6	inspire guide inquiry
C7	It can help students master the knowledge better when we chose appropriate teaching method. But every student has different, every method has it's limitation. so collect some level of students and teach them based on their properties is important
C8	ideally: students read book, find the problem, discuss with teacher; Practically: teacher guide students find the knowledge in a short time
C9	heuristic and discussion method
C10	ideally: main object is students' understandings, master model and have more hands on activities; Practically: lectured centered
Questions	**How would you describe inquiry-based teaching?**
UA1	Getting students to notice and infer
UA2	students help to formulate questions where needed to investigate design relevant experiment develop means to calculate data and interpret data based on various models
UA3	It is where the teacher is basically a facilitator, while the students “teach themselves” by experimentation. Students are given limited guidance by the teacher while they discover truth.
UA4	when a question is raised and then an answer is searched by using labs(activities)

	and information sources
UA5	Inquiry-based teaching is when you create an environment where students can perform experiments to discover fundamental principles for themselves.
UA6	Guiding students to develop understanding of scientific principles by thought experiments, laboratory procedures, and inductive/deductive reasoning instead of telling them the principles and then applying the principles to problems.
UA7	Inquiry –based teaching is another word for “discovery learning.” The purpose of inquiry is for the students to work together to discover a new topic on their own. It is very student-centered where the teacher is more of a facilitator instead of a lecturer.
UA8	Inquiry based teaching is learn the principle of the topic based on experiment or at least experimental data.
UA9	student led/teacher directed-develop the thinking’s process of students
C1	find problem ask question solve the problem
C2	use experiment and students' prior knowledge to inquiry the new knowledge by teachers' guiding
C3	We want cultivate students to have creativity and practice spirit, inquiry-based teaching is a effective and best approach.
C4	based on the prior knowledge, with the guided of teachers, make prediction of the unknown content, then learn the new knowledge
C5	Students get the answers by their prior knowledge and use of tool like books doing experiments
C6	students as a main body make a conclusion about an unknown content
C7	inquiry-based teaching can guide students into the teaching process, enforce the perceptual knowledge, guild students to think the unknown content
C8	inquiry-based teaching is a good method to cultivate the creativity of students
C9	give a problem, students find and ask the connection between problem and content, solve the problem
C10	treat students as the main body, teacher guide, but based on the real situation, there are not much inquiry
Questions	**How would you value the importance of students' active participation in discussion in your physics lesson? Please describe the reasons for your answer as well.**
UA1	Important, the more they can apply what you are teaching to their experience, the better they will understand.

UA2	It is very important, students need to have opportunities to compare data collected by other students and their representation and then to discuss trends variations extrapolations and sources of error
UA3	Student participation is essential. How else am I to know if they understand? Also, it keeps their minds engaged in the material. That is why I try to ask every student at least one question every day.
UA4	Some students learn very well by listening. Others learn through discussion, so participation is very important.
UA5	Active participation in discussions is important, particularly for some students. Certain students are able to be really engaged in ideas without actively contributing to the discussion. But most of the students need some engagement verbally to be fully engaged mentally. That said, most of the time I do not actively enforce universal engagement in discussions. As for the specific lesson you observed, discussion was pretty important because I wanted to get some feedback from students to help me assess their level of understanding.
UA6	It is valued. Regardless of teaching method, engaged students will learn with competent teaching. From experience, I have definitely had the most success with smaller classes, or when I have a cooperating (student) teacher. When the student-teacher ratio is lower, better classroom discussions can occur, and teachers can better ensure appropriate discussion when working in groups.
UA7	Very important. Being a part of the discussion helps students get a strong grasp on a concept. They are able to hear and participate in questions that they already had or new questions they hadn't thought of yet.
UA8	The students' participation is very important for two reasons. First the lesson is very boring without the active participation of the students. Second the participation gives immediate feedback about whether the students understand the material.
UA9	very valuable--the more they question the more they are involved+ vice verse
C1	The process of the discussion is the process of learning and thinking, it is very important.
C2	active participation is important, it help students get the unknown content by themselves
C3	active participation is important, it help students to think, and it is the process to got the knowledge for students
C4	Students' active participation reflect students' attitude of learning, students are

	the main body, only when students learning by themselves earnestly, then they will really get the knowledge.
C5	Important, students' participation could reflect the effectiveness of teacher's instruction, also students get know more.
C6	it is important, because students are the main body of learning
C7	Let students find their own thought, and adjust their opinion between discuss.
C8	students can experience and comprehend the knowledge
C9	students' active participation let students experience inquiry process of knowledge further more
C10	it can improve the students' interests and enthusiasm for studying
Questions	**How would you value the importance of students' experiments and observations during your physics lesson? Please describe the reasons for your answer as well.**
UA1	High, but it is difficult to get them to do it.
UA2	It is critical because student understanding must begin with concrete experience and then proceed to representations and abstract generalizations.
UA3	Students must have some hands-on activities to fully understand the experimental side of physics. Also, I've found that experiments cause students to have better understanding of lecture material.
UA4	I believe labs are extremely valuable to teach concept and observation/ thinking skill
UA5	In the lesson you observed, there was no experiment or lab work. I did perform a demonstration, the purpose of which was to give students another look at a concept that I had demonstrated the day before. But for my course as a whole, I believe lab work is very important for several reasons. Students need to interact physically with the phenomena that we study in order to more fully understand those phenomena. They need to be engaged in small-group discussions to more fully process the ideas involved. The need to engage in physical experiments because we need to drive home the most fundamental of Scientific concepts: that experiments and observations are the foundation of truth, rather than authority or theory.
UA6	They are important because they reinforce the students' conceptual understanding of the material.
UA7	Laboratory activities and Demonstrations make the physics "come to life" for the students. They are able to then relate to the tougher concepts that physics

	represents and they're able to reason through all those equations that we teachers write on the board and prove for them. Without lab my students would probably go crazy and just become the dreaded "plug & chug" extraordinaire!
UA8	Experiments and observations are very important. The most important aspect of experiments and observations is that they are done properly and in the spirit of science.
UA9	very important--it is the outward display of what their mind is thinking
C1	it is important for students doing the experiment, they can experience the mystery of physical in person
C2	students' participation make a better interactive, but Teacher's demonstration can help teacher control the class, and also have effectiveness
C3	students doing experiments can help them explore the new knowledge, can put the knowledge into practice, and get the real knowledge in their minds
C4	Only when students doing experiments in person, they can understand the new knowledge much better, can put the knowledge into practice, instead only by reading a book , understanding and mastering stay in the level of memory, easy to forget
C5	They are important—it help students to think by themselves, got the knowledge in their own way
C6	students' participation make a better interactive , but since class time limit and the requirements of the course, it is hard to control the time, and there are uncertainty factors in students' experiment; Teacher's demonstration can avoid the result of the above, but students participation will be less.
C7	teacher's experiment save time, and have a stronger purpose, students 'experiment have more uncertainties, but students can have a clear conclusion
C8	It is more important for students doing experiment than the teacher did. students' experiment develop skill of hands and mind, and also analytical ability; teacher's experiment develop the observation ability
C9	Let students connect to real life, experience the real life, and make a conclusion.
C10	Experiment did by students should be some surprise for them, first let students have some questions, also students should interested in the experiment; the experiment did by teacher should be show some physics model, which would be have more real meaning.

Appendix E

Description of each of observed lessons

These are description for each lesson wrote by researcher when observing the lesson, it includes briefly what teacher and students did in the class. The word from A1 to A9 and C1 to C10 represent the order researcher observed the lessons from the US (A) or China(C). For example, A5 means the fifth lesson in the US the researcher observed.

A1: The whole class was designed as student-centered. Students conducted the experiments all by themselves for 50 minutes out of 60 minutes of the class time. Such as: They drew the line of light ray from a laser pointer on paper. They also used a mirror to check the position of colored pushpins placed in a straight line on an index card for investigating how light travels. Teacher was sitting at her desk in the classroom doing her own things. She did not talk and ask questions unless students asked her to be checked during the experiments. The checkpoint happened two times in this class, during which teacher listened to student explanation of what they did and gave comment with one or two sentences. Even after all the experiments were over, teacher didn't summarize anything. The whole class kept silence and waited for the ring. However the packet for the experiments appears to have good pre-activity questions, which may have guided students generate predictions before doing the experiments. The procedures are described in such a way that students can perform the experiments step by step. The questions written in the packet, such as "Does the light actually travel from behind the mirror?" and "How can you check that your incident and reflected rays are correct?"

A2: Teacher started the class for checking homework. Then, he asked a question that when adding more bulbs into a parallel circuits, will the total resistant goes up or down. Students gave them prediction by raised their hands; after prediction teacher asked students to simulate the parallel circuits. Student follow the instruction by simulating the parallel circuits on the computer with software, by adding bulbs in the circuits, students got the data： voltage and current; and then students used the data to calculate the total resistant. Finally after students having the total resistant, teacher asked them to input the data into excel, and to get the graph with relationship between total resistant and number of bulbs. In this class, teacher led students to get concept by doing exploration: simulation and analysis. Graph was used in this lesson for representing the changing of resistant, and formula was introduced to give the relation of resistant with length, surface area, and property of wire. Additionally, teacher showed some wires to help students connect the content to their daily life. This class more like peer discusses, but I did not see much talk between peers. Most of the talking has been done by teacher, such as he asked students what and how to do with the simulation and analysis. Sometime teacher came to students and checked the data, but it did not happen a lot. There was also no group-group talk. Whole class discuss happened at the end of the class, however it was more like teacher's speech, students were listening to the teacher.

A3: Teacher started with asking students to touch the table leg of the table and other thing to feel the temperature, and asked why it feels different even the temperature is same, several students answered randomly, and then teacher guided to conduction. By asking how temperature conducts between inside and outside of the classroom, teacher guided to the formula of conduction. Second, teacher wrote the concept of convection on the board, and explained it by using the example of the heat convection of the classroom. Finally, teacher taught the concept of Radiation by giving the example of it, and also introduced the formula of radiation. After teacher finished the lectured, two students asked questions. And then teacher started to check homework. This is a teacher centered class, however teacher asked a lot questions, and sometimes single students answered it sometimes students answered randomly, it helped to guide the concept. There were no group-group talks or whole class discussion.

A4: Teacher first explained Archimedes' principle by showing some pictures, then using formula p=F/A to explain some principle of mechanics and explained the exercise, it seems simple, only need plug in some number. Teacher told the concept of buoyancy, explained by picture, and then explained the relevance exercise. Finally, teacher use the example of why boat can float to explain the buoyancy. Teacher taught the concept by explaining the relevant exercise, and students already did those exercise. Most of the exercise seems simple, just need to find the formula and plug in the number. Teacher asked several questions students randomly answered them, and one student asked three questions to the teachers. There was no group-group talk whole class discussion or students-students discussion.

A5: Teacher show a little experiment of light at first, and the explained how the color filter works by showing the color pictures, after explained the concept, teacher explained the exercise that students have did. Then teacher gave each student a click and show a series of questions, every time students did the questions, teacher waited for 1 or 2 minutes, then use computer show all the students answers, if most of the students did it wrong, teacher will explained it. But the questions seems easy, such as: the focal length of converging length is 1 bigger than zero, 2 smaller than zero; what is the total reflection angle with n1=1.35, n2=1.25; This class was like a teacher centered exercise class, students did multiple chose on the class; teacher did not asked many questions, and 4 questions asked by students. During the click questions, students discussed with peers randomly, except that there was no other discussion.

A6: Fist teacher checked homework. Then teacher asked a student draw a parallel circuit on the board, and he explained. After that, teacher asked students to discuss two questions on the work sheet; it was about the current of parallel circuit for 10mins. Then teacher asked the answers, single students explained by their own way. After that, teacher started taught the total resistance of the parallel circuit, he asked students made the prediction, and then teacher calculated the total resistance to show the answer. By knowing the total resistance, teacher asked student how to calculate the total current, single student answered it, then teacher show the calculation by some numbers. At last, teacher concluded the parallel circuit by comparing to the series circuit, most of the conclusion was about formula. At the end of the class, teacher gave the homework, and students did the homework on the class, some of them asked teacher question until the ring rang. This was a teacher centered class, teacher taught the concept connect to the homework, teacher asked a little questions, and single students answered them, students asked question at the end of the class privately, there were students-students discussion at the beginning of the class. No other discussion happened.

A7: Teacher introduced some concept, like electric potential energy point charges for five minutes. Then teacher handed out the exam sheet for last class, when students got the sheet, they discussed with peers. After 10 minutes, teacher asked to do simulation on the computer follow the experiment sheet. Students were simulating the force between different charges, and built charge path by adding negative or positive charge for the rest of the class time. This was a student centered class, Students-students talk and group-group talk happened during the simulation. Also teacher was going around answering students' questions. But there were no whole class discussion at the end.

A8: it was an exercise class for AP test. There were 31 questions. For every question, teacher read and explained it, then asked some relevant question to guided students to get the answer. Several students randomly answered the question. Most of the question were easy, teacher introduce the formula and asked students to plug in the number. If the problem was difficult, teacher would explain more detail. Some time teacher said some strategies to have to AP test. It was a teacher lectured class; teacher asked some questions, and one question asked by student. Students sometimes discussed with peers privately.

A9: Teacher started the class by asking the content students had learnt last classes, and guided made the conclusion about single lens and mirror. Based on that, teacher guide students to make up the telescope by multiple lens, he taught the concept by adding lens one by one, at the same time asking students questions; and using the formula, teacher guided students to figure out the magnification. Teacher then introduced another three kinds of telescopes by using different kinds of lens and mirrors. For teaching the principle of the telescope, teachers draw the diagram on the board for every time. At last, teacher gave two questions to students as homework, and they can started do it at the class, during which students discussed in a group. This was a teacher lectured class, but teacher asked lots of questions, and several students answered them. Two questions asked by students. Except group discussion happened at the end, there were no other discussion happened between students.

C1： At first, teacher concluded the content students learnt last class, by asking questions, teacher guide students to propose universal gravitation and centripetal force and their formulas. Teacher asked question how can we calculate the mass of the earth, by asking questions, teacher show the students the method to calculated the math of the earth. Then teacher asked students solve to problem of calculate the mass of moon, students did it individually by several minutes. After that, teacher asked if there were another method to calculate the math of earth, teacher guided students to got the second method, and conclude these two method. Then teacher asked students to solve the mass of sum. Students took 2mins to solve it, and teacher explained it after that. Second, teacher guided students to solve the density of the earth, and then asked students solve the density of sum by themselves. At last, teacher concluded all the methods to calculate the mass of centre object and compare with the methods of calculating the density of centre object. This was a teacher lectured class, but teacher asked a lot of questions, and the whole class answered them randomly. There no question asked by students and no any kinds of discussion happened.

C2: at the beginning teacher show three resonance phenomena, asked students to think about them, and asked students read the book for 10mins. After reading, teacher asked students find out any kinds of oscillate and the relevance frequency. All the students answered randomly. Then teacher show the experiment equipment to demonstrate the natural frequency and frequency of forced oscillation, students made suggestion about how to do the experiment, and take part in it, like count the time, also after experiment, students discuss the result by the questions asked by teacher. After the concept of frequency, teacher show the demonstration of resonance, again students made prediction and suggestion, then count the phenomena and had a discussion guided by teacher, finally come out the idea with resonate. This class guided by teacher, students actively participates in the experiments teacher did. During the whole class, teacher asked lots of questions, most of the students answered randomly, no questions asked by student. Whole class discussion happened, there were no other discussion.

C3: Teacher asked students review the content for last class guided students come up the formula of universal gravitation and centripetal force, and asked students how to calculate the mass of earth. Teacher guided students to figure out the methods of calculating the mass of earth by asking questions. Then teacher asked if there is another method, again teacher guided students to conclude the other method. After these two methods, teacher taught the way to calculate the mass of sum, and asked student to derive the density of the sum. Students spent 5mins to solve the question individual. Teacher picked some typical wrong answers form the students and explained them. Then teacher guided students concluded some notification for doing these kind of calculations. At last, teacher asked students to read the book about the content of how to find unknown object for several, teacher explained it after reading. This was a teacher lectured class, but teacher asked a lot of questions, and the whole class answered them randomly and three answered by single student, one question asked by student. There were no any kinds of discussion happened.

C4: Teacher guided students to conclude the content for the last class by asking questions. Then teacher showed a picture about an apple falling form tree, and said Newton thought that the force of gravity may be the same kinds of the force of earth to moon. Then teacher asked students to read the book for 5mins. After reading, teacher asked what method does Newton come out to prove and why, single students answered. Then teacher guided students to follow Newton's way to calculate the gravity of a object with same mass to moon and also calculate the force that earth to moon by the period of the motion of moon. Then it turned out these two forces had same number. Teacher guided students made the conclusion of universal gravitation and formula. Then teacher introduce Cavendish, and his experiment to calculate the G, teacher did a little experiment to show the principle of his experiment. At last, teacher asked students to calculate the universal gravitation between two people away 1 meter, by this calculation teacher guided students to make the some notification when using the formula. This was a teacher lectured class, but teacher asked a lot of questions to guiding students, most of the questions answered by whole class randomly, three of them answered by single student, three questions asked by students during the lectured, there were no any kind of discussion happened between students.

C5: First teacher explained different kinds of satellites like synchronous satellites polar satellites by drawing them on the blackboard, and give some examples; secondly, teacher guided students to calculate the difference between gravity and universal gravitation, and gave an example. Third, teacher guided students to calculate the velocity of a satellite. At last, teacher asked students how to launch the synchronous satellites; he guided the students to get three steps. This was a teacher lectured class, but asked a lot of questions, all the result guided by teacher's questions, there was one question asked by students. There were no discussion happened between students.

C6: At First, teacher asked students to do a little game to introduce the theme of the class-- pursuit of conservation-energy. Teacher asked several questions about conservation in daily lives like number mass and so on. Then teacher showed the free fall of a ball, asked students to calculate the velocity for two points. After several minutes' calculation, teacher guided students to conclude that there was a connection between velocity and high. After this example, teacher asked students to calculate another example---a ball falling from a slope; again students derive the relation between velocity and height. After these two examples, teacher guided students get the concept to conservation of energy. Then teacher show the experiment of Galileo's by video. At last, teacher introduced other kinds of energy like heat light and so on. Then teacher asked students to read the book for rest of the time. This was a teacher lectured class, but asked a lot of questions, all the result guided by teacher's questions, there were two questions asked by students privately, and teacher answered them publicly. There were no discussion happened between students.

C7: At First, teacher asked what students had learnt for last class, whole class answered the questions. Then based on students' answer, teachers derive the of the equation of theorem of kinetic energy step by step. Teachers asked students to provide some notifications when using the theory, several students answered the question. After teachers finished introducing the theory, he give three relative problems to students do solving, for each problem, students had 3to 4 minutes to solving, and then teacher asked students to give their result, then explained the problem.

C8: teacher started the class by introducing the vibration in the daily life, and then asked students to read the book for 7 minutes. After students finishing the reading, teacher show a little experiment of vibration, and then introduce the concept of vibration, how to represented the vibration. Then teacher draw the graph of a spring oscillator, by introduce how the oscillator vibrate, teacher taught the mode of ideal vibration, then he provide a S-T diagram of vibration and show how to get it. At last teacher asked students to simulate the S-T diagram with peers using papers and pencil, then students did the experiment for 10 minutes. After that, teacher show some good S-T diagram students did. Teacher show another experiment of vibration of a ball vibrates by the force form air flow.

C9: it was an exercise class for college entrance exam. Teacher gave students about 20mins to do the problems first, during this time, teacher went around check the students and also he got prepared to problems on the boards. For every question, teacher first asked students' answers, and then explained it. Single student was asked to stand up to answer the questions. For some difficult questions, teacher wrote some formula and draw some diagrams on the boards and explained the questions step by step, at the same time he keep asking questions to students, but no students answered them. It was a teacher lectured class; but students solved problems by themselves for half of the class times.

C10: it was an exercise class for college entrance exam. Students already finished the problems before the class. Teacher gave answers to students at the beginning of the class; all students checked their own answers. Teacher asked to students which questions they did wrong and need explanations. Students said the difficult questions and teacher explained one by one. For each question, teacher first asked students' wrong answers, and then explained it step by step by writing some formula and drawing some diagrams on the boards, at the same time she keep asking questions to students, all students randomly answered the questions. It was a teacher lectured class; but students seem actively take part in the class.