THE UNIVERSITY OF QUEENSLAND

AUSTRALIA

An Investigation of Chinese Senior Secondary Physics Teachers' Perceptions and Implementation of Inquiry-Based Teaching in China

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BSc; GDipEd; MEdRes

A thesis submitted for the degree of Doctor of Philosophy at

The University of Queensland in 2014

School of Education

Abstract

Recent reform to the Chinese national secondary science curricula has made inquiry a compulsory component of teaching objectives. It encourages science teachers to provide their students with more inquiry experience. However, many Chinese science teachers are finding it very challenging to adopt inquiry-based teaching (IBT) in their classrooms (B. Zhang, et al., 2003). The traditional teaching approaches still dominate in Chinese secondary classrooms (Salili, Zhou, & Hoosain, 2003). In addition, many teachers can not conduct IBT effectively (Y. Zhao, 2011; Qian, 2012). These issues are mirrored in many other education systems in the world where IBT is mandated. Evidence suggests that teachers all over the world struggle to implement inquiry-based changes to their teaching practices (R. Anderson, 2002; Campbell, Oh, Shin & Zhang, 2010).

With an aim of addressing the barriers to the effective enactment of IBT in science classrooms, this study contributes to our understanding of the enactment of IBT by investigating Chinese senior secondary physics teachers' perceptions and implementation of IBT. A mixed-methods approach has been employed to explore teachers' beliefs about science teaching and learning, perceptions of IBT, and their inquiry practices. Using teacher surveys, in-depth semi-structured interviews and case studies, this study provides an insider's view to Chinese physics teachers' perceptions and enactment of IBT in their unique teaching contexts.

This study has found that Chinese secondary physics teachers' beliefs about the nature of science, teaching, and learning, were closely aligned (or nested) but sometimes conflicting. These beliefs interacted together to exert complex influences on teachers' instructional decisions regarding the use of IBT, which in turn affect subsequent inquiry practices. The decision-making process included a process of interpretation in which teachers matched their understanding of inquiry with their beliefs. Teachers' prior experience played vital roles in developing teachers' beliefs, their understanding of inquiry, and their pedagogical knowledge and skills for IBT.

This study also found that Chinese secondary physics teachers developed diverse inquiry practices, which shared some common pedagogical characteristics. There is a discrepancy, however, between teachers' intended inquiry practice (instructional decisions) and actual inquiry practice in their classrooms. The teaching context, teachers' perceptions of inquiry, and their pedagogical knowledge and skills for IBT affected the way in which their instructional decisions were put into effective inquiry practices.

This study also drew attention to the powerful influences of the sociocultural context in China on teachers' instructional decisions and their inquiry practices. Among these factors, the test-oriented student assessment system and limited teaching time were found to be particularly influential on teachers' implementation of IBT. Other influential contextual factors included: the nature of students, classroom culture, school environment, collegial influences, and practical factors such as class size and resources.

These major findings provide an overall picture of how Chinese physics teachers perceived and implemented IBT in the teaching context in China. It is suggested that it is possible and practical for Chinese physics secondary teachers to implement IBT. However, their inquiry-based instruction was often constrained by their beliefs and their teaching contexts, and distorted by their misconceptions and lack of pedagogical knowledge about inquiry. These issues point to three compelling challenges that Chinese physics teachers are encountering for their use of IBT, including challenges due to changing beliefs, pedagogy challenges, and cultural challenges. These challenges need to be appropriately addressed in order to improve teachers' success in implementing IBT.

The study contributes to knowledge in international science education by offering deeper and more detailed insights into Chinese senior secondary physics teachers' perceptions and implementation of IBT. Particularly, it adds to the existing body of research on classroom enactment of inquiry-based teaching by providing five contrasting cases, describing how teachers' beliefs, perceptions of inquiry, and inquiry practices interacted in their teaching contexts. The study also provides valuable information that can help researchers, teacher educators, and curriculum designers support teachers' implementation of IBT.

Declaration by author

This thesis is composed of my original work, and contains no material previously published or written by another person except where due reference has been made in the text. I have clearly stated the contribution by others to jointly-authored works that I have included in my thesis.

I have clearly stated the contribution of others to my thesis as a whole, including statistical assistance, survey design, data analysis, significant technical procedures, professional editorial advice, and any other original research work used or reported in my thesis. The content of my thesis is the result of work I have carried out since the commencement of my research higher degree candidature and does not include a substantial part of work that has been submitted to qualify for the award of any other degree or diploma in any university or other tertiary institution. I have clearly stated which parts of my thesis, if any, have been submitted to qualify for another award.

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Publications during candidature

Zhu, Z., & Geelan, D. (2013). Chinese secondary physics teachers' beliefs and instructional decisions in relation to inquiry-based teaching. *Electronic Journal of Science Education, 17*(2), 1-24.

Zhu, Z., & Fan, X. (2014). Improving the efficacy of questioning techniques in science teachers' inquiry instruction. In Pixel (Ed.), *Conference proceedings of the 3rd International conference of New Perspectives in Science Education* (pp. 400-403). Florence, Italy: libreriauniversitaria.it. Available http://conference.pixel-online.net/NPSE/files/npse/ed0003/FP/0303-STM202-FP-NPSE3.pdf

Zhu, Z. (2010). *An analysis of Chinese secondary physics teachers' beliefs and instructional practices regarding inquiry-based teaching*. Paper presented at the 2010 Australasian Science Education Research Association (ASERA) Conference, Port Stephens, Australia.

Zhu, Z. (2008). *A comparison study of students' reasons for taking Physics between two Australian high schools and two Chinese high schools*. Paper presented at the 2008 Australian Association for Research in Education (AARE) Conference, Brisbane, Australia

Publications included in this thesis

No publications included

Contributions by others to the thesis

No contributions by others.

Statement of parts of the thesis submitted to qualify for the award of another degree

None

Acknowledgements

I would like to express my sincere thanks to those who have helped and supported me along this journey. I am grateful to my advisors, Dr. Tony Wright, Dr. David Geelan, and Prof. Martin Mills, for their continued patience, encouragement, understanding and advice. I am thankful too for the guidance that Prof. Robyn Gillies has offered as the chair of my review panel. I am also appreciative of the other members of my review panel for their insightful comments and feedback, including Prof. Martin Mills and Prof. Rob Gilbert.

I would like to thank the teachers and students who participated in this study. Thank you for your patience and cooperation in this research project and giving me so much of your valuable time. My sincere thanks also go to the schools and district research leaders, for your support and offering me opportunities to sample and access the participants in schools.

I thank my colleague and friend, Xinxin Fan, for the stimulating discussions and comments, and for all the fun we have had in the last three years. Also I thank my colleagues in University of Queensland: Deirdre White, Michelle White, Jianwei Liu, and Neville Smith for their warm support during my study.

I especially want to thank my husband, Fangming, and my lovely twin daughters, Laura and Rayna. Without your warm love, unfailing support and encouragement, I would not have been able to complete this work.

Keywords

science education, inquiry-based teaching, senior secondary physics teaching, teacher beliefs, perceptions of inquiry, teaching context, China

Australian and New Zealand Standard Research Classifications (ANZSRC)

ANZSRC code: 130212, Science, Technology and Engineering Curriculum and Pedagogy, 80%

ANZSRC code: 130313 Teacher Education and Professional Development of Educators, 20%

Fields of Research (FoR) Classification

FoR code: 1302, Curriculum and Pedagogy, 80%

FoR code: 1303, Specialist Studies in Education, 20%

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List of Abbreviations used in the thesis

ANOVA	Analysis of Variance
ASEP	Australian Science Education Project
BSCS	Biological Sciences Curriculum Study
CBAM-LoU	Concern-Based Adaption Model - Level of Use
CEE	College Entrance Examination (China)
DA	District area
DCP	District Coordinators of Physics (in teaching and research)
DIS	Digital Information System
ESC	Elementary Science Study
IBT	Inquiry-based teaching
LoI of IBT	Levels of Implementation of IBT
MOE	Ministry of Education of the People's Republic of China
NRC	National Research Council
NSES	National Science Education Standards
NSTP	Nuffield Science Teaching Project
OECD	Organisation for Economic Co-operation and Development
PCSSSS	Physics Curriculum Standards for Shanghai's Secondary Schools (China)
PSSC	Physical Sciences Study Committee
SCIS	Science Curriculum Improvement Study
SHMEC	Shanghai Municipal Education Committee (China)
SSSEE	Senior Secondary School Entrance Examination (China)
ST	School type
TE	Teaching experience

1. Introduction

This thesis presents a multi-method research project conducted in Shanghai, China, with the intention of deepening our understanding of how secondary senior physics teachers perceive and implement inquiry-based teaching (IBT), in their teaching context. This thesis provides a snapshot of the status quo of IBT in Chinese secondary physics teachers' classrooms based on information collected from surveys, interviews, and case studies. Moreover, it brings an insider's view of teachers' inquiry practice by presenting the case studies of five teachers who interpreted inquiry within their belief system, and designed and adapted inquiry-based instruction to their students in their teaching contexts.

1.1 The context of this Study

The context of this study is the recent reforms to the Chinese national science curricula. This ongoing curriculum reform requires science teachers to change their educational beliefs and instructional practices to accommodate the curriculum change, to look after the need of every student and focus on developing students' science literacy. A shift from teacher-centred to student-centred instruction is emphasised, and inquiry-based teaching (IBT) is strongly encouraged (Ministry of Education of PRC [MOE], 2006a, 2006b).

"Inquiry in the classroom" refers to an intellectual process through which students develop knowledge and understanding of scientific ideas and the ways in which scientists study the natural world (National Research Council [NRC], 1996). Inquiry-based learning and teaching has been defined as a key element of science education reform in many educational jurisdictions throughout the world. For example, the Australian Science Education Project (ASEP) was developed between 1969 and1974 as Australia's first national curriculum project. The ASEP materials are activity based and engage students in inquiry strategies (Fraser, 1978). IBT approaches to school science have developed ever since. The Nuffield Science Teaching Project (NSTP) was developed in England in 1960s. It was the first large-scale attempt to reform both teaching approaches and content in school mathematics and science in England. The developed courses were characterised by their reliance on practical work carried out by students and the spirit of inquiry that infused the teaching (Nuffield Foundation, n.d.). The National Science Education Standards (NSES) (NRC, 1996) was developed in the United States with a strong advocate for IBT. According to NRC, inquiry is not only a learning goal but also a teaching method. The standards were broadly consistent with the objectives of a number of curricular projects undertaken in the 1960s and 1970s, including the Biological Sciences Curriculum Study (BSCS) programs in biology, the Physical Sciences Study Committee (PSSC) materials in physics, and the Science Curriculum Improvement Study (SCIS) and Elementary Science Study (ESC) units for elementary school science, which incorporated approaches to teaching and learning that would be consistent with the spirit of inquiry (NRC, 2000).

The Chinese national science curricula also attach importance to inquiry-based teaching and learning. These reforms advocate "a variety of other learning activities such as active participation, exchange and co-operation, exploration and discovery to enable the students to become independent learners", and state that "learning science should be a hands-on experience, where the student actively deploys his scientific knowledge" (Poisson, 2001, p. 17). The reform initiatives are aimed at a change of the classroom culture, putting emphasis on more authentic contexts and student activities containing elements of inquiry.

Therefore, the objectives of the science curriculum standards include inquiry as a compulsory component. Consequently, science teachers are strongly encouraged to use IBT in their classrooms to teach science. They are encouraged to provide their students with more inquiry experience, yet are not provided with ready-made models of enacting IBT.

However, issues emerge in science teachers' implementation of IBT. Many Chinese science teachers found it very challenging to adopt IBT in their classrooms (Lan & Zhou, 2006; G. Liu, 2004; B. Zhang, et al., 2003; Y. Zhao, 2011). Furthermore, many Chinese secondary physics teachers could not conduct IBT effectively (Y. Zhao, 2011; Qian, 2012). In addition, a range of practical constraints, such as time and the assessment system, have been reported to impede teachers' implementation of IBT (Lin, 2003; F. Liu, 2008; Muju Zhu, 2007; Y. Zhao, 2011).

These issues are mirrored in many other education systems in the region and the world in which IBT is mandated. Evidence suggests that teachers all over the world struggle to implement inquiry-based changes to their teaching practices (R. Anderson, 2002; Campbell, Oh, Shin & Zhang, 2010; Roehrig & Kruse, 2005; Saad & BouJaoude, 2012). One issue is that IBT requires science teachers to change or adapt their existing belief systems to accommodate the philosophy of IBT (R. Anderson, 2002; Crawford, 2007; Keys & Bryan, 2001). Changing teachers' beliefs, however, is difficult (Nespor, 1987; Pajares, 1992; Richardson, 1996). Meanwhile, IBT requires the teacher to engage students in the processes of inquiry, which demanding a high level of pedagogical knowledge and strategies, such as how to coach, mentor and collaborate with students (R. Anderson, 2002; NRC, 1996). The trouble is that many teachers are left to their own devices to develop the necessary knowledge and strategies. Furthermore, teachers encounter barriers and dilemmas in their implementation of IBT, such as school culture and political issues (R. Anderson, 1996; Tobin & McRobie, 1996; Wallace & Kang, 2004).

Noting these issues in science teachers' enactment of IBT, prior research suggests that "only through a more detailed view of the nuances of interpretation and enactment of curricula by teachers can individuals begin to build an understanding of best means to support productive enactment of classroom inquiry science teaching" (McDonald & Songer, 2008, p. 990). This study, therefore, is designed to reveal the challenges to the effective enactment of IBT in science classrooms, and contribute to our understanding of the enactment of IBT by investigating how Chinese senior secondary physics teachers interpret IBT and implement it in their specific teaching contexts. The answers to these questions are significant in attempting to understand teachers' perceptions and implementation of IBT in their unique teaching contexts. Meanwhile, they provide valuable information that can help researchers, teacher educators, and curriculum designers support teachers' implementation of IBT.

1.2 The issues in Previous Research

Chinese researchers and educational leaders have exerted considerable effort to convince teachers to try IBT. Earlier Chinese studies looked into classroom practices with a focus on student academic achievement and/or engagement with science activities in implementing IBT (e.g., D. Huang, 2003). A small amount of studies pointed out that teachers' beliefs, perceptions and knowledge about inquiry play an important role in their implementation of IBT (e.g., G. Liu, 2004; Y. Zhao, 2011). Little research attention, however, has been given to investigating how teachers interpret inquiry within their belief systems and in turn affect their implementation of inquiry, as well as their motivations and reasons for implementing IBT.

Similar issues can be found in earlier studies in western countries showing that teachers' perceptions have not been given adequate research attention. Keys and Bryan (2001) note, "We have little knowledge of teachers' views about the goals and purposes of inquiry, the processes by which they carry it out, or their motivation for undertaking a more complex and often difficult to manage form of instruction" (p. 636). Gregoire (2003) also argues, "What is needed is greater understanding of the mechanisms involved in belief change and how beliefs affect the interpretation of reforms" (p. 149).

Other Chinese researchers attempted to find a solution to this problem by focusing on theories (e.g., Dong, 2010; Jiang, 2004; H. Li, 2003; Lu, 2005; Yan Wang, 2008). They developed theoretical instructional models/process for IBT and provided sample lessons, and sometimes tested, or required the collaborative teachers to implement them in the classroom. They were concerned about the models/processes of carrying out IBT, and the resultant consequences on students' learning outcomes, particularly the test scores. Although these studies demonstrated promising results in terms of improving students' test scores and interest in learning, they generally ignored the complexity of the teaching enterprise, leading to a depersonalized, context-free, and mechanistic view of teaching (Doyle, 1990). There is a wide gap between the developed theoretical models and the real practice in teachers' specific teaching context. At the same time, the research on how teachers interpret inquiry, develop, and enact practice-oriented instructional models in their unique teaching contexts is scant.

Again, there are similar issues identified in previous studies conducted in western countries. Keys and Bryan (2001) in their review of the studies on inquiry-based instruction argue that, in much of the previous research on inquiry, inquiry-based instruction was initiated and designed by researchers, and taught by researchers themselves or collaboratively implemented with the expertise of teachers in their classrooms, "limiting our understanding of how inquiry teaching and learning look in an ordinary classroom taught by teachers." Therefore, they reiterated that "more research is needed on teacher-designed approaches to inquiry based instruction, as well as teacher-designed adaptations of curriculum to their own unique situations" (p. 641).

These previous Chinese studies mostly followed quantitative research agendas to assess the effectiveness of IBT. Two typical quantitative research methods seemed to be given great emphasis in previous Chinese studies. One is a quantitative survey with teachers and students (e.g., D. Huang, 2003), the other a quasi-experimental design using an experimental and a control group (e.g., Jiang, 2004; X. Liu, 2011; Yan Wang, 2008). These research methods cannot capture the complicated nature of classroom practices.

Very limited research attached importance to qualitative and multi-method research methods. Several studies (e.g., G. Liu, 2004; Hong, 2006; Y. Zhao, 2011) have examined teachers' perceptions and enactment of IBT in the classroom, and identified a few reasons for the teachers' failure or ineffectiveness in the implementation of IBT. They emphasised the importance of transforming teachers' beliefs for successful implementation of IBT. They, however, did not observe how teachers interpret, create, or adapt conceptions of IBT within their belief system, and incorporate it into their day-to-day teaching practice under the influence of their teaching contexts. None of them applies a sociocultural lens to examine "how teachers implement inquiry within the cultural context of their local situations" (Keys & Bryan, 2001). It seems there is a big piece missing in the educational research map when it comes to understanding the reasons for teachers' reluctance to take up the inquiry modes mandated in the new curricula.

1.3 Purpose of this Study

As stated above, a critical gap is revealed in the existing Chinese research on understanding teachers' perceptions and enactment of IBT. Given this situation, the current study applies a sociocultural lens to examine how teachers interpret and implement inquiry within the cultural context of their local situations. It is intended to explore how the beliefs Chinese physics teachers hold affect their instructional decisions regarding IBT and how they interpret IBT and implement it in their regular teaching. The study also examines what shapes teachers' inquiry practices in the classroom, and the challenges they are encountering in their implementation of IBT. The answers to these questions are significant in attempting to understand the challenges, and to establish the possibility and practicality of incorporating IBT in Chinese secondary physics teachers' regular teaching practice, and therefore, proposing several implications for teacher professional development and curriculum reform. This study is also expected to add to the existing body of literature on IBT, by providing valuable information on Chinese physics teachers' perspectives and their instructional models of implementing IBT. This study will make a significant contribution to knowledge in this area.

1.4 Research Questions

This study aims to address the following research questions:

- Q1: How do Chinese physics teachers perceive IBT?
- Q2: What are teachers' beliefs about the nature of science, teaching, and learning ?
- Q3: How do Chinese physics teachers implement IBT in their specific teaching contexts?
- Q4: What are the relationships between teachers' beliefs, perceptions of IBT, and their implementation of IBT?
- Q5: To what extent does the teaching context in China influence teachers' implementation of IBT?

1.5 Theoretical Framework

Keys and Bryan (2001) suggest four theoretical frameworks appropriate for conducting research on teacher beliefs, knowledge, and practice of inquiry. These include: 1) coordination of cognitive constructivist and sociocultural constructivist frameworks, 2) cultural models of meaning, 3) dialogic function of language, and 4) transformational models of teaching reform. They suggest that these four theoretical frameworks may be used individually or in combination.

This study combines the first and fourth ones as the theoretical frameworks. The main idea of the first theoretical framework is that “a sociocultural lens can be applied to research on inquiry-based instruction by examining how teachers implement inquiry within the cultural context of their local situations, and how tools, language, and social organizations are used by teachers and interpreted by students” (Keys and Bryan, 2001, p. 633). Keys and Bryan suggest that working with teachers will necessitate taking into account cultural factors in their environment, including constraints to inquiry such as time and resources. The last theoretical framework emphasises applying the construct of teacher beliefs to research on inquiry, because belief structures play a major role in teacher decision making about curriculum and instructional tasks (Nespor, 1987; Pajares, 1992; Richardson, 1996). Therefore, research on teachers’ instructional change should recognise the importance of teacher beliefs and the integral relationship between beliefs and teaching practices.

Keys and Bryan (2001) go further to claim that “although a variety of methodologies that might be appropriate for any particular study may be derived from these frameworks, we believe the most fitting included naturalistic, interpretive, ethnographic, case, dialectical, hermeneutic, and phenomenological methodologies (p. 632).” This study employs multi-method methodology that is further justified later. Within the selected theoretical frameworks, this study makes use of multi-method research methodology, along with a sociocultural lens, to find out how Chinese secondary physics teachers perceive and implement IBT in their specific teaching contexts.The Structure of the Thesis

This thesis consists of eight chapters. Following this introductory chapter, a review of literature is presented in Chapter 2 to establish the need for a better understanding of teachers’ perceptions and enactment of inquiry-based teaching (IBT). Chapter 3 details the methodologies used to answer the research questions. The main findings from the teacher surveys, teacher interviews, and five case studies are respectively reported in Chapters 4, 5, and 6 to paint the picture of the status quo of IBT in Chinese physics teachers’ classrooms. Chapter 7 triangulates and discusses the main findings from surveys, interviews and case studies, in relation to the research questions, and constructs a model for understanding the relationships between teachers’ beliefs, perceptions, and inquiry practice, in the current teaching context in China. The thesis concludes with Chapter 8 which summarises the findings, describes the implications and limitations of this study, and suggests directions for future research.

2. Literature review

This chapter presents a literature review that outlines the foundation of the present study with the intention of advancing our understanding of science teachers' perceptions and enactment of inquiry-based teaching (IBT). This body of reviewed literature included both relevant studies that were done in western countries and those conducted in China. Relevant literature is reviewed that describes inquiry and IBT, theoretical instructional models of implementing IBT, and how inquiry is enacted in the real classroom setting, as well as the reasons why teachers do or do not adopt IBT in their classrooms. Particularly, the Chinese literature, including some not available in English, addresses Chinese teachers' concerns about, and enactment of, IBT. These documents help define the research gap which needs to be bridged to understand how teachers conceive and implement IBT in their specific situations. This review contributes to knowledge in international science education by offering deeper and more detailed insights into the complex sets of reasons why teachers do or do not adopt inquiry-based teaching in their classrooms.

Although inquiry is defined as a key element of science reform efforts in countries around the globe during the past 50 years or so (e.g., ASEP; Millar & Osborne, 1998; Ministry of Education (Taiwan), 1999; MOE, 2006a; NRC, 1996; NSTP (Nuffield Foundation, n.d.); Tomorrow98, 1992), inquiry teaching is difficult for many teachers to put into successful practice, past (e.g., Rutherford, 1964; Welch, Klopfer, Aikenhead, & Robinson, 1981) and present (e.g., R. Anderson, 2002; Campbell, Oh, Shin & Zhang, 2010; Roehrig & Kruse, 2005; Saad & BouJaoude, 2012). There are many factors which have been reported to influence the teachers' instructional decisions and their enactment of inquiry in classrooms. These factors include:

- Teachers' beliefs about the nature of science, science teaching, and learning (Brickhouse, 1990; Cornett, Yeotis, & Terwilliger, 1990; Cronin-Jones, 1991; Gallagher, 1991; Hashweh, 1996; Lakin & Wellington, 1994; Lederman, 1999; Lotter, Harwood, & Bonner, 2007; Pope & Gilbert, 1983; vanDriel, Beijaard, & Verloop, 2001)
- Teachers' understanding and pedagogical knowledge about inquiry (R. Anderson, 2002; Costenson & Lawson, 1986; Crawford, 2000; NRC, 2000)
- Practical issues such as pedagogical constraints, classroom size, resource, time, and classroom management issues (Akcay, 2007; Baker, Lang, & Lawson, 2002; Costenson & Lawson, 1986; Harris & Rooks, 2010; Jackson & Boboc, 2008; Songer, Lee, & Kam, 2002)

- Contextual influences such as the curriculum and high-stakes testing, the nature of students, school culture, and requirements from educational stakeholders (Munby, Cunningham, & Lock, 2000; Roehrig & Luft, 2004; Savasci & Berlin, 2012; Tobin & McRobbie, 1996; Wallace & Kang, 2004)

The following sections review the relevant studies. The review starts with literature on inquiry and inquiry-based teaching (IBT), including descriptions of inquiry, approaches to inquiry, IBT and instructional models of implementing IBT. The next sections review studies on science teachers' beliefs and their influences on teachers' implementation of IBT, science teachers' perceptions of inquiry and their influence on teachers' implementation of IBT, and barriers and dilemmas that are connected with IBT. These studies were reviewed for the purpose of finding how science teachers, particularly Chinese secondary physics teachers, perceive and implement IBT. The chapter concludes with an identification of the issues in relevant studies on Chinese secondary physics teachers' implementation of IBT, and an explanation of the relevance between the related literature and the present study.

2.1 Classroom Inquiry

2.1.1 Characteristics of classroom inquiry

Although inquiry is a major theme in science curricula policy documents among nations, a variety of meanings associated with the term "inquiry" is revealed in these documents (Abd-EL-Khalick et al., 2004, p.398). Furthermore, despite its widespread acceptance by the science education research community, how to define classroom inquiry and its merits continues to be the subject of much debate (Barrow, 2006; Camins, 2001; DeBoer, 1991). Settlage (2003) asserts that the term "inquiry" has been "one of the most confounding terms within science education" (p. 34).

Nevertheless, these curricula documents and prior research on classroom inquiry are all concerned with issues associated with the enactment of inquiry both as means (instructional approaches) and as ends (learning outcomes) in science classrooms. For example, the NSES (NRC, 1996) are committed to including inquiry as both science content and as a way to learn science (NRC, 2000). The standards thus use the term *inquiry* in two ways. The content standards for "science as inquiry" include both abilities and understanding of inquiry (NRC, 2000). In addition, the term *inquiry* also refers to teaching strategies and the process of learning associated with inquiry-oriented activities (Bybee, 2010). Therefore, according to the NSES, inquiry is not only a learning goal, but also a teaching method (NRC, 2000).

By comparing international science curricula, Abd-EL-Khalick et al., (2004) proposed four dimensions that could construct the space of inquiry:

> One [dimension] could include the types of knowledge and understandings ... Another dimension could include a range of inquiry-related activities ... A third dimension could include a range of skills… needed to meaningfully engage in inquiry at one level or another. A fourth dimension could comprise a range of spheres, including personal, social, cultural, and ethical, with which any of the aforementioned outcomes could interface. When navigating through this four-dimensional space, one could think of the elements on each dimension either as possible outcomes of, or as prerequisites for meaningful engagement in, inquiry-based science education. (p.415)

They went further to suggest that "the former would help conceive and place more emphasis on inquiry as means", while "the latter would help gauge the level at which students could engage in inquiry and help emphasize inquiry as ends" (p415).

This study adopts a description of classroom inquiry from the NSES (NRC, 1996) which is widely referenced by recent science educational research, particularly the Chinese ones. According to the NRC (1996),

> Inquiry is a multifaceted activity that involves 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, analyse, and interpret data; proposing answers, explanations, and predictions; and communicating the results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations. (p. 23)

In a similar way, the Physics Curriculum Standards for Shanghai's Secondary Schools (Trial Version) (PCSSSS) (Shanghai Municipal Education Committee [SHMEC], 2004) describe classroom inquiry as the following: "The process of scientific inquiry includes identifying a question, formulating hypotheses, designing an investigation plan, using tools and collecting evidence, analysing data and developing explanations, and communicating" (p. 27). With respect to each element, the standards give further specific requirements for different levels of students at different year levels (see more descriptions in section 2.7).

2.1.2 Levels of inquiry

Most students need extensive practice to develop their inquiry abilities and understandings to a point where they can conduct their own investigation from start to finish (Bell, Smetana & Binns, 2005, Schwab, 1966). Their inquiry skills need to be scaffolded by the teacher until they are able to develop questions, methods, and conclusions on their own (Banchi & Bell, 2008). Consequently, scientific inquiry should be designed and implemented with increasing complexity to meet students' needs at different stages. Therefore, science teachers should possess a comprehensive understanding of the relationships between different levels of inquiry, and thus include in their teaching logical, coherent, and systematic approaches to inquiry that help their students become scientifically literate in a comprehensive way.

In the literature, although levels of inquiry were described in different ways, they commonly demarcate the continuum with descriptive stages, and differentiate whether the teacher or the learner is responsible for developing specified learning outcomes.

Schwab (1966) suggests that students need to develop thinking skills and strategies prior to being exposed to higher levels of inquiry. He developed three levels of inquiry that align with the breakdown of inquiry processes.

1. Students are provided with questions, methods and materials and are challenged to discover relationships between variables.
2. Students are provided with a question; however, the method for research is up to the students to develop.
3. Phenomena are proposed but students must develop their own questions and method for research to discover relationships among variables.

A four-level model of inquiry was developed by Rezba, Auldridge and Rhea (1999), and modified by Bell, Smetana, and Binns (2005), based on Schwab's (1962) three approaches to "laboratories" and Herron's (1971) three levels of openness of inquiry in science activities. This four-level model defined the degree of student ownership in inquiry in incremental ways:

> Confirmation Inquiry: Students confirm a principle through an activity in which the results are known in advance.
> Structured Inquiry: Students investigate a teacher-presented question through a prescribed procedure.
> Guided Inquiry: Students investigate a teacher-presented question using student designed/selected procedures.
> Open Inquiry: Students investigate topic-related questions that are formulated through student designed/selected procedures. (Bell, Smetana, & Binns, 2005)

Similarly, Llewellyn (2007, 2011) summarised four means that teachers regularly use to initiate student inquiries in the classroom, based on the level and significance of ownership of teachers and students in inquiry activities. According to Llewellyn (2011),

> A demonstrated inquiry or discrepant events is a teacher-led presentation focusing on a particular topic or phenomenon geared toward capturing students' attention. (p. 13)
>
> In structured inquiry, students engage in a hands-on activity or lab, collect and organize data, and draw conclusions, but follow a precise set or sequence of instructions and procedures provided by the teacher or the textbook. (p. 13)
>
> In guided inquiry, the teacher poses the question or the problem to be investigated and suggests the materials to be used while the students, on their own, design and carry out a procedure for the investigation. (p. 14)
>
> Self-directed inquiry is a situation where students generate their own questions concerning a topic or phenomenon and then design their investigations, identify variables, and select and carry out procedures to answer these questions. (p. 14)

The National Research Council (NRC, 2000) describes an even more detailed inquiry rubric (see Fig. 2-2). This continuum ranges from more to less learner self-direction with respect to five features of inquiry, describing the variation in the amount of structure, guidance, and coaching the teacher provides for students engaged in inquiry. According to NRC (2000), these five features of inquiry apply across all grade levels. Furthermore, each essential element can vary and it is not necessary that every inquiry has to include all five of these essential features. Inquiry-based teaching can also vary in the amount of detailed guidance that the teacher provides for students with respect to each of the five essential features (NRC, 2000).

Figure 2-1 Essential Features of Classroom Inquiry and Their Variations

Essential Feature	Variations			
1. Learner engages in scientifically oriented questions	Learner poses a question	Learner selects among questions, poses new questions	Learner sharpens or clarifies question provided by teacher, materials, or other source	Learner engages in question provided by teacher materials or other source
2. Learner gives priority to **evidence** in responding to questions	Learner determines what constitutes evidence and collects it	Learner directed to collect certain data	Learner given data and asked to analyze	Leaner given data and told how to analyze
3. Learner formulates **explanations** from evidence	Learner formulates explanation after summarizing evidence	Learner guided in process of formulating explanations from evidence	Learner given possible ways to use evidence to formulate explanation	Learner provided with evidence
4. Learner connects explanations to scientific knowledge	Learner independently examines other resources and forms links to explanations	Learner directed toward areas and sources of scientific knowledge	Leaner given possible connections	
5. Learner communicates and justifies explanations	Learner forms reasonable and logical argument to communicate explanations	Learner coached in development of communication	Learner provided broad guidelines to sharpen communication	Learner given steps and procedures for communication

More ——— Amount of Learner Self-Direction ——— Less
Less ——— Amount of Direction from Teacher or Material ——— More

While models of differentiated levels of inquiry differ, in each model the levels of inquiry progressively move from less intellectually sophisticated to more intellectually sophisticated, and in which the locus of control shifts from the teacher to the student. It is necessary that students can progress through hierarchical levels of inquiry with increasing complexity as they move toward deeper levels of scientific thinking. Meanwhile, it takes time for students to develop the confidence and skills needed to accomplish higher levels of inquiry.

Science teachers should, therefore, tailor inquiry lessons to the readiness and developmental levels of their students. Teachers should take into account their students' prior experience of inquiry and their differences to decide when and how to introduce inquiry-based opportunities in their courses (Llewellyn, 2011). Furthermore, science teachers need vary the amount of support they provide to students when they transit from a more structured, teacher-controlled format to more open-ended explorations initiated by students (NRC, 2000). The very structured, simplified, teacher-directed approach is appropriate for students when they are first learning to conduct science inquiry. Students need to be taught in a structured sequence rich in details about how to perform a multitasked assignment in order to be successful (Gabel, 2006). However, as students gain experience with science inquiry, they become more independent of the teacher in conducting their science inquiries (Gabel, 2001). Therefore, a teacher needs to scaffold students with fading, which ultimately enables students to solve a problem or carry out a task independently to achieve new learning (Gabel, 2006). Consequently, this poses different requirements for their approaches when organising different levels of inquiry.

2.2 Inquiry-based Teaching (IBT)

2.2.1 Characteristics of IBT

A number of studies and meta-analyses have shown that inquiry-based teaching (IBT) produced a variety of positive student outcomes. These included: cognitive achievement, process skills, scientific literacy, vocabulary knowledge, conceptual understanding and critical thinking, and positive attitudes toward science (Bredderman, 1982; Haury, 1993; Hurd, 1998; Khalid, 2010; O. Lee, Hart, Cuevas & Enders, 2004; Kyle, Bonnstetter, & Gadsden,1988; Lott, 1983; Minner, Levy, & Century, 2010; Shymansky,1984; Shymansky, Hedges, & Woodworth, 1990; Shymansky, Kyle & Alport, 1983; Weinstein, Boulanger, & Walbergs, 1982; Wise & Okey, 1983).

Although prior studies have shown the positive effects of IBT, and inquiry has long been used to characterise good science teaching, what is seen as constituting inquiry in science instruction varies widely across the literature (R. Anderson, 2002). Dewey (1910, 1916) placed inquiry at the center of his educational philosophy. He stated, “The method of science, problem solving through reflective thinking, should be both the method and valued outcome of science instruction in America’s schools” (Dewey, 1916, p. 18). Schwab (1960) advocated an approach to teaching science that was grounded in the idea of science education being an “inquiry into inquiry.” He considered that science should be taught in a way that was to be consistent with the way modern science operates. Edelson (1998) suggests that inquiry-based instruction can take many forms in science classrooms. Some scholars (e.g., Schwab, 1962; Polacek & Keeling, 2005) even argue that any science activity can be converted into an inquiry-based activity without making big changes or revisions. Duschl (1994) argues that there is no one single correct way of doing inquiry. Perhaps the most crucial requirement to conduct inquiry in the classroom is that the science teacher is able to adopt a paradigmatic view that is congruent with the core of inquiry: to put questioning (rather than knowledge transmission) at the centre of the teaching and learning processes. Bybee (2010) suggests that teaching science as inquiry includes understanding scientific inquiry and developing the cognitive abilities associated with the processes and methods of science. Therefore, inquiry-based teaching refers to an integrated and linked instructional sequence designed with the intention of helping students learn science concepts, as well as understanding inquiry and developing cognitive abilities aligned with inquiry.

Nevertheless, in order to distinguish inquiry-based teaching and learning from a general sense of inquiry and from inquiry as practiced by scientists, the NRC (2000) defines the following five features as essential characteristics of classroom inquiry from the learners’ perspective.

1. Learners are engaged by scientifically oriented questions;
2. Learners give priority to evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions;
3. Learners formulate explanations from evidence to address scientifically oriented questions;
4. Learners evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding; and
5. Learners communicate and justify their proposed explanations. (p. 25)

NRC (2000) suggests that “these essential features introduce students to many important aspects of science while helping them develop a clearer and deeper knowledge of some particular science concepts and processes” (p. 27). In addition, each essential element can vary and it is not necessary that every inquiry has to include all five of these essential features. Inquiry-based teaching can also vary in the amount of detailed guidance that the teacher provides for students in each of the five essential features (NRC, 2000). Each variation emphasises particular points and meets the needs of students with different inquiry abilities. They are all acceptable as long as they give priority to evidence and engage students in thinking.

In addition, since inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations (NRC, 1996), inquiry-based teaching (IBT) in science goes beyond the traditional teaching approaches that focus on accumulation of facts and development of de-contextualised science process skills. Using IBT is aimed to provide students with experiences that foster the development of scientific knowledge, skills, and thinking habits. It embraces the constructivist view that students learn best by doing and by active engagement.

2.2.2 Inquiry-based instructional models

Researchers have developed several well-known models of inquiry instruction.

Schwab (1960) considered that science should be taught in a way that was to be consistent with the way modern science operates. He encouraged science teachers to use the laboratory to assist students in their study of science concepts. Students could also use and read reports or books about research and have discussions about problems, data, the role of technology, the interpretation of data, and any conclusions reached by scientists. Schwab's idea of teaching science as inquiry produced the Biological Science Inquiry Model (Schwab, 1965). This model was developed by the Biological Science Curriculum Study (BSCS) (Schwab, 1965) for use in school biology. The essence of this model is to teach students to process information using techniques similar to those of research biologists – that is, by identifying problems and using a particular method to solve them (Schwab, 1965). This model includes the following phases: Area of investigation is posed to the student; Students structure the problem; Students identify the problem in the investigation; Students speculate on ways to clear up the difficulty.

The Learning Cycle is an inquiry-based teaching model which can be useful to teachers in designing instructional strategies in science. The model was originally proposed by Atkin and Karplus (1962), developed by Karplus and Thier (1967); Lawson, Abraham, and Rener (1989); Barman and Kotar (1989); Martin, Sexton, and Gerlovich (1999); Bybee (1997), and among others. The initial model included three stages: Exploration, Concept Development, and Application. Although in later literature the Learning Cycle has been presented in different forms, the basic stages did not differ much. Student inquiry activities start from the exploration stage, in which students are exposed to hands-on activities and generate new concepts; at the second stage, students develop the concept; and at the last stage, students are given opportunities to explore the usefulness and application of the concept. A useful and extended discussion of the Learning Cycle Approach with examples can be found in Lawson (1995).

BSBC 5E Instructional Model (Bybee, et al., 1989) is the further development of the Learning Circle model. It was developed with the recent emphasis on constructivism and assessing students' prior knowledge (Llewellyn, 2007). This model suggests that teachers' instruction consists of five phases: Engagement, Exploration, Explanation, Elaboration, and Evaluation. Each phase has a specific function and contributes to the teacher's coherent instruction and to students' development of a better understanding of knowledge. Useful examples of using the 5E model in inquiry-based classroom can be found in Llewellyn (2007, 2011).

The Inquiry Training instructional model was developed by Suchman (1962) from observing and analysing the methods employed by creative research personnel and combining pedagogical factors. This model is based on the premise that the intellectual strategies used by scientists to solve problems and inquire into the unknown can be taught to students. Inquiry training is designed to bring students directly into the scientific process through exercises that compress the scientific process into small periods of time. An Inquiry Training Lesson includes five stages: Confrontation with the Problem, Data Gathering-Verification, Data Gathering-Experimentation, Formulating an Explanation, and Analysis of the Inquiry Process.

These above reviewed instructional models all suggest that an inquiry-based instructional model incorporates the features of inquiry into a sequence of coherent learning experiences that are designed to challenge students' current conceptions and provide time and opportunities for reconstruction, or learning, to occur (Bybee, 1997).

2.2.3 How science teachers implement IBT in science classrooms

The literature of science literacy encourages science teachers to implement IBT in their regular teaching (e.g., National Science Education Standards; Science for All Americans: Project 2061). Unfortunately, this does not always happen. Research shows that teachers are generally very uncertain how to conduct a competent inquiry practice although they are clearly aware of the need to teach using inquiry-based methods (Marshall & Smart, 2013). One of the chief reasons cited in the literature is that the teachers are often inadequately prepared to use it (Costenson & Lawson, 1986). In addition, science education literature does not provide a framework that helps teachers and teacher candidates clearly understand the scope and sequence of different inquiry approaches (Wenning, 2005). Furthermore, the well-known instructional models had a primary disadvantage in that they simplify the world. Teachers can be misled into thinking of them as lockstep, prescriptive devices rather than guides for designing inquiry-based instruction (NRC, 2000).

There is a relatively rich source of information on how elementary science teachers in the United States enacted inquiry in the classroom. This information mostly comes from teachers' narratives of their own beliefs of inquiry and their stories of inquiry practices. Some teachers described how they developed activities to help students generate questions, or how they used discussion to shape children's natural questions into topics for investigation (Doris, 1991; Gallas, 1995; Pearce, 1999; Whitin & Whitin, 1997). Some teachers linked science inquiry with reading and literature, as well as a variety of types of writing, including journals, observations, and creative stories (Nissley, 2000; Pearce, 1993; Reardon, 1993). And some teachers established a collaborative community of scientists. A significant part of inquiry is meeting to discuss science ideas, progress, and findings (Doris, 1991; Gallas, 1995; Reardon, 1993; Saul, 1993; Whitin & Whitin, 1997).

At the secondary school level, there were limited studies examining how science teachers use inquiry as a regular part of teaching practice. The following reviews a few of them.

Crawford (2000) reported that a teacher in his ecology class implemented a complex model of inquiry-based teaching termed "collaborative inquiry". The teacher

> carefully conceived and developed the initial question of each project, gathered resource materials, orchestrated the instruction, mentored students in designing data collection plans, guided them in carefully collecting data, modelled for them how to systematically analyse and grapple with the data, encouraged them to ask questions and draw initial inferences, monitored and critiqued the writing-up of scientific reports, and finally, coordinated a final presentation of students' findings to review-boards composed of scientists and citizens. (p. 934)

However, the model of IBT used in her study was implemented through ecological projects which took students many weeks to accomplish. It was different from the situation in which a teacher took much less time (one or several lessons) to teach the textbook content in a more typical science classroom. Indeed, little research has been done to understand how teachers perceive and implement inquiry-based instruction in their ordinary classrooms.

Lotter, Harwood, and Bonner (2007) examined three science teachers' instructional practices when implementing IBT in their day-to-day teaching practices. It found that these three teachers' approaches to IBT were centred on teacher-directed inquiries, involving different classroom activities. Jane spent class time with students engaged in discussions of biology terms as well as involved in interactive hands-on activities. Charles allowed his students to investigate problems, but the problems were teacher selected and the inquiry process was highly teacher controlled to allow for coverage of a given subject area. And Steve's inquiry-based teaching methods mainly took the form of teacher-led discussions of open-ended questions in which students investigated what they knew and what information they still needed to know to answer the questions.

White, Shimoda, and Frederisen (1999) reported how three middle school science teachers in urban public schools taught fundamental concepts of physics by using a computer-based inquiry curriculum. Instead of emphasizing facts and details, they used this curriculum to engage students in authentic scientific investigations that asked students to create and apply models of force and motion. They also challenged students to inquire into their own learning, through an exercise that invited students to generate and discuss a personal assessment of their performance in class.

These examples suggest that teachers implement inquiry-based instructions based on the needs of particular learners, the specific learning goals, and the context for learning. Keys and Bryan (2001) assert that multiple modes and patterns of inquiry-based instruction are inevitable since "teaching actions will necessarily differ based on factors in the local environment, such as teacher knowledge, student age, student language proficiency etc.". Multiple modes and patterns of inquiry-based instruction are therefore desirable because "they will paint a rich picture of meaningful learning in diverse situations" (p. 632). In addition, more research is needed on teacher-designed approaches to inquiry-based instruction, specifically in high school classrooms, which is often constrained by high-stakes testing and fixed schedules (Keys & Bryan, 2001).

2.2.4 Strategies that facilitate inquiry-based teaching

The teacher is the key element of IBT. Costenson and Lawson (1986) suggest that teachers must be skilled in using inquiry teaching techniques to implement inquiry in classrooms. These strategies and skills are important to facilitate IBT and encourage student success in the inquiry-based classroom. Among them, questioning techniques and classroom management skills are two types of important strategies for effective implementation of IBT.

Questioning is the heart of inquiry-based, science teacher instructional activities (Brandon, Taum, Young, Pottenger III, & Speitel, 2008; Duschl, 1994). Teachers use guided questions to help students to construct knowledge and to reflect on what they have learned (Gabel, 2006). When used properly, questions can assess prior knowledge, encourage explorations, and engage students in critical thinking.

Researchers suggest several essential questioning techniques needed for implementing inquiry-based instruction. These include the notion that: Teachers should use questions in a structured way to allow students to demonstrate understanding and possible misconceptions. They should use different types of questions to lead and focus the thinking process of students to achieve an intended goal. They should know how to ask questions at an appropriate time and how to give feedback to an answer (Llewellyn, 2005). They should give enough wait-time after a student's response to increase the quality of student thinking and increase the eventual number and quality of student responses (Lawson, 2010; Llewellyn, 2005; Rowe, 1973, 1974). They should also use questions to foster communication among all participants, including teachers and different students (Llewellyn, 2005). All these skills are important aspects of teachers' questioning skills used to create a learner-centred, inquiry-based classroom. More detailed discussions about questioning techniques in inquiry-based classroom can be found in Lawson (2010) and Llewellyn (2005, 2007).

Many studies (e.g., Baker, et al., 2002) suggest that management issues are central obstacles to the effective use of student inquiry. These issues could be categorized in the following aspects: (a) use of time in the classroom, (b) learning-environment constraints, (c) students' focus and motivation, and (d) safety concerns (Jackson & Boboc, 2008). Science teachers should develop several effective strategies for overcoming each of these barriers and effectively facilitate inquiry-based instruction. A detailed discussion of the strategies can be found in Llewellyn (2005) and many educational articles such as Jackson and Boboc (2008).

2.3 Teachers' Beliefs and their Implementation of IBT

Research suggests that teachers' beliefs are one of the most crucial factors for effective implementation as teachers use their own theories and actions to translate and transform rhetorical curriculum into practice within their unique classroom contexts (Manouchehri & Goodman, 1998; Wenger, 1998). A great issue is that the way in which teachers think about their practice and about student learning is more closely linked to their belief systems rather than to the new curriculum mandates (Yerrick, Parke, & Nugent, 1997). If teachers hold beliefs that are not consistent with the intents of the curriculum, it may be very difficult for them to put inquiry-based instruction into their regular teaching. A wide gap may exist between what is taught in the classroom and what is described in the curriculum standards (Marsh, 1991). Gregoire (2003) argues that this gap will persist without "understanding how teachers' beliefs relate to their practice or to student outcomes" (p.149). Understanding science teachers' beliefs, therefore, will provide crucial information to understand why teachers adopt some particular methods of instruction in their classrooms.

Numerous studies have been conducted to understand the relationship between teacher beliefs and classroom practice. For the sake of the current study, the following literature review focuses upon those studies which investigated science teachers' beliefs and their enactment of inquiry-based instruction including constructivist instruction.

2.3.1 Characteristics of teacher beliefs

Teachers' beliefs have been described in various ways in prior literature. Nespor (1987) suggests that belief systems are episodic, affective, and are built on existential presumptions. They rely heavily on affective and evaluative components. This reliance could significantly influence teachers' interpretation of and attitudes towards future events.

Nespor (1987) refers to belief systems as personal pedagogies or theories that guide teachers' practices. He suggests that beliefs are peculiarly suited for making sense of the teaching contexts because "the contexts and environments within which teachers work, and many of the problems they [teachers] encounter, are ill-defined and deeply entangled" (p. 324). Similarly, Hollingsworth (1989) suggests that teacher beliefs serve as "culturally based filters" to help them make sense of the content, their roles as teachers, their students, and their instructional strategies.

Luft and Roehrig (2007) state that teachers' beliefs relate to their knowledge, attitudes and classroom practices, associated with personal experience, and affect teachers' cognitive schemata in different ways. They further suggest the following point of view on science teachers' beliefs:

> We consider beliefs to be propositions that individuals think are true. Since these beliefs are based on personal judgment and evaluation, they can be non-evidential… In terms of science teaching, we consider beliefs to be core and peripheral… and epistemologically oriented… All teachers have personally constructed beliefs about teaching. As teachers engage in their field of instruction, these beliefs expand in their epistemological orientation. (p. 47)

Since teachers' beliefs are derived from significant episodes in and out of classrooms, including significant emotional component (Nespor, 1987; Richardson, 1996), they are generally contextualized and associated with personal experience. It is not surprising that a wide variance of belief systems can be found among individual teachers within a similar group.

Teachers' beliefs may be complex and nested (Bryan, 2003; Tsai, 2002), and their nature is discrete and multidimensional (Fang, 1996; Garmon, 2004; Kagan, 1992; Richardson, 1996).

Furthermore, a teacher may hold competing belief sets. For example, on the one hand, a teacher may view science as a continuous process of discovery and believe that IBT supports students' critical thinking and deep understanding of science, and have a passion for using IBT in their classrooms (Wallace & Kang, 2004). On the other hand, a teacher may continue to view factual knowledge as the most important student outcome that is achievable through repeated drills and practice (Cronin-Jones, 1991), and give greater priority to transmitting facts than to enabling students to carry out their own investigations (Tobin & McRobbie, 1996). Research suggests that beliefs within a system that are incompatible or inconsistent with one another may remain so, as long as they are not examined against one another (Abelson, 1979; Green, 1971).

Some researchers (Kagan, 1992; Nespor, 1987; Tobin, Tippins, & Hook, 1994) define beliefs as a form of knowledge that enables people to meet their goals, whereas others (Pajares, 1992; Richardson, 1996) express the need to distinguish between belief and knowledge. Pajares (1992) explains that knowledge is based on objective fact, while beliefs are based on evaluation and judgment. Richardson (1996) stated that beliefs are different from knowledge because they do not need to be true. Mansour (2009) proposes a further distinction between beliefs and knowledge by saying, "While knowledge often changes, beliefs are "static". In addition, whereas knowledge can be evaluated or judged, such is not the case with beliefs since there is usually a lack of consensus about how they are to be evaluated" (p. 27). Nevertheless, Pajares (1992) synthesises findings on beliefs and notes, "Knowledge and beliefs are inextricably intertwined, but the potent affective, evaluative, and episodic nature of beliefs makes them a filter through which new phenomena are interpreted" (p.324). In a similar way, van Driel, Beijaard, and Verloop (2001) suggest that experienced science teachers have developed "a conceptual framework in which knowledge and beliefs about science, subject matter, teaching and learning, and students are integrated in a coherent manner" (p. 145). Lantz and Kass (1987) suggested that individual teachers may have developed quite different frameworks or "functional paradigms", even when they teach the same curriculum.

2.3.2 The influence of teacher beliefs on their implementation of IBT

Research has shown that belief structures play a major role in defining teaching tasks and organizing the knowledge and information relevant to those tasks (Nespor, 1987; Pajares, 1992; Richardson, 1996). Teachers' beliefs about the nature and acquisition of knowledge, the curriculum, teaching and learning, students and themselves, and the teaching context impact the ways in which they enact inquiry practices (Crawford, 2000; Gallagher, 1991; Pope & Gilbert, 1983; Tobin & McRobbie, 1996; Wallace & Kang, 2004). Furthermore, "beliefs help teachers interpret classroom life and orient them when faced with a particular challenge, problem, or dilemma, such as the implementation of standards-based curriculum materials" (Powell & Anderson, 2002, p. 128).

Meanwhile, some studies also found that the relationship between teachers' beliefs and their instructional practices was not unidirectional (Levitt, 2002; Munby, Cunningham, & Lock, 2000; Tobin & McRobbie, 1996). Teachers' instructional practices could modify or reinforce their beliefs. For example, Levitt (2002) revealed that beliefs and practices of the teachers in his study changed in a reciprocal way through implementation of the curriculum models. Tsai (2002) argues that science classes, laboratory exercises, and relevant activities in teacher education programmes may have reinforced teachers' traditional views of teaching science, learning science, and the nature of science.

The following sections review the relevant studies on science teachers' beliefs and their influences on instructional practices regarding IBT.

Beliefs about the nature of science

Teachers' beliefs about the nature of science were often found to shape their interpretations of curriculum documents and instructional approaches (Brickhouse, 1990; Brickhouse & Bodner, 1992; Pajares, 1992).

For many teachers, school science knowledge is a prescribed set of facts, principles, and concepts to be transmitted by the teacher and memorized by the students. These conceptions can be significant obstacles to implementing inquiry-based teaching (Gallagher, 1991; Pope & Gilbert, 1983; Tobin & McRobbie, 1996; vanDriel, Beijaard, & Verloop, 2001). For example, Gallagher (1991) found that science teachers who held such views were found to pay little instructional attention to the process of obtaining scientific knowledge. Pope and Gilbert (1983) found that science teachers with the absolutist views of truth and knowledge tended to pay little attention to students' conceptions during instruction.

Some science teachers also see science as an objective body of knowledge created by a rigid "scientific method" (Brickhouse, 1990; Duschl & Wright, 1989; Gallagher, 1991). For example, Hashweh (1996) found that empiricist-oriented teachers tended to believe that scientific knowledge is an objective collection of facts and emphasized the "scientific method" as a paradigm for scientists. Brickhouse (1990) described a teacher who viewed "the scientific method" to be a linear and rational process "that leads on unambiguously to scientific truth", believed "scientific procedures to be predetermined" (p. 55), and held that "science activities require following directions to get correct answers" (p. 56). These beliefs were found to inhibit teachers' attempts to involve students in inquiry activities (Hashweh, 1996; Wallace & Kang, 2004). Wallace and Kang (2004) argued that without a firm understanding of how scientists work, teachers may be inhibited in how to involve students in inquiry activities.

Beliefs about science teaching and learning

Teachers' beliefs about teaching and teachers can constrain, or support, their use of more student-centred instruction. Roehrig and Kruse (2005) report that secondary science teachers with predominantly traditional beliefs showed little change in their classroom practices and a low level of implementation of a reform-based curriculum. In contrast, teachers with constructivist beliefs were found to recognize students' prior knowledge and use varied teaching strategies to develop students' conceptual understanding (Heshweh, 1996).

Teachers' beliefs about their students and how students learn can also create barriers, or provide support, to more student-centred instruction. For example, Cronin-Jones (1991) found that science teachers who believed that the factual content acquisition was the most important student outcome and that students learned best through repeated drill and practice were found to be unable to enact a constructivist-based curriculum in the ways that the developers intended. Crawford (2007) found that some of the prospective teachers believed that the very nature of the typical high school learner precluded a teacher's use of inquiry. This belief likely constrained their intentions to teach science as inquiry. In contrast, Cornett, Yeotis, & Terwilliger (1990) reported that a first year middle school science teacher who believed that student learning should involve higher level thinking exhibited this belief in her use of inquiry teaching techniques in her advanced science course. Wallace and Kang (2004) found that teachers who believe their students have the cognitive capacity to process both the learning goals of the mandated curriculum and the learning goals set by the teachers accomplished more meaningful inquiry activities.

Teachers' beliefs about effective teaching are also found to exert positive, or negative, influence on their instructional decisions regarding the use of IBT. Teachers' views of what constitutes effective teaching and learning influence their choice of instructional strategies used in their inquiry practices (Lotter et al., 2007). However, teachers do not necessarily agree that the curriculum standards reflect effective teaching. Lotter et al. (2007) suggested that teachers' views of effective instruction being at odds with inquiry teaching practices may stem from what Tobin and McRobbie (1996) described as "cultural myths". These myths are related to teachers' beliefs about the transmission of knowledge, being efficient, maintaining the rigour of the curriculum, and preparing students to be successful in examinations (Tobin & McRobbie, 1996), often hinder teachers' efforts to enact science education reform. In contrast, Crawford (2000) found that a high school biology teacher, who believed that effective science instruction involved students in the investigation of authentic community-based problems, successfully developed and sustained an inquiry-based classroom.

Competing belief sets

Prospective teachers are often reported to hold competing belief sets (Bryan, 2003; Bryan & Abell, 1999; Crawford, 2007; Wallace & Kang, 2004). Haney and McArthur (2002) examined the beliefs of prospective science teachers and their classroom practices in the context of constructivist teaching. They suggest that there are at least two kinds of beliefs in operation: central beliefs and peripheral beliefs. "The central beliefs were defined as those dictating subsequent teaching behaviors; whereas the peripheral beliefs were those that were stated but not operationalized" (p. 783). Bryan (2003) found that beginning teachers may hold beliefs that inquiry-based approaches support student thinking and conceptual understanding of science, as well as other conflicting beliefs that are related to the transmission of knowledge and coverage of content. Wallace and Kang (2004) found that the investigated science teachers held competing belief sets when considering the implementation of inquiry-based instruction. On the one hand, these teachers' beliefs about students, efficiency, rigor, and exam preparation override inquiry implementation. One the other hand, each teacher also showed a core belief set in favour of inquiry. Luft and Roehrig (2007) found that teachers do not compartmentalise different beliefs.

These conflicting beliefs may affect their instructional practice in science classrooms. Prior studies have shown that the implementation of IBT is influenced by complex sets of personal beliefs that many teachers hold about the nature of science and science teaching (Crawford, 2007; Wallace & Kang, 2004). Tobin, McRobbie and Anderson (1997) investigated the discursive practices of a prospective teacher in a physics class. They found that the investigated teacher held beliefs that conflict with constructivism such as content coverage and preparing students for examination, in addition to constructivism. Although the teacher believed that students should have more autonomy in the classroom and should be engaged actively in learning process, he continued to lay emphasis on goals such as learning to use formulas to perform calculations and memorizing facts.

2.4 Teachers' Understanding and Pedagogical Knowledge about Inquiry and their Enactment of IBT

According to the National Science Education Standards (NRC, 1996), inquiry is defined as both a pedagogical strategy and a learning goal. To use this new teaching approach, the science teachers need to construct meanings of IBT first and learn how to implement it.

2.4.1 Teachers' interpretation of inquiry

Encountering a new curriculum, teachers are expected to interpret the curriculum document, "internalise" (Vygotsky, 1962, 1978) it and use it as a frame of reference. They have to make sense of the curriculum document and then translate the ideas into action in their classrooms. During this period of intense thinking about the curriculum document and its meaning for their practice, they have to contend with many factors, for example, the ideas in the document such as inquiry-based instruction.

This process is "at once both historical and dynamic, contextual and unique… [it] entails interpretation and action" (Wenger, 1998, p. 54). Teachers bring in their own experiences, intuitions, reflections and the context of classrooms when interacting with the curriculum document (Fernandez, Ritchie, & Barker, 2008). Yerrick et al. (1997) argue that teachers do not develop their knowledge of teaching through abstract reflection upon teaching removed from the context of school. Clark and Peterson (1986) suggest that teachers have strong sets of personal theories and beliefs that influence how they perceive plans and actions of teaching. Pajares (1992) asserts that beliefs make teachers the filter through which new knowledge is interpreted and, subsequently, integrated in existing belief construct.

On this account, it is necessary to differentiate teachers' "perception" from their "beliefs" because perception is transformed into belief in a way of interpretation and adaptation. The researcher of this study, therefore, distinguishes teachers' "perceptions of inquiry" from their beliefs based on Armstrong's (1988) description that perception is the acquisition of a belief or a potential belief. The researcher also uses the word "understanding" to imply a combination of perceptions and knowledge that the teacher holds about IBT.

In a word, how teachers perceive inquiry is crucial to their enactment of IBT. However, teachers demonstrated variable understandings in relation to inquiry (R. Anderson, 2002; Crawford, 2007; Keys & Bryan, 2001; Wallace & Kang, 2004). Their perceptions of inquiry could be obstacles to their implementing IBT in science classrooms. A number of misconceptions about inquiry-based learning and teaching were often found among science teachers. For example, "True inquiry occurs only when students generate and pursue their own questions"; "Inquiry teaching occurs easily through use of hands-on or kit-based instructional materials"; "Student engagement in hands-on activities guarantees that inquiry teaching and learning are occurring"; and "Inquiry can be taught without attention to subject matter" (NRC, 2000, p. 36). These misconceptions often result in inquiry science being taught as either the scientific method or as "hands-on" disconnected activities. Some teachers may think they are doing inquiry-based teaching when in fact they still use direct instruction in classrooms (Tobin & McRobbie, 1997). Many teachers tend to take student interest and involvement in the classroom as sufficient and necessary conditions for worthwhile learning, and rely on activities for their own sake. Activity becomes a substitute for the process of knowledge construction. Teachers may also tend to abstract parts of a constructivist approach from the whole and thus distort their understanding of its application (Windschitl, 2008).

O. Lee et al. (2004) argue that these problems will continue to exist as long as teachers do not experience inquiry-based learning for themselves. It is suggested that most teachers are products of their own schooling, training, and experiences as teachers (Becker, 1991). They were schooled in an educational environment that features teacher-centred instruction, fact-based subject matter and drill and practice (Russell, 1993). Therefore, these teachers have no experience on which to base a visualisation of the student-centred inquiry-based instruction demanded by the new curriculum. It is difficult, therefore, for them to visualize inquiry teaching in actual practice and difficult to put into successful practice (R. Anderson, 2002).

Prior research has suggested that science teachers' perceptions of inquiry-based instruction are strongly associated with teachers' experience, including teachers' schooling experience in terms of majors and degrees that teachers hold (T. Smith et al., 2007), teachers' teaching experiences (Luft, 2001; Smerdon, Burkam, & Lee, 1999), experience with inquiry learning, prior authentic scientific research experience (Crawford, 2007) and training experience (Goodrum, Hackling, & Rennie, 2001; van Driel, Bulte, & Verloop, 2008). Teachers' experience plays an important role in their interpretations when they first encounter the new materials, and in their attempts to understand what is required of them (Kirk & MacDonald, 2001).

2.4.2 Teacher's pedagogical knowledge

Costenson and Lawson (1986) suggest that a precise understanding of scientific inquiry and being skilled in inquiry teaching strategies, along with sufficient understanding of the structure of knowledge, are crucial ingredients for implementing inquiry in the classroom. They argue, "Lacking this knowledge and skills, teachers are left with little choice but to teach facts in the less effective expository way" (p. 158). They asserted that one of the chief factors contributing to teachers' difficulties in implementing IBT is that the teachers are often inadequately prepared to use it (Costenson & Lawson, 1986).

2.5 Demands and challenges inquiry-based teaching poses to teachers

IBT requires teachers to obtain greater understanding and knowledge about science as inquiry and to redefine their views on the purposes of education (Crawford, 2000).

Richardson and Placier (2001) suggest that it is essential that teachers reflect upon their own epistemologies and undergo a fundamental transformation of their thinking about teaching and learning for instructional change to occur. However, changing teachers' beliefs is a complex and challenging process. It was argued that the entire belief systems may be static, difficult to shift (Nespor, 1987), and generally not affected by reading and applying the findings of educational research (Hall & Loucks, 1982). Changing people's beliefs is tantamount to changing who they are as individuals (Nespor, 1987), because beliefs provide personal meaning and assist in defining relevancy (Pajares, 1992). Rokeach (1968) argued that some beliefs that are associated with people's personal identity – who they are and how they fit into their world – have a high degree of connectedness and are thus more central. "The more central a belief, the more it will resist change" (Rokeach, 1968, p. 3). For teachers, their beliefs are difficult to change because they are based in part on their practical teaching knowledge that has been learned over many years of classroom experience (Lortie, 1975). Furthermore, changing beliefs in the altered context involves a process that is fraught with conflict. It implies that, in order for changes to occur, there must be some deconstruction of beliefs before another set can be constructed. Even when a teacher may be committed to innovative practices and beliefs, the cultural norms in the classroom continue to support lecture-based instruction, subject-centred curriculum, and measurement-driven accountability. This process, argues Woods (1996), can "lead to periods of disorientation, frustration, even pain" (p. 293). Therefore, Nespor (1987) asserts that belief change and instructional change must be a matter of gradually replacing teachers' beliefs with more relevant beliefs.

In addition, to implement IBT also demands that science teachers update their pedagogical knowledge and strategies in order to be able to confidently and properly incorporate inquiry into their regular teaching practice. Challenges have been identified in prior research in science education. Gabel (2006) suggests that teaching science inquiry is a complex process that requires students to perform multiple tasks well to conduct a meaningful scientific inquiry. It demands a high level of pedagogical knowledge, such as how to coach, mentor and collaborate with students (R. Anderson, 2002; Crawford, 2000; NRC, 1996). It requires that teachers develop approaches that situate learning in authentic problems, model actions of scientists to guide and facilitate students in making sense of data, and support students in developing their personal understandings of science concepts (Crawford, 2000). Its complexity also suggests that teachers need to take on a myriad of roles in IBT (Crawford, 2000). Furthermore, successfully teaching science inquiry "involves integration of subject matter as well as integration of findings from the fields of educational psychology, neuroscience, and pedagogy" (Gabel, 2006, p. 248). The difficulty is that many teachers are left to their own devices to develop such needed knowledge and strategies.

Furthermore, a teacher has to decide whether the overall benefits exceed the costs of implementing a curriculum innovation. Marsh (1991) suggests that this process "inevitably involves a cost as teachers have to learn something new and sacrifice the style with which they are familiar" (p. 27). For many science teachers, considering instructional changes in their classrooms is a process in which they examine their beliefs about the subject matter, teaching and learning, and their feelings around the need for change, to weigh the personal costs and benefits (Fernandez et al., 2008). Teachers need to acknowledge their capacity for change in terms of their disposition, energy, and social support before they change their practice (Fernandez & Ritchie, as cited in Fernandez et al., 2008).

Although IBT is identified as a key element of science reform efforts (e.g., NRC, 1996; MOE, 2006a), inquiry teaching is difficult for many people to visualize in actual practice and difficult for many teachers to put into successful practice (R. Anderson, 2002). What is required of teachers is not simply new actions and approaches, but new beliefs, knowledge and pedagogical strategies. These take time to develop, are complex and are often resisted on the basis of teachers' existing beliefs and pedagogical structure. It would take considerable effort for teachers and students to enact the vision of inquiry put forth in the curriculum standards in their classrooms.

2.6 Barriers and Dilemmas Associated with IBT

Research has shown that implementing a curriculum reform is not a straightforward process. There are many obstacles and constraints between the intended curriculum, as it is written in the documents, and the enacted curriculum which is implemented in the classrooms (Manouchehri & Goodman, 1998). In addition, teachers considering new approaches to education face numerous dilemmas, many of which have their origins in their beliefs and values (R. Anderson, 2002).

As reviewed in previous sections, teachers' beliefs about the nature of science, science teaching and learning, as well as their understanding and pedagogical knowledge about inquiry, could act as significant barriers to their use of IBT (see sections 2.3 and 2.4). Besides these factors, a number of contextual factors and practical issues have been reported over the last decades to constrain teachers' intention to carry out IBT.

Contextual factors include the curriculum and high-stakes testing, the nature of students, school culture and requirements from educational stakeholders (see Crawford, 2007; Munby, Cunningham,

& Lock, 2000; Roehrig & Luft, 2004; Tobin & McRobbie, 1996; Tobin, McRobbie, & Anderson, 1997; Wallace & Kang, 2004). Among them, the influence of high-stakes testing is a significant constraint which has been frequently reported to have negative impacts on teachers' implementation of IBT. For example, Corcoran and Matson (1998) reported that teachers were "most likely to use inquiry and other hands-on methods if they were aligned with the test or if they taught in an untested grade" (p. 31). Wideen, O'Shea, Pye, and Ivany (1997) concluded that the high-stakes examinations not only discouraged teachers from using strategies which promoted inquiry and active student learning, but also affected the language of classroom discourse. Passman (2001) found that the pressure of high-stakes examination turned the case study teacher away from inquiry towards more teacher-directed classroom. Geelan, Wildy, Louden, & Wallace (2004) affirmed that science teachers face dilemmas when they have to struggle between teaching for understanding and teaching for examination.

Other contextual factors are also often reported to impact both teachers' beliefs about, and enactment of, IBT. For example, Crawford (2007) found some prospective teachers' beliefs about the nature of students, gained from actual practice during the school, constrained their intentions to teach science as inquiry. They also found that prospective teachers' implementation of inquiry instruction was affected by their mentor's expectations. McGinnis, Parker, and Graeber (2004) reported that novice teachers encounter affordances and constraints arising from the school culture, and these constraints can deter teachers from successfully implementing reformed-based teaching strategies. Roehrig and Luft (2004) reported that one prevalent constraint experienced by beginning secondary science teachers in implementing scientific inquiry lessons was teacher concerns about student ability and classroom management. Savasci and Berlin (2012) affirmed that school type (public vs. private) and grade level (middle school vs. high school) may influence teacher constructivist beliefs and their ability to implement these beliefs in the science classroom.

Practical issues include class size, inadequate time, resource constraints, pedagogical constraints related to technology, and classroom management issues (see Akcay, 2007; Baker, et al., 2002; Costenson & Lawson, 1986; Harris & Rooks, 2010; Jackson & Boboc, 2008; Smerdon et al., 1999; Songer et al., 2002; Supovitz & Turner, 2000).

R. Anderson (2002) provided a picture of many of these barriers and dilemmas. In this picture barriers and dilemmas were clustered in three dimensions, the technical dimension, the political dimension and the cultural dimension.

> The technical dimension included limited ability to teach constructively, prior commitments (e.g., to a

> textbook), the challenges of assessment, difficulties of group work, the challenges of new teacher roles, the challenges of new student roles, and inadequate inservice education. The political dimension included limited inservice education (i.e., not sustained for a sufficient number of years), parental resistance, unresolved conflicts among teachers, lack of resources, and differing judgments about justice and fairness. The cultural dimension—possibly the most important because beliefs and values are so central to it—included the textbook issue again, views of assessment and the "preparation ethic," i.e., an overriding commitment to "coverage" because of a perceived need to prepare students for the next level of schooling. (p. 8)

These prior studies show that the task of preparing teachers for IBT is much bigger than simply the technical matters. The task must be addressed in the political and cultural context of the schools in which teachers work (R. Anderson, 2002).

2.7 What the Chinese Physics Curriculum Standards Say about Inquiry and IBT

The new National Physics Curriculum Standards (MOE, 2003) was issued in 2003 and has been piloted as test documentation in practice. It emphasises that physics teachers should make physics accessible to all students instead of a small number of bright students (MOE, 2001), and embrace the idea that learning physics is a set of students' psychological activities which relies on students' own thinking and practices.

Teachers are encouraged to implement inquiry-based instruction, namely, engaging students in their own investigations to answer their own questions, and evaluating students by their ability to understand the processes of physics (MOE, 2003). According to the national physics curriculum standards (MOE, 2003), physics lessons at the senior secondary level (Grades 10-12) should focus more on the quality of student learning in IBT. Students should "experience the procedure of scientific inquiry, understand the meaning of scientific inquiry, try to use scientific inquiry to investigate physics problems and verify the physics laws" (p. 9).

In order to achieve this objective, various suggestions are made for physics teachers' instructional practices. Physics teachers should "create various opportunities for students to learn to design investigation plan" (MOE, 2003, p. 57); teachers should "create some problem-solving scenarios and some tasks for students to develop inquiry questions" (p. 57); and teachers should "find out the weaknesses of the process of student inquiry so as to take steps to improve it" (p. 57), when designing and enacting teaching plans.

The national curriculum standards provided guidance for provincial level curricula designing (MOE, 2001). The Physics Curriculum Standards for Shanghai's Secondary Schools (Trial Version) (PCSSSS) (SHMEC, 2004) was issued in 2004 with a great emphasis on inquiry, following the agenda of the national curriculum standards, and based on the needs of the urban development of Shanghai and the signs of the times (SHMEC, 2004).

The great emphasis on inquiry can be easily identified from the expectations that the standards set for both students and teachers. According to the PCSSSS (SHMEC, 2004), science curricula lay emphasis on scientific inquiry, "devoting attention to students' personal experience and their process of participating in scientific inquiry, and developing scientific skills and methods" (p. 27). In particular, for senior secondary school students (Grades 10-12), the curriculum standards state that,

> The scientific inquiry activities at the senior secondary level should provide the students with further opportunities to participate in complete inquiries based on their experience in junior secondary schools. They should allow the students to experience and know about the procedure of scientific inquiry, which inquires into the important laws and theories and based on hypotheses and experiments. They should develop students' inquiry abilities, particularly the abilities to design systematic investigation plans, employ mathematical tools to analyse evidence, and evaluate scientific inquiry activities. Based on these abilities, students form a deep understanding of the essential elements of scientific inquiry. Students should pose questions and formulate hypotheses or predictions through logical reasoning and scientific imagination, based on their prior knowledge and observed evidence. Based on the questions and hypotheses, they design investigation plan, choose tools, apparatus and equipment to widely gather evidence, and then analyse data to verify or modify hypotheses, and eventually form results. (pp. 36-37)

The PCSSSS further describes specific requirements of inquiry for different levels of students (see SHMEC, 2004, p. 37). By setting these specific requirements of inquiry for students, it suggests that science teachers should implement IBT by aligning their goals and teaching styles with the standards.

Science teachers are required to "attach importance to scientific inquiry, create inquiry opportunities for students, and allow them to experience the process of inquiry" (SHMEC, 2004, p. 55). More specifically, in their classroom teaching,

> [Teachers] should pay attention to the thinking process of students, encourage students to propose questions, assumptions and solutions. [Teachers] should organise and guide students to collaborate, communicate, and share results with each other, in order to foster all students' development (pp. 55-56).

Furthermore, they should "employ various methods to create scenarios for inquiry, determine inquiry tasks, design inquiry plan and organise inquiry activities" (p. 111).

Clearly, the PCSSSS highlights the importance of inquiry in students' learning for the development of science literacy. However, the curriculum standards do not give specific prescriptions for how to conduct IBT in the classroom, except for some examples of student inquiry activities. It will be up to the teachers to formulate patterns of teaching actions that accomplish the goals set forth by the curriculum standards.

2.8 Earlier Studies around IBT in China

The Chinese science teachers are encouraged to implement IBT in their classrooms. However, many Chinese science teachers found it very challenging to implement IBT in their classrooms (G. Liu, 2004; B. Zhang et al., 2003; Y. Zhao, 2011). It was found that the traditional teaching approaches still dominant in Chinese secondary classrooms (Salili, Zhou, & Hoosain, 2003).

Many Chinese scholars writing in the field of curriculum and instruction have attempted to find a solution to the problem of the limited uptake of IBT by science teachers by focusing on theory. For example, there are many articles discussing different aspects of IBT, such as the psychological basis of IBT, strategies to implement IBT, differences between IBT and other approaches, teacher roles in IBT (e.g., Gao & Liang, 2002; Guan & Meng, 2007; He, 2002; Lu, 2005). On the other hand, the amount of research grounded in real classroom contexts, either qualitative or quantitative, is relatively small. Particularly, only a small number of these studies are related to secondary physics. Nevertheless, a review of these studies may help the reader understand how Chinese secondary physics teachers implement IBT in their classrooms.

2.8.1 Chinese secondary physics teachers' implementation of IBT

A number of studies gave research effort to developing models for inquiry instruction in classrooms (e.g., Dong, 2010; Jiang, 2004; Lu, 2005; Yan Wang, 2008), following a Theory→Model→Practice research trend. In this research method, the researcher chooses a theoretical framework and develops an instructional model of IBT, then applies this model to practice, and/or examine its effectiveness. Typically, these studies employed quantitative research methods, including student surveys and quasi-experimental studies, to examine the effectiveness of the implemented models. These included students' academic achievement in terms of test scores and students' development in some non-intellectual factors such as interest, attitudes, and confidence.

For example, Dong (2010) developed a new model of scientific inquiry teaching based on Popper's four-step problem-solving schema and the key elements of inquiry. According to Dong, inquiry-based teaching should be a dynamic process. Therefore, it should include a large loop from a question to a new question and an inner loop of testing hypotheses. She argued that to some extent this model is better than the static model suggested by the curriculum standards as it reflects the real process of scientific inquiry activities. This model received favourable comments from experts and was tested by some science teachers. However, this study only gave two examples of lessons using this model, but did not examine its effectiveness.

Lu's (2005) study is another typical example. Lu proposed a model of inquiry-based physics teaching based a concept of "compound learning cycle". The development of this model was based on several influential models of inquiry-based learning, Learning Circle models for science instruction (Bybee, 1997; Karplus & Their, 1967) in particular, presenting a compound form. Lu suggests that the Compound Learning Cycle model includes nine following stages: Engage Educe, Expect, Engineer, Explore, End, Exchange, Elaborate and Evaluate. The Evaluate stage occurs within all stages. This study further provided several teaching examples using this model.

This Theory→Model→Practice research trend is also found in many other studies on developing instructional models of IBT, for example, Yan Chen's (2004) "probing into model", Yan Wang's (2008) "concept-mapping-based model" of IBT, J. Xu's (2009) "lecture-directing model" of IBT. Different from the two above-mentioned examples, these studies all used quasi-experimental design to examine the effectiveness of the teaching model.

Another line of research, following a similar research agenda, experimented on IBT with the aid of educational technology. Studies conducted by Y. Li (2003), Xiao (2005), Z. Li (2006), X. Zhang (2009), and X. Liu (2011), are typical examples. They proposed various instructional models of implementing IBT using different educational technology, designed lessons using these models, and tested these models in their own, or cooperating teachers' classes using a quasi-experimental design. The involved educational technology included multimedia, internet, campus intranet, WebQuest, computer-based virtual experiment, online study tools, digital games, and etc.

The findings of these studies generally suggest that using educational technology to facilitate IBT has positive influences on increasing students' test scores, and information technology can be reasonably and effectively integrated with IBT in physics teaching in senior high schools. However, the researchers also raised a range of issues related to teachers themselves and technology per se, that may affect the implementation of IBT, such as teachers' misunderstandings, unqualified teachers (G. Liu, 2004), expensive apparatus, complex requirements for operating instruments, and a lack of examples and teaching resources (T. Wang, 2002a).

All these studies have shown a number of interesting prospects for IBT in day-to-day teaching in Chinese physics classrooms. However, these studies focus on developing models of inquiry instruction from the theoretical perspective and examining effectiveness in terms of students' achievement scores, leading to a depersonalized, context-free, and mechanistic view of teaching (Doyle, 1990), in which the complexity of the teaching enterprise is not acknowledged.

In contrast to the Theory→Model→Practice model of the above studies, a small number of studies developed scholastic understanding from researching physics teachers' practice. Among these empirical studies, many of them are front-line teachers' self-reports of understanding of inquiry and experience in implementing IBT, for example, designing inquiry-based teaching regarding particular content (e.g., L. Zhang, 2004; S. Zhao, 2002； Meng Zhu, 2011); formulating questions for inquiry (e.g., Shen, 2004; X. Xu 2002); designing inquiry-based exercises (Z. Zhang, 2003); and using particular educational technology in the classroom to facilitate IBT (e.g., Pei & Wu, 2006; T. Wang, 2002a, 2002b). A typical example is T. Wang's (2002a, 2002b) studies. T. Wang investigated how to apply the Calculator-based Laboratory System (CBL) to physics teaching to improve students' inquiry-based learning. He conducted experimental teaching using CBL with his students, observed and recorded students' behaviours in inquiry activities, collected students' feedback and surveyed participating students. The results revealed that using CBL to carry out inquiry activities could increase students' interest in learning new knowledge and skills and develop their inquiry abilities.

A very small proportion of these studies employed multi-method research to investigate secondary physics teachers' understanding and implementation of IBT. They surveyed physics teachers and students, interviewed teachers, and observed teachers' classrooms to obtain rich data and form a comprehensive understanding. For example, G. Liu (2004) employed a multi-method research to investigate junior secondary physics teachers' perceptions and implementation of IBT. The data were collected from survey, interviews and classroom observations. Results showed that the interviewed teachers' understanding of IBT was superficial and incomplete. The survey indicated that teachers' experience and school context were two major influential factors that affected teachers' perceptions of IBT. Analysis of teachers' inquiry practices revealed issues in managing inquiry-based classroom and several pedagogical issues in implementing IBT. This study suggests that there is a difference between teachers' implementation of IBT and what is required by the curriculum reform.

X. Chen (2008) used a case study to investigate how a physics teacher implemented inquiry-based learning in her teaching. The data were collected from interviews with students and teachers, classroom observations, and communications with teachers and students. This study provided valuable information on teachers' inquiry practice, and their concerns about, and reflection on, implementing inquiry practice, as well as students' feedback on inquiry-based learning.

These above-mentioned studies and a few other studies (e.g., Hong, 2006; F. Li, 2010; Y. Zhao, 2011) looked into classroom practices using multi-method research design. Although to some extent the data analysis of these studies was not sophisticated enough, they provided meaningful perspectives towards understanding Chinese physics teachers' inquiry practice.

On the other hand, although these studies were concerned about teachers' perceptions of IBT, they did not give sufficient research attention to teachers *per se* as individuals. Although some studies have identified factors that contribute to teachers' reluctance toward implementing IBT, it is difficult to find teachers' perspectives of how and to what extent those factors influence their interpretations of IBT and motivations for implementing IBT. Teachers' beliefs, their understanding and pedagogical knowledge of inquiry, and the interactions between beliefs, perceptions of inquiry, and inquiry practices, are further neglected.

2.8.2 Chinese secondary physics teachers' concerns about implementing IBT

Research showed that Chinese secondary physics teachers demonstrated different concerns about implementing IBT. Many Chinese science teachers found it very challenging to implement inquiry-based teaching (IBT) in their classrooms (B. Zhang et al., 2003). Furthermore, many of them found that their efforts of trying IBT turned out to be ineffective (Qian, 2012). They showed various concerns about the enactment of IBT at different aspects. These concerns were often raised from their reflections upon their teaching practice, student situations, and teaching contexts.

Concerns about teachers and teaching strategies

Physics teachers raised concerns about teachers themselves and teaching strategies relating to implementing IBT. For example, Yao (2003) pointed out that teachers themselves constitute serious constraints for their implementation of IBT, due to their narrow scope of knowledge and incomplete knowledge structure, "transmit-receive" traditional teaching styles, weak sense of collegial collaboration, and a lack of ability to develop and utilise curriculum resources. Carson (2007) argued that the ongoing curriculum reform in China challenges teachers' cultural positions in their classrooms. Meng (2003) asserted that many Chinese teachers are unfamiliar with inquiry-based learning and balanced science. Y. Zhao (2011) pointed out that many teachers know the key elements of inquiry and the requirement of the curriculum standards for IBT, yet do not know how to implement it.

Yao (2003) found that the physics teachers in his study were concerned about the strategies used to implement IBT. Their concerns subsequently affected their implementation of IBT. Jiang (2004) raised six typical concerns about how to implement IBT and how to use curriculum materials: (a) Whether new curricular materials can be integrated effectively into teachers' instructional practices; (b) How to find investigation topics that are appropriate, feasible, and interesting to high school students with a variety of backgrounds and ability levels; (c) How to strike a balance between the learning objectives, students' interests and teachers' instruction; (d) How to balance inquiry activities with other learning activities to ensure sufficient knowledge structure; (e) How to evaluate student learning during the procedure of IBT; and (f) How to deal with the relationship between in-class and after-class learning. Lin (2003) raised seven teachers' concerns regarding teaching from a more comprehensive perspective, including: (a) How to select topics for IBT; (b) How to determine the inquiry objective; (c) How much emphasis should be given to each section of inquiry with different content; (d) How to change the role of teacher; (e) How to create a constructive environment for inquiry; (f) How to foster students' sense of questioning; and (g) How to cater for students with different learning abilities and foster their development in inquiry.

Concerns about students and learning

Physics teachers and educational researchers are also concerned about student qualities, abilities, perceptions, and their learning outcomes in implementation of IBT. For example, Lin (2003) suggests several issues of student qualities in implementing IBT: (a) differences in understanding of scientific inquiry; (b) significant discrepancies in inquiry skills; (c) differences in cognitive development; and (d) differences in non-intellectual factors such as motivation, interest, emotion, and so forth.

A considerable number of studies are concerned with students' beliefs, perceptions, and other non-intellectual factors, such as interest, that may influence, and may be influenced by, the implementation of IBT. For example, Yao (2003) found that the proficiency level of students significantly influenced the effect of inquiry-based learning. Y. Zhang, Meng, Gao, Li, and Xin (2003) investigated 645 senior high school students' beliefs about science and their practical abilities in order to determine the feasibility of implementing IBT with these students. They found that many students had relatively rigid epistemological beliefs about science learning and the practical abilities of these students were poor. However, these students showed a sense of inquiry and questioning. The authors concluded that these students could benefit from IBT. D. Huang (2003) surveyed 272 Grade 11 students to investigate their perceptions of the influence of implementing IBT on learning physics. This study found that students generally held positive attitudes towards inquiry-based learning after experiencing it, while high-achieved students showed significantly lower interest in inquiry-based learning than did other students. C. Huang (2006) examined 122 Grade 11 students' perceptions of inquiry-based learning. She found that 64% of the participants agreed that it was necessary to implement inquiry-based learning, and 87% hoped to receive various help from teachers. The author went further to suggest that in order to implement IBTL effectively, physics teachers should focus on student interest and learning habits, psychological characteristics and social relationships. Yuhang Wang, Guo, and Zeng (2006) investigated the effectiveness of IBT on students' conceptual change by following a class of students throughout one school year.

Some other studies are concerned more about students' academic performance in IBT. They examined students' academic achievement in terms of students' test scores (e.g., Jiang, 2004; X. Liu, 2011; Yan Wang, 2008). Some of them (Yan Chen, 2004; S. Xu, 2006; Zhou, 2004) further examined the academic achievement of students with different levels of abilities. For example, Zhou (2004) found that IBT significantly benefit high-achieving students, long term IBT could promote test scores for students with average abilities, while IBT has no effect on test scores for students with low proficiency level. S. Xu (2006) had similar findings that the high-achieving and above-average ability students could quickly adapt themselves to IBT, while below-average ability students were more accustomed to didactic teaching. In these studies, teachers felt successful when students' test scores improved. They were also concerned about students' inquiry skills, scientific attitudes, and thinking. However, these seemed to be given lower priority than test scores.

Concerns about test preparation

Test preparation is an overriding concern of many high school physics teachers in China, because "in the senior high school classes [in the Eastern Asian countries], the emphasis is very firmly upon external examinations, graduation competencies and tertiary entrance criteria" (Marsh, 1991, p. 35). In China, the College Entrance Exam (CEE) is very competitive, particularly for admission to the public universities. Teachers are subject to high pressure from administrators, parents, students and themselves to help students earn a high score on the exam. To better prepare students for CEE, they pay great attention to problem solving skills. A teacher who could help students improve problem solving skills is considered to be a good teacher. The CEE requires teachers to put lots of time and effort into training students' problem solving skills, which, however, becomes an obstacle for teachers to implementing IBT because it needs time and students' vitality to experience the process of learning (Qian, 2012).

Furthermore, there is a strong link between students' examination scores and teacher's ranking (Gao, 2007; Hickey & Jin, 2007). The higher the student scores, the higher the rank given to the teacher.

This teacher evaluation system works as a major vector for teachers' promotion and dismissal (Gao, 2007; Hickey & Jin, 2007). As a result, classroom teachers tend to match their teaching styles to the examination requirements (Yang Chen, 1999), ignoring the introduced student-centred pedagogies.

Other practical issues

Besides the concerns mentioned above, several practical issues are also of great concern to physics teachers' implementation of IBT. These include: time, resources, and management issues. Time, experimental condition, resource and management issues are also of concern for Chinese teachers when planning the implementation of IBT (Lin, 2003; F. Liu, 2008; Y. Zhao, 2011; Muju Zhu, 2007; Zong, 2007; B. Zhang, et al., 2003). To varying extents, these concerns caused difficulties in teachers' implementation of IBT. Deficiencies in resources, equipment and space and questions about how to manage big classes, organise group activities and provide specific instructions for activities, and how to guarantee students' security, could all daunt teachers who are attempting to implement IBT (F. Liu, 2008). In particular, limited access to various resources seems to be a great obstacle for teachers to implement inquiry-based curricula in rural schools (Zong, 2007).

In all, teachers' concerns suggested that efforts to implement IBT in China face a number of challenges. These concerns indicated that to some extent Chinese teachers are aware of the gap between the requirements of IBT for understanding and pedagogical strategies and their current teaching situation. In addition, these concerns also revealed that many teachers are confused about how to implement IBT to meet the requirements of curriculum standards. According to the curriculum reform, science teachers should "attach importance to scientific inquiry, create inquiry opportunities for students, and allow them to experience the process of inquiry" (SHMEC, 2004, p. 55). However, the curriculum standards do not give specific guidance for how to conduct IBT, except for some examples of student inquiry activities. It will be up to science teachers to formulate patterns of teaching actions that accomplish the goals set forth by the curriculum standards.

2.8.3 Issues in earlier Chinese studies on IBT and the implications for the present study

Several issues in relation to the Chinese studies on IBT were distinct in the review of the Chinese literature on IBT specific to upper secondary physics. Discussion of the rationale and methodological approaches used by different investigators may shed light on the limitations of research conducted in this field to date.

As the review shows, very few Chinese studies on teachers' implementation of IBT give research attention to teachers' beliefs, their understanding and knowledge of inquiry, and the interactions between these factors and inquiry practices. Most of the current studies on IBT in China are homogeneous and following similar research agendas. They are concerned about the processes/models of carrying out IBT, and the resultant consequence of IBT on students' learning outcomes, particularly test scores. The perspectives of the teachers are generally overlooked or given a very low priority.

Although there is a small amount of research investigating teachers' perceptions of inquiry and their inquiry practice, little research emphasis was placed on investigating teachers' beliefs, their motivations and reasons for implementing IBT. There is a dearth of literature oriented towards understanding teachers' inquiry practice, associated with teachers' beliefs and their interpretation of inquiry, in their unique teaching contexts.

Second, a number of studies focused exclusively on developing instructional models for IBT from the theoretic perspective, yet the research on how teachers develop practice-oriented instructional models in their unique teaching contexts and incorporate IBT into their day-to-day teaching is scant. The earlier studies followed a Theory→Model→Practice research trend, ignoring the complexity of the teaching enterprise, leading to a depersonalized, context-free, and mechanistic view of teaching (Doyle, 1990). There is a wide gap between the developed theoretical models and the real practice in teachers' unique teaching context. The present study examined teachers' practical models and was developed with an intention to build an understanding of how teachers develop and adapt inquiry-based instruction for different contexts.

The third issue relates to the research methodology of those studies that were conducted in a real classroom context. The review found that only a small number of studies attached importance to qualitative and multi-method research methods. Two typical quantitative research methods seemed to be given great emphases. One typical research method is a quantitative survey with teachers and students (e.g., D. Huang, 2003). It was mainly used to obtain teachers' and students' perceptions of IBT. Another typical kind of quantitative research method is a quasi-experimental study using an experimental and a control group (e.g., Jiang, 2004; X. Liu, 2011; Yan Wang, 2008). Normally, two parallel classes were carefully chosen and taught using IBT and traditional approaches respectively, and students' achievement compared based on the end-of-term test scores. This research method tends to ignore the teachers' impact on students' learning and tends to treat classroom discourse as a mechanical and static procedure. Such a research method, if used alone or as a major method, cannot capture the complicated nature of classroom practices.

These issues indicate that there is a big piece missing from the Chinese educational researchers' map.

Certainly, research on science teachers' educational beliefs, practical knowledge, and inquiry practice will help educational researchers better understand the challenges that science teachers encounter in implementing IBT, and map out what experiences within a professional development program will best facilitate science teachers' implementation of IBT.

The present study addresses several issues in the Chinese literature on teachers' implementation of IBT. First, it uses a multi-method research methodology to collect both quantitative and qualitative data from various sources including surveys, interviews, field notes, casual talks, and case studies. The main research effort falls into an area that is almost entirely unresearched: close-grained qualitative research at the classroom level focusing on teachers' beliefs and practices in the classroom, and how those beliefs and practices interact.

Second, this study takes an interpretive approach to characterize how teachers connect their beliefs to practice and how they interact with the curriculum to implement IBT in their local teaching context. The understanding of teaching practice is developed from the perspective of teachers. This approach is almost in a reverse trend from most Chinese studies on teachers' implementation of IBT, in which the researcher chooses a theoretical framework and develops an instructional model of IBT, and then applies this model to practice and examine its effectiveness.

This study also responds to the need for more studies conducted at the senior secondary level to better understand the challenges that Chinese science teachers encounter in their implementation of IBT. It sheds light on teacher resistance to the implementation of inquiry-based curricular reforms in China and internationally, and is timely because such reforms are being rolled out – and resisted – in science education classrooms all over the world.

3. Methodology

This chapter presents the rationale and a discussion of the research methodology that addresses the study's research questions. It starts with an overview of the methodology used in this study, then describes the sampling of participants, and the data collection procedures, including a thorough discussion of each selected method and the instruments, followed by the general framework for data analysis. This chapter concludes with a discussion of the trustworthiness and ethical considerations of this study.

3.1 Mixed-methods Methodology

As identified in the literature review, little Chinese research has employed qualitative and multi-method approaches to investigate science teachers' perceptions and implementation of inquiry-based teaching (IBT). Very few studies applied a sociocultural lens to examine how teachers implement inquiry within the cultural context of their local situations. Therefore, studies that adopt a multi-method research approach and a sociocultural lens contribute to bridging the gap between previous studies and the demand for research documenting the sophisticated nature of teachers' instructional practice.

The purpose of this study is to understand how Chinese secondary physics teachers' beliefs, perceptions of inquiry, and their inquiry practice interacted in their teaching context in China. The researcher is aware that it is not possible to fully understand these phenomena and relationships without considering a variety of information. A mixed-method research design that includes quantitative and qualitative methods to generate a rich and comprehensive understanding (Creswell, 2003; Tashakkori & Teddlie, 2003) is considered to be appropriate for investigating the research questions in this study. Also, the mixed-method approach offers a collection of flexible research designs that seem well suited to support rigorous examination of promising ideas (Harwell, 2011).

3.1.1 Mixed-methods research approach

Literature suggests that mixed-methods studies are studies "that are products of the pragmatist paradigm and that combine the qualitative and quantitative approaches within different phases of the research process" (Tashakkori & Teddlie, 2008, p. 22). The mixed methods "combine qualitative and quantitative methods in ways that bridge their differences in the service of addressing a research question" (Harwell, 2011, p. 151). Mixed-methods research design "recognizes the importance of traditional quantitative and qualitative research but also offers a powerful third paradigm choice that often will provide the most informative, complete, balanced, and useful research results" (Johnson, Onwuegbuzie, & Turner, 2007, p. 129). It allows for the "opportunity to compensate for inherent method weaknesses, capitalize on inherent method strengths, and offset inevitable method biases" (Greene, 2007, p. xiii). Pajares (1992) and Richardson (1996) have argued that multiple forms of data were needed in order to understand the complicated nature of teacher beliefs.

In response to the research questions, this study used surveys, semi-structured interviews, and case studies to generate rich and contextualised data on teachers' perceptions and enactment of IBT. The quantitative data collected in the current study is concerned with how Chinese physics teachers' perceptions of inquiry relate to their beliefs, and further affect their instructional decisions regarding IBT; how they interpret IBT and implement it in their specific teaching contexts; and the challenges they are encountering in their implementation of IBT. The quantitative data are concerned with the status quo of the average level of teachers' implementation of IBT, the influential teachers' concerns and constraints, and relevant professional development. It is also concerned about whether their district area, teaching experience and school type make differences in teachers' opinions and enactment of IBT.

3.1.2 The concurrent triangulation design

This study employs a "concurrent triangulation design" (Creswell, 2003) that guides the construction of specific features of a mixed-methods study. The primary purpose of using this design is for confirmation, corroboration or cross-validation within a single study (Creswell, 2003). In this design, qualitative and quantitative data are collected concurrently. Weight should be equal but can be given to either kind of data in mixing the findings. The qualitative and quantitative data are analysed separately, and are integrated during the interpretation phase (Creswell, 2003; Harwell, 2011). The strengths of this design include offsetting weaknesses inherent to one kind of method by using both, and needing a shorter data collection period (Harwell, 2011).

The current study gives greater priority to qualitative data, because the complexity of teachers' beliefs and inquiry practice in their teaching contexts demands the researcher "study things in their natural settings, attempting to make sense of, or interpret, phenomena in terms of the meanings people bring to them" (Denzin & Lincoln, 2005, p. 3). Qualitative data focus on discovering and understanding the experiences, perspectives, and thoughts of participants. It explores meaning, purpose, or reality (Hiatt, 1986). Therefore, the qualitative data carries more weight in the current study. Meanwhile, the researcher attempts to use quantitative data (surveys data in this study) to respond to some research questions, combining probability theory to test statistical hypotheses to "maximize objectivity, replicability, and generalizibility of findings" (Harwell, 2011).

In summary, a mixed-method research design combining different research methods, and a concurrent triangulation design, is appropriate to provide in-depth and meaningful data to answer the research questions of this study.

3.2 Research Design

In response to the research questions, this study has collected data about teachers' beliefs, understanding and knowledge of inquiry, and their instructional practices regarding IBT. Multiple methods, therefore, are employed to collect data. The following diagram (Fig. 3-1) shows the study's research design and how it answers the research questions. As the diagram shows, this study takes place in three phases. In phase one, a questionnaire is administered to physics teachers. In phase two, purposefully selected teachers are interviewed. In phase three, case studies are conducted. All methods are discussed in detail in the following sections.

Surveys

The survey was designed to collect information on the status quo of teachers' implementation of IBT (level of implementation), teachers' perceptions of own inquiry practices, and their views on the constraints and difficulties in implementing IBT, and relevant professional development. The instrument used is specifically discussed later in this chapter.

Semi-structured interviews

Semi-structured interviews were employed to explore the participating teachers' beliefs and perceptions of inquiry and IBT. They were also used to investigate teachers' instructional decisions regarding the use of IBT, and professional development they demanded for implementing IBT.

The semi-structured interview is a research method used for exploring data grounded in participants' experience as well as those data that are theory laden (Galletta, 2013). It provides a very flexible technique for small-scale research (Drever, 1995). By using both structured and open-ended questions, a semi-structured interview not only allows the researcher to maintain the focus of the study during data collection, but also allows bringing up new ideas or issues during the interview as a result of what the interviewee says (Merriam, 1998).

Figure 3-1 Research Method Design

Research Questions: *Q1: How do Chinese physics teachers perceive IBT? Q2: What are teachers' beliefs about the nature of science, teaching, and learning ? Q3: How do Chinese physics teachers implement IBT in their specific teaching contexts? Q4: What are the relationships between teachers' beliefs, perceptions of IBT, and their implementation of IBT? Q5: To what extent does the teaching context in China influence teachers' implementation of IBT?*

Data to be collected	Methods		Relationship between data and research questions	Sources of information
Data concerning teachers' perceptions of their own inquiry practices, and their concerns of implementing IBT	Survey		The data provide information on the general status of teachers' enactment of IBT, and identifies the prominent challenges that teachers are encountering in their implementation of IBT. (*Q1*)	65 physics teachers
Data concerning teachers' perceptions of inquiry and IBT	Semi-structured interview		Interviews provide insights into physics teachers' perceptions of inquiry and their ideas of how IBT would be implemented in their classrooms. It also provides insight into the influences of a variety of factors on their instructional decisions regarding IBT. (*Q1,Q4, Q5*)	15 purposefully selected teachers
Data concerning teachers' beliefs, perceptions of IBT, instructional decisions and instructional practice regarding IBT, and the relationships between beliefs, perceptions of IBT, and implementation of IBT	Case studies	Semi-structured interview	Interviewing teachers provides insights into the process of how physics teachers interpret IBT and match it with their own beliefs to construct meanings, and explores their perceptions of how IBT would be implemented in their classrooms. It also provides insight into the influences of a variety of factors on teacher beliefs and in turn practices. (*Q1, Q2, Q4,Q5*)	5 purposefully selected teachers
		Classroom observation Informal conversation Field notes	Classroom observations and informal conversations provide data showing what actually happens in the classroom, an in-depth understanding of teachers' pedagogy in conducting IBT, and how their beliefs and perceptions relate to their practice. Field notes provide contextual information on teachers' inquiry practice, such as school environment, student situation, resource, etc. (*Q3, Q4, Q5*)	

Case studies

A case study methodology (Flyvbjerg, 2011; Merriam, 1998; Yin, 2003) was chosen for this study in order to focus closely on specific teachers and their beliefs, understanding and knowledge of inquiry, and instructional practices in relation to IBT. The underpinning assumption is that teachers' instructional practice is the consequence of a complex, dynamic, individual, and context-dependent instructional decision-making process under the influences of the teaching context.

The case study is a research strategy which focuses on understanding the dynamics present within single settings (Eisenhardt, 1989). Researchers who implement case study designs pay considerable attention to contextual conditions, such as procedural and sociocultural factors, that may contribute to a case (Demetriou, 2009; Yin, 2003). Flyvbjerg (2011) notes that "case study produces the type of concrete, context-dependent knowledge that research on learning shows to be necessary to allow people to develop from rule-based beginners to virtuoso experts" (p. 302).

Case studies can involve either single or multiple cases, and numerous levels of analysis (Yin, 2003). A multiple case study approach allows researchers to gain insight into the phenomenon in more than one context (Stake, 1995). Conducting multiple case studies also offers the advantage of allowing comparisons to be made within and across cases which can add confidence to the findings of the study (Merriam, 1998; Stake, 1995; Yin, 2003). In the current study, multiple case studies were used to research and compare teachers' perceptions and enactment of IBT in different contexts. Therefore, purposeful sampling of participants (Merriam, 1998; Stake, 1995) was employed in this study.

Yin (2003) suggests that the use of multiple sources of evidence allows the researcher to address a broader range of issues, and to develop "converging lines of inquiry, a process of triangulation". In this study, interviews, classroom observations, informal conversations, and field notes are used as the source of data in case studies. Interviews are the most common source of data in case study research (Merriam, 1998). Observations are also an important but highly subjective data source whose use must be carefully considered (Merriam, 1998). However, observation provides a valuable source of qualitative data because the process occurs in natural settings (Merriam, 1998; Miles & Huberman, 1994; Yin, 2003). It provides first-hand accounts of events rather than an interpretation collected via interviews (Merriam, 1998). Maxwell (1996) argues that observations and interviews can provide a more complete and accurate account than either can alone. In addition, "informal conversational interviews" can add some important dimensions (Patton, 2002) to case study research. They are likely to produce information or insights that the researcher could not have anticipated. Field notes allow the researcher to describe the setting, participants, and comment on the surroundings (Merriam, 1998). These approaches compensate for the inherent methodological weaknesses of classroom observations.

The cases presented in this study are intended to offer rich, contextual explorations of the beliefs and practices of particular teachers in particular classrooms, as "occasions for reflection" (Geelan, 2004, p. 4) on the part of readers, who are assumed to be experts in the field of science education. They also provide the readers with "empirical materials" (Denzin & Lincoln, 2005, p. 25) to inform their thinking about the implementation of IBT.

3.3 Participant Sampling

This study involved a total of 102 senior physics teachers from three districts of Shanghai, China. Among them, 37 physics teachers from one suburban district participated in a pilot study, and another 65 physics teachers from two urban districts participated in the formal study. Among the 65 physics teachers, 15 teachers from different types of schools in one district were interviewed. Five of them participated in the case studies.

3.3.1 Shanghai, China

The study was conducted in Shanghai, a major city in the eastern part of China. Shanghai was chosen mainly due to its superior economic conditions and better educational resources compared with other regions of China (OECD, 2011). This provided a probability of comparing this study with earlier studies on teachers' inquiry practice that were done in western countries. It was chosen also because it is well positioned to inform the reform processes in the rest of China as the IBT reforms spread more broadly across the nation. Prior to the two rounds of national curriculum reforms initiated in 1992 and 1998 respectively, Shanghai was required by the former State Education Commission (now the Ministry of Education) to initiate its first and second round of curriculum reforms respectively (see, SHMEC, 2005), which meant that schools in Shanghai had a "head start" in implementing IBT compared with schools elsewhere in China. The new senior secondary curriculum standards and textbooks were used in all schools from 2006. Inquiry and IBT were introduced to the curriculum standards from then on.

The two selected districts in the formal study are typical urban districts of Shanghai. There is no significant difference between these two districts and other urban districts in Shanghai in terms of educational resources and teaching resources for teachers and students. Therefore, they were chosen mainly due to their accessibility to the researcher, but were also seen as representative of similar districts across Shanghai.

3.3.2 Survey participants

At the first stage of this study, the researcher contacted with the district coordinators of physics teaching and study (DCP)[1] of these three districts to seek for assistance. The DCP is a person who

[1] China has also developed a rather rigorous framework and system of teaching. At the grassroots level, subject-based "teaching-study groups" engage in study and improvement of teaching on a daily basis... The "teaching-study group" is supervised for each of its subject areas by the "teaching-study office" in the Education Bureau (in a rural country or city district), which is in turn supervised by the relevant "teaching-study office" in the Education Department in the provincial or municipal government. Professionally, all these "teaching-study"setups work under the Basic Education

takes a position to direct curriculum implementation at the school level, and to organise teaching and studies, and professional development programs for physics teachers in that district, to align with the requirement of the Municipal Education Commission. They provided the researcher with important opportunities for meeting all physics teachers of these districts in teaching and research activities organised at the district level. With their assistance, the researcher met the major part of the senior secondary physics teachers at the district meeting. These teachers were invited to participate in this study. Finally, 37 senior physics teachers from a suburban district participated in the pilot study before the formal survey. 65 senior physics teachers of two selected districts participated in the formal survey. Information on the formal survey participants is given in Table 3-1.

Table 3-1 Information on the formal survey participants (n=65)

Characteristics		District A (n=39)	District B (n=26)	Total
Gender	M	24	14	38
	F	15	12	27
School Type	Key	15	10	25
	Non-Key	24	16	40
Teaching	≤5yrs	8	4	12
	5-10yrs	13	7	20
	11-15yrs	4	7	11
	>15yrs	14	8	22
Degree	Bachelor and over	38	26	64
Year level	G10	19	8	27
	G11	15	7	22
	G12	3	6	9
	Combo	2	5	7

3.3.3 Interviewees

Fifteen physics teachers were purposefully selected for interviews. A snowball sampling technique was used to select the interviewees. These teachers were all from the same district (District A). The DCP of this district introduced several teachers from different types of schools for interviews and helped gain access to their schools. The participating teachers were then asked to assist the researcher in identifying other potential interviewees. Finally, 15 teachers with different years of teaching experience and from different school types participated in interviews. Teacher demographical information is shown in Table 3-2.

Department II within the central government's Ministry of Education. The Basic Education Department II is charged with all matters related to curriculum development, textbook production, pedagogy enhancement and school management for the whole nation.(OECD, 2011, p.88)

School background was an important criterion to select teachers. There is a total of nine senior high schools in this teacher's district, including two municipal key public schools[2], six non-key public schools, and one non-key private school. These different types of schools admit different groups of students according to their rankings in the competitive Senior Secondary School Entrance Examination (SSSEE). Teachers who are facing different groups of students tend to hold different beliefs and often develop different instructional strategies based on their student situations.

Another important criterion for selection was teachers' experience. The participants, who had different levels of teaching experience, were able to provide information about teacher beliefs at different career stages. The rationale for this selection was based on findings that experienced science teachers and beginning teachers tended to have different beliefs about, and approaches to, teaching science, along with different attitudes towards curriculum reform and different trends in belief change (Luft & Roehrig, 2007; Wallace & Kang, 2004). In addition, experienced science teachers, as opposed to beginning teachers, were likely to possess an integrated set of knowledge and beliefs, which is usually consistent with how they act in practice (van Driel, Beijaard, & Verloop, 2001). This may cause significant differences in their classroom instructional practice.

Table 3-2 Information on the 15 interviewees

CODE	Gender	Degree	Teaching experience	School Type	Year level
Wen*	Female	Bachelor	<1 year	Key public school	Grade 10
Xu	Male	Bachelor	<1 year	Non-key public school	Grade 10
Min*	Male	Master	4 years	Non-key private school	Grade 10
Li	Male	Bachelor	5 years	Non-key private school	Grade 12
Wang	Male	Bachelor	5 years	Key public school	Grade 10
Lin	Female	Bachelor	6 years	Key public school	Grade 11
Dong	Male	Bachelor	7 years	Non-key public school	Grade 9&10
Xiao	Male	Bachelor	8 years	Key public school	Grade 9&10
Liu	Male	Bachelor	10 years	Key public school	Grade 12
Yao	Female	Bachelor	10 years	Key public school	Grade 11
Ding*	Female	Bachelor	11 years	Key public school	Grade 10
Jun	Male	Master	11 years	Key public school	Grade 11
Zhao*	Male	Master	18 years	Non-key public school	Grade10&12
Pan*	Male	Bachelor	20 years	Non-key public school	Grade 10
Lu	Male	Bachelor	27 years	Key public school	Grade 10

* These teachers participated in case studies.

** Pseudonyms have been used for all teacher names.

[2] Key schools: The key schools have advantages in enrolling students and obtaining educational input over the normal public schools. Compared with other schools, the municipal key schools enrol students who have higher test scores in the senior secondary school entrance examination (SSSEE). Furthermore, the municipal key schools receive educational input both from the municipal government and the district government. Other schools in this district receive educational input from the district government.

3.3.4 Participants of the case studies

Five purposefully selected physics teachers were invited to participate in case studies. These teachers were carefully selected to represent a range of contexts and levels of teaching experience. The rationales for selection were, as stated previously, that teachers who were facing different groups of students and having different levels of experience, tended to hold different beliefs and often develop different instructional strategies. Another criterion for inclusion was that each of the selected teachers indicated that they had tried IBT, or were currently trying IBT, in their classrooms. All the teachers were teaching Grade 10 physics at the time of the study. Among them, one was a student teacher at the time. All the teachers held at least a bachelor degree in physics education. Their schools were conveniently accessible to the researcher. Information on the five participants is given in Table 3-3.

Table 3-3 Information on the five participants in case studies

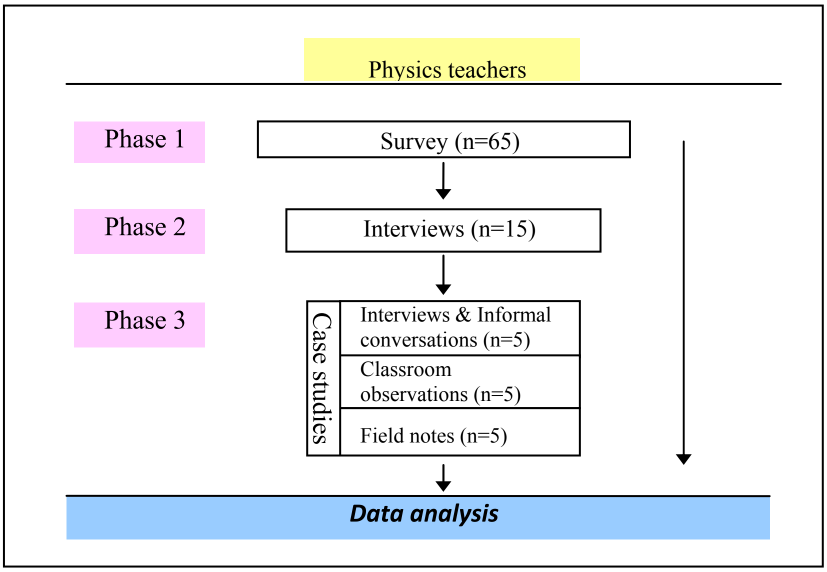
CODE	Gender	Degree	Teaching experience	School Type	Year level
Ding	Female	Bachelor	11 years	Key public school	Grade 10
Wen	Female	Bachelor	<1 year	Key public school	Grade 10
Pan	Male	Bachelor	20 years	Non-key public school	Grade 10
Zhao	Male	Master	18 years	Non-key public school	Grade 10&12
Min	Male	Master	4 years	Non-key private school	Grade 10

*Pseudonyms have been used for teacher names.

3.4 Data Collection

This study took place in three phases. The data collection occurred in a sequence from collecting general information to collecting in-depth data, with the sample size of participants purposefully narrowed down. When the data were collected was adjusted according to the real situation of each school and the participant. An overview of the processes of data collection is shown in Fig. 3-2. The instruments used in each phase are discussed in detail in the following part.

Figure 3-2 The process of data collection



3.4.1 Phase one: Survey

The survey was designed to collect information on teachers' perceptions of own inquiry practices, and their views on the constraints and difficulties in implementing IBT. In order to achieve this target, a questionnaire was administered to 65 senior secondary physics from two districts. Questions were developed to focus on four related aspects of teachers' implementation of IBT (see Appendix A).

- Approaches to classroom inquiry and instructional models of implementing IBT (Questions 1 & 2)
- Level of implementation of IBT (Question 3)
- Influences of teacher concerns on implementation of IBT (Question 4)
- Influence of relevant professional development activities on implementing IBT (Questions 5, 6 & 7)

The question (Question 3) that was concerned with teachers' level of implementation of IBT was adapted from the Concern-Based Adaption Model - Level of Use of the Innovation (CBAM-LoU) (Hall, Loucks, Rutherford & Newlove, 1975). The CBAM-LoU is a self-assessment instrument designed for adoption of an educational innovation. There are eight levels defined to describe behaviours of innovators: *(0) Non-Use, (I) Orientation, (II) Preparation, (III) Mechanical Use, (IVA) Routine, (IVB) Refinement, (V) Integration,* and *(VI) Renewal*. These levels are intended to describe the actual behaviours of adopters rather than affective attributes (Hall, et al., 1975). They describe the actions that educators engage in as they become more familiar with and skilled in using a practice or adopting a change.

This instrument has been successfully used for assessing the implementation of reform initiatives. For example, Griffin and Christensen (1999) stated that the CBAM-LoU was efficient to be used as an indicator of an educator's progress along a technology utilization continuum.

The researcher modified this instrument to assess the Chinese senior secondary physics teachers' Levels of Implementation of IBT (LoI of IBT) in their classrooms. Fig.3-3 defines the eight levels of implementation of IBT (coded from 1 to 8). The levels increase with the degree to which teachers are familiar with and skilled in using IBT. Participants were required to circle the level that best fitted their statuses.

Figure 3-3 Level of Implementation of Inquiry-Based Teaching (LoI-IBT)

	Description of Behaviours
1.	**Level 0_Non-Use**: I have little or no knowledge of inquiry-based teaching, no involvement with it, and I am doing nothing toward becoming involved.
2.	**Level 1_Orientation**: I am seeking or acquiring information about inquiry-based teaching.
3.	**Level 2_Preparation**: I am preparing for the first activity of inquiry-based teaching.
4.	**Level 3_Mechanical Use**: I have implemented some activities of inquiry-based teaching, with little time for reflection. My effort is primarily directed toward achieving the requirements set by the new curriculum standards.
5.	**Level 4A_Routine**: I feel comfortable implementing inquiry-based teaching. However, I am putting forth little effort and thought to improve inquiry-based teaching or its consequences.
6.	**Level 4B_**Refinement: I vary approaches to inquiry-based teaching to increase the expected benefits within the classroom. I am working on maximizing the effects with my students.
7.	**Level 5_Integration**: I am combining my own efforts with related activities of other teachers and colleagues to achieve impact in the classroom.
8.	**Level 6_Renewal**: I re-evaluate the quality of the approaches to inquiry-based teaching, seek major modifications of, or alternatives to, present approaches to achieve increased impact, examine new developments in the field, and explore new goals for myself and my school or district.

Adapted from the Concerns-Based Adoption Model - Levels of Use (CBAM-LoU) (Griffin & Christensen, 1999)

Questions that were concerned with other aspects of teachers' implementation of IBT were developed based on the literature review and the findings of prior studies. For example, question 2 provides items about approaches to inquiry for teachers to choose, presenting a continuum that includes three broad categories: Guided, Open-ended, and Teacher-collaborative approaches (D'Avanzo and McNeal 1997).

Question 4 describes 17 items of concerns in implementing IBT which were identified and summarised from the Chinese literature (Yan Chen, 2004; Hickey & Jin, 2007; Jiang, 2004; Lin, 2003; F. Liu, 2008; G. Liu, 2004; Meng, 2003; Qian, 2012; S. Xu, 2006; Yao, 2003; Y. Zhao, 2011; Muju Zhu, 2007; Zhou, 2004; Zong, 2007). A sample item is "IBT needs a lot of time and my teaching hours are limited" (see Appendix A). Respondents were required to choose the level of influence of these concerns on their attempts to implement IBT. Five-point Likert scales were used to rate the participants' responses, for example, 1 = not at all influential, 2 = slightly influential, 3 = somewhat influential, 4 = very influential, and 5 = extremely influential.

Several questions are concerned with the influence of relevant professional development activities on teachers' implementation of IBT. These were focused on three aspects:

- Relevant teaching and research activities regarding IBT (Question 5)
- Strategies important to the successful implementation of IBT (Question 6)
- Factors helpful to form or change teachers' views about IBT (Question 7)

These questions were developed based on findings from prior Chinese studies (see Hong, 2006; G. Liu, 2004; F. Li, 2010). Five-point Likert-type scales were used to rate the participants' responses.

A pilot study was carried out before the formal survey. The purpose of the pilot study was to test the reliability and validity of the survey, clarify the questions, and identify any issue that needed to be addressed before the main data collection. After the data was collected, item analyses were conducted for those questions which had more than six items, to improve the reliability and validity of the survey. Teachers' suggestions were considered to clarify and reedit the items to further improve the validity of the survey. Based on the test results and the teachers' feedback and suggestions, those items which contributed little or nothing to the measurement were deleted, and some items were modified to be more effective in data collection.

3.4.2 Phase two: Interviews

Semi-structured interviews were organised with 15 purposefully chosen physics teachers. The key questions of this interview (see Appendix B) were adapted from those used in related studies (see

Lotter et al., 2007). These include both structured and open-ended questions to help define the areas to be explored and generate rich responses, and also allow the conversation to diverge in order to pursue an idea or response in more detail. A sample question is “How would you define inquiry?”

The semi-structured interviews with teachers were individually arranged in teachers’ work place, lasting 30-50 minutes. (The length of interview was adjusted according to the real situation.) All interviews were audio-recorded and then fully transcribed. Analysis was conducted in Chinese and then significant quotes translated into English.

3.4.3 Phase three: Case studies

Case studies were conducted with five purposefully chosen physics teachers. The case studies tried to address the following questions: (a) What are teachers’ educational beliefs, understanding and knowledge of inquiry, and their instructional decisions regarding IBT, (b) How do teachers enact IBT in their regular teaching, and (c) How do teachers interpret inquiry within their beliefs, and incorporate it into their teaching practice.

This study chose to use interviews, classroom observations, informal conversations, and field notes as the source of data in case studies. Triangulation of the data sources contributed to developing the case for each participant. The emphasis of the case studies is placed on understanding how teachers implemented IBT and why they considered those particular teaching approaches to be appropriate in their classrooms.

Interviews and informal conversations

The participants in the case studies had been interviewed at phase two. Their interviews included more questions than other interviewees. These questions were not only concerned with teachers’ perceptions of inquiry and IBT and related instructional decisions, but also concerned with their beliefs about the nature of science, teaching, and learning science, and their teaching contexts. A sample question is “What kind of physics lesson do you think is effective?” The interviews with these teachers were lasting 50-60 minutes.

The researcher kept constant contact with the case study teachers. One teacher (Pan) offered the researcher an opportunity for a second interview because both the researcher and he thought it was necessary to further explain some important perspectives. Other teachers used email to clarify and confirm their perspectives. The interviews were digitally recorded and transcribed for analysis.

Informal conversations were conducted with teachers before and after classroom observations to better understand their inquiry practice. Questions were asked in relation to specific teaching and learning activities observed in the classroom observations. For example, after one lesson on "The Resultant of Forces" Ding was asked: "Why did you use a new teacher demonstration, instead of the one in the textbook, to explain the parallelogram rule?", and "How did you decide to use this demonstration?" These informal conversations were audio-recorded when it was possible to do so; otherwise they were recorded in the researcher's field notes after the school visits.

Informal conversations also occurred when the researcher phoned the participants to ask or clarify their perspectives after school visits. For example, an informal phone conversation lasting approximately 10 minutes was held with Wen and Zhao respectively. Notes were taken during these conversations by the researcher and referred to during data analysis.

Classroom observation

The classroom observations examined the features of inquiry in teachers' inquiry practice referring to the inquiry rubric (NRC, 2000). A table was developed to describe these behaviours (see Appendix C). Teachers' questioning strategies to guide and facilitate student inquiry were given particular attention in implementing IBT in classroom observation. The *Inquiry Science Questioning Quality Criteria* (Brandon et al., 2008, p.248) were used in examining teachers' questioning strategies (see Appendix D). It also refers to Llewellyn's (2011) four levels of inquiry to determine teachers' approaches to inquiry.

The teachers' classrooms were observed during one school semester (from September 2009 to January 2010) to record the details of their instructional practices in relation to IBT. Classroom observations were arranged according to teachers' convenience. Teachers were told that the researcher would prefer to observe classes which dealt with several topics if it was possible and practical to do so (so teachers were possibly compared with each other if they taught the same topics).

Each teacher was observed three to five times. Each observation lasted for the duration of the lesson, ranging from 40-50 minutes. The observed lessons included lessons that used the traditional style of teaching, and lessons that used inquiry-based teaching. All inquiry-based teaching lessons were audio-taped. The researcher sat at the back of the classrooms and acted as a non-participating observer. Field notes were recorded during the classroom observations and after the school visits. Informal conversations were conducted and recorded before or after the observed lessons.

Field notes

The researcher used field notes to record teachers' instructional practices during classroom observations. Field notes were also used to describe the contextual information of teachers' inquiry practice, such as school environment, participants, and the researcher's comments on the surroundings.

3.5 Data Analysis

3.5.1 Quantitative data (survey)

The study analysed quantitative data using Stata and Excel. The participants' responses were coded and categorised according to the scales of questions.

Depending on the data type collected in different questions, Chi-square test for Independence (including Fisher's exact test) or Rank-sum test was conducted to determine whether there are significant associations between the examined variables (for example, association between teachers' approaches to inquiry and school types). For questions that employed 5 point Likert-type scales, analysis of variance (ANOVA) was conducted to examine whether the participants' responses are significantly different from each other by district areas, school types, and levels of teaching experience. For all analyses, $P < 0.05$ was considered significant. A comparison and discussion were then conducted based on the results of the analyses.

3.5.2 Qualitative data (interviews, classroom observation, and field notes)

This study employed an interpretive approach (Berg, 2004) to analyse qualitative data. This approach is against a depersonalized, context-free, and mechanistic view of teaching. As Tobin (2000) describes, an interpretive study "endeavor[s] to understand a community in terms of the actions and interactions of the participants, from their own perspectives" (p. 487). The interview analysis of this study focused on meaning (Kvale, 2007) in order to capture the participants' own meanings and points of view.

Thematic analysis (Boyatzis, 1998; Braun & Clarke, 2006) was conducted to analyse the interview transcripts, classroom observation and field notes. While some research traditions such as grounded theory (Strauss & Corbin, 1998) tend to draw themes from qualitative data inductively, this is not the only available approach. Braun and Clarke (2006) outline inductive, deductive and mixed approaches to thematic analysis of qualitative data. The present study used a mixed approach, scrutinising data for recurring themes using a constant comparative method, meanwhile seeking data relevant to the themes identified in the research questions.

Interviews

Using the mixed approach described above, each teacher's responses were carefully examined to develop an initial set of descriptive categories (Glaser & Strauss, 1967). After categories were developed for each individual teacher, the categories were grouped, synthesised, and compared across the interviewed teachers to identify common themes (Braun & Clarke, 2006; Leech & Onwuegbuzie, 2008). The common themes were then reviewed, refined, and finally defined and named (Braun & Clarke, 2006). The final themes revealed how the teachers perceive classroom inquiry, the nature of science, teaching and learning, and what factors influenced their decisions regarding implementing IBT. The final thematic analysis step involved reporting themes to address the research questions, including compelling examples extracted from the data to adequately represent findings (Braun & Clarke, 2006; Leech & Onwuegbuzie, 2008).

Classroom observation and field notes

Thematic analysis was also conducted to examine classroom observation and field notes to identify teachers' instructional models of implementing IBT, the features of inquiry in their classroom inquiry, and the strategies they used to manage the classroom and facilitate their teaching. Audio recordings and informal conversations were also referred to for this purpose. This process allowed for data triangulation (Krefting, 1991; Miles & Huberman, 1994). At times, notes and recordings were also referred to in order to clarify particular events that took place before and after classroom observation.

The analyses started with identifying the teachers' instructional models of implementing IBT according to the pedagogical components and sequences that characterised their inquiry practice. This process began with an initial examination of all the five teachers' instructional practice to distinguish the basic pedagogical components according to their main pedagogical functions. When these components were distinguished, an iterative examination of each case study teacher's inquiry practice was carried out to define the pedagogical components and their sequence, so as to identify the phases of their instructional models of implementing IBT.

Then the researcher closely examined the process of classroom inquiry in each teacher's classroom. The process of classroom inquiry included the six essential elements, which were prescribed in the *PCSSSS* (SHMEC, 2004): (a) Identifying a question, (b) Formulating a prediction/ hypothesis, (c) Designing the investigation plan, (d) Using tools and collecting evidence, (e) Analysing data and developing explanations, and (f) Communicating procedures and results. A built-in schema was used to illustrate how a teacher managed these elements in the process of classroom inquiry.

By drawing the pedagogical components and their sequences, together with a built-in schema representing the inquiry process, each teacher's instructional model was able to be depicted.

With this big picture, the analysis further examined the features of classroom inquiry in each teacher's classroom to find out how teachers guide and manage student inquiry. The teachers' and students' behaviours in the whole process of inquiry in relation to the essential elements of scientific inquiry (SHMEC, 2004) were analysed. Teachers' approaches to inquiry were determined by Llewellyn's (2011) four levels of inquiry (see 2.1.2). Teachers' questioning strategies used in IBT were also examined.

Information obtained from analysing surveys, interviews, and observations of classroom practices was interpreted through triangulation. Teachers' inquiry practice was linked to their beliefs, knowledge, their pedagogical understanding of IBT, and instructional decisions regarding IBT which were revealed from the interview analysis. Informal conversations and field notes were used as additional support for understanding the relationships.

3.5.3 Within-case analysis and cross-case comparisons

The individual cases were analysed with an ethnographic orientation, considering the sociocultural perspectives on teaching and learning. Contextual and cultural issues were explored when interpreting the role of teachers' beliefs in their implementation of inquiry-based instruction in the classrooms. The researcher tried to explore the integration of cultural beliefs and individual beliefs as they collectively impact teachers' instructional decisions regarding IBT. An ethnographic lens was also applied to make sense of the cultural context in the classroom where learning occurred.

After the individual cases were analysed and conclusions were drawn, a cross-case comparison was conducted among the five case studies. The analytical technique of pattern matching (finding patterns and building an explanation of these patterns) (Yin, 2003) was used in this process. The comparisons led to the development of series of generalisations concerning the Chinese teachers' models of implementation of IBT.

3.6 Trustworthiness of this Study

Seale (1999) states that the "trustworthiness of a research report lies at the heart of issues conventionally discussed as validity and reliability" (p. 266). Lincoln and Guba (1985) suggest that the idea of discovering truth through measures of reliability and validity is replaced by the idea of trustworthiness, which is "defensible" and establishing confidence in the findings. They proposed four criteria for assessing the trustworthiness of qualitative research and explicitly offered these as an alternative to more traditional quantitatively-oriented criteria. These include credibility, transferability, dependability and confirmability.

3.6.1 Credibility

Credibility is an important criterion in establishing that the results of qualitative research represent a "credible" conceptual interpretation of the data drawn from the participants' original data (Lincoln & Guba, 1985; Trochim, 2006). It refers to the confidence one can have in the truth of the findings. Credibility can be established by various methods. This study employed four methods: triangulation, prolonged and persistent field work, peer examination, and participant review.

Triangulation

Many researchers (Krefting, 1991; Lincoln & Guba, 1985; McMillan & Schumacher, 2006; Merriam, 1998; Padgett, 2008) agreed that triangulation is typically a strategy for improving the validity and reliability of research or evaluation of findings through the use of multiple perspectives. Creswell (2003) explained that triangulation includes the use of different data sources of information "by examining evidence from the sources and using it to build a coherent justification for themes" (p. 196). Patton (2002) further suggests that "triangulation strengthens a study by combining methods". This can mean using several kinds of methods or data, including using both quantitative and qualitative approaches".

For this study, triangulation seemed particularly relevant, as it not only engaged multiple methods, such as surveys, interviews, observation and field notes, but also involved different kinds of data, for example, qualitative and quantitative data. They provided deep insight into teachers' inquiry practice and corroborate one another, leading to a more valid, reliable and diverse construction of reality.

Prolonged and persistent field work

Sufficient time should be spent in a context to develop an understanding of the phenomenon, group, or culture in broad perspective before focusing on a particular aspect or theme embedded in that context (Lincoln & Guba, 1986). Prolonged and persistent field work also allows interim data analysis and corroboration to ensure the match between findings and participant reality (McMillan & Schumacher, 2006).

In this study, the researcher spent much time on reading the textbook, visiting teachers' schools, and observing more teachers' lessons at teachers' convenience as a non-participating observer, before formally collecting the data for the case study. This strategy allowed the researcher to be familiar with the teachers and their students. This familiarity also allowed the researcher to maintain constant contact with case study participants. It also encouraged participants to provide responses and reflect on their true feelings and opinions. The persistent observation also allowed the participating teachers and students to become accustomed to the presence of the researcher and behave as they regularly behaved. Through prolonged and persistent field work, the researcher acquired a sufficient depth of understanding to assess the quality of the data.

Peer examination

Credibility can be enhanced through peer examination (Krefting, 1991; Merriam, 2008; Seale, 1999; Shenton, 2004). Peer examination was utilized during the process of data analysis. The researcher's supervisor debriefed the whole process of data analysis and assisted the researcher in the refinement of initial classification codes used to analyse interviews. After the codes were collated into themes and sub-themes, a Chinese colleague who is researching in a similar area of inquiry-based teaching was asked to independently code several segments of interview transcripts using these themes. Once this was done, the researcher and her colleague met to discuss their interpretations and understanding. A following discussion was arranged among the researcher and her academic advisors to clarify the coded themes. This process resulted in substantial agreement between the researcher, her colleague and her academic advisors. Furthermore, peer examination was used in the data translation. The same Chinese colleague was asked to independently translate several segments of interview transcripts into English. After that, the researcher and her colleague discussed their translations to avoid ambiguous translations. Peer examination conducted by a researcher working in similar settings corroborated the findings of this study.

Participant review

Participant review during the process of data analysis can also contribute to a study's credibility (McMillan & Schumacher, 2006). This technique was employed by the researcher during the scrutiny of the interview data in the process of data analysis. The researcher contacted participants to confirm their opinions for the accuracy of different representations. The researcher also emailed or phoned them to confirm their perspectives. For example, one teacher offered the researcher an opportunity for a second interview to provide more opinions. Some teachers had several informal conversations with the researcher to confirm and explain their opinions. Email contacts between the researcher and some teachers were used to clarify some perspectives. Informal phone conversations lasting approximately

10 minutes were conducted with some teachers. Notes were taken during the conversations by the researcher and referred to during data analysis.

3.6.2 Transferability

Transferability refers to the degree to which the research findings can apply or transfer to other contexts (Lincoln & Guba, 1985). Thick description is a technique establishing transferability. Thick description is described by Lincoln and Guba (1985) as a way of achieving a type of external validity. By describing a phenomenon in sufficient detail one can begin to evaluate the extent to which the conclusions drawn are transferable to other times, settings, situations, and people. In this study, the researcher provided sufficient information that can be used by the readers to determine whether the findings are applicable to the new situation (Lincoln & Guba, 1985).

3.6.3 Dependability

Dependability is a criterion of trustworthiness that refers to the extent to which interpretation was constructed in a way which avoids instability other than the inherent instability of a social phenomenon (Lincoln & Guba, 1985). In order to enhance the dependability of qualitative research, it is necessary to describe the exact research methods that were used to collect and analyse data (Krefting, 1991; Shenton, 2004).

In this study, the researcher utilised the following strategies to evaluate inconsistency during data collection and analysis: Peer examination, Code-recode, and Dense description of research methods. Already discussed were the benefits of peer examination and dense description. These strategies allowed the researcher to enhance the dependability of this study.

3.6.4 Confirmability

Confirmability is a measure of how well the inquiry's findings are supported by the data collected (Lincoln & Guba, 1985). Shenton (2004) asserts "steps must be taken to help ensure as far as possible that the work's findings are the result of the experiences and ideas of the informants, rather than the characteristics and preferences of the researcher" (p. 72). To achieve confirmability, a study demonstrates that the findings and data are clearly linked. This study employed peer examination (debriefing), and a clear description of decisions made during the research process (Krefting, 1991; Shenton, 2004). These strategies allow collaborators external to the research an opportunity to evaluate or confirm the research procedures.

3.7 Ethical Considerations

It is imperative that educational researchers ensure that ethical principles are upheld at all times as they conduct research involving human subjects (Wilson & Stutchbury, 2009). Educational researchers should take special care to properly inform their research participants of the possible risks and consequences of the research. In addition, they are expected to protect the privacy of research participants and data as much as is possible (Howe & Moses, 1999).

This project has been cleared in accordance with the ethical review guidelines and processes of The University of Queensland's Human Experimentation Ethical Review Committee (Approval Number 09-001). The following part describes the ethical considerations of this study.

1. Participant consent forms and information sheets are distributed to, and obtained from, the participants before the formal data collection. Participants are informed of the purpose of the study, the procedures followed, and the uses of the data. Participants are also informed of their rights, including the fact that they may withdraw their consent at any time or may refuse to answer any particular questions.

2. Make sure that the participants understand what is being researched and why the researcher wants to interview them and observe their classrooms.

3. The appearance of the researcher in the classroom, as an outsider and an observer, may create some uncomfortable feelings for the teachers and students, and further cause influences on the classroom interactions, and students' performance in classroom activities. The researcher takes effective strategies to minimize these influences, for example, having some casual talks with the students before lessons to allow them to be familiar with the researcher, and sitting at the back of the classroom to be a non-intrusive observer.

4. The confidentiality of the participants is guaranteed and strictly maintained during and after data collecting. The data are collected in de-identified form. Participants' identities are not recorded or revealed. Interviews and case studies are conducted individually. The time and places for interviews and classroom observations are decided by the participants at their convenience. The raw data will be securely stored in the University of Queensland only for a sufficient period to collate and analyse. Only the researcher and her academic advisors who have a valid reason for listening the audiotapes are permitted to do so. Only pseudonyms are used during data analysis and in the thesis or any related research report.

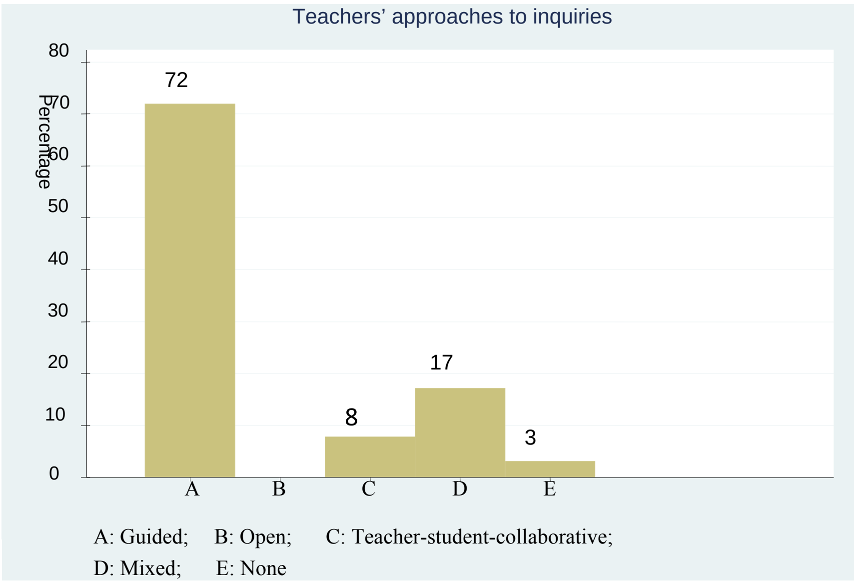
4. Phase one: Survey

This chapter reports on and discusses the quantitative data collected from the survey conducted in two districts of Shanghai. The survey was designed to collect information about teachers' implementation of IBT and the challenges they perceived in their implementation of IBT.

4.1 Approaches to Inquiry

The results demonstrate that the majority of the participants (72%) chose the teacher-guiding approach to inquiry when they implemented inquiry-based teaching (IBT) (Fig. 4-1).

Figure 4-1 Approaches to inquiry (n=64)



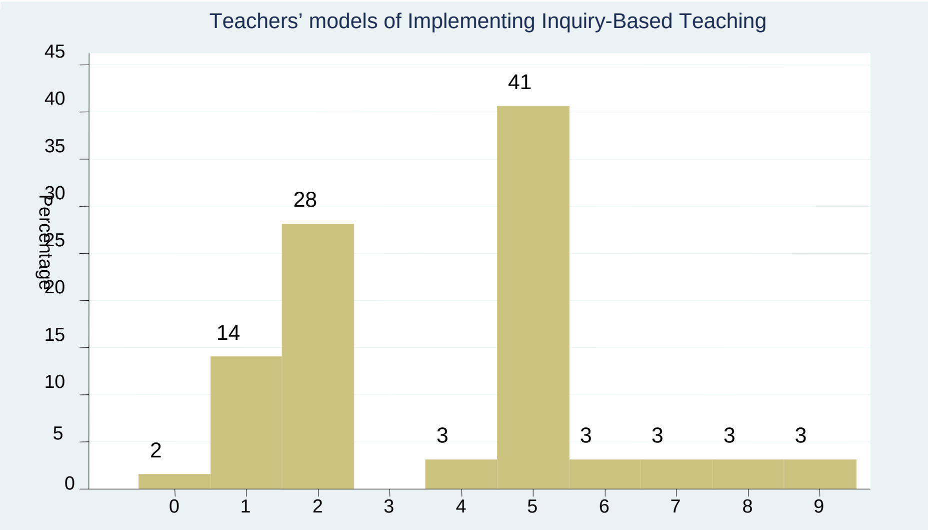
It appeared that most teachers preferred to, or felt most comfortable with, using a guided approach to inquiry. Some teachers reported they used a collaborative approach (8%) or a mixed (17%) approach to inquiry, while no participant claimed that they entirely adopted an open inquiry in the classroom. Only 3% of participants reported that they had not used any approaches to inquiry.

Fisher's exact tests reveal that there was no statistically significant difference in teachers' approaches to inquiry between district areas, between school types, and among teachers with different levels of teaching experience.

4.2 Instructional Models of Implementing IBT

The results show that most participants preferred to implement IBT through regular classroom activities (Fig. 4-2). It is found that two models and their combination occupied most of the teachers' classrooms: implement IBT using student experiment (item1, 14%), implement IBT in a section of lesson (item 2, 28%), and use both of the aforementioned two models to implement IBT (1&2, 41%). Together, they make up to 83% of the participants.

Figure 4-2 Models of Implementing IBT (n=64)



0=None;
1=Implementing IBT using student experiment;
2=Implementing IBT in a section of lesson, e.g. group discussion, formula deduction, and etc;
3=Guiding students to conduct a literature investigation;
4=Using group research projects on designated topics that takes one week or longer;
5=1&2; 6=1&2&3; 7=1&2&4; 8=2&3or4; 9=All of them

* Because the participants were allowed to choose multiple items, Fig.4-2 lists the five original items (0-4) and all selected combinations (5 to 9).

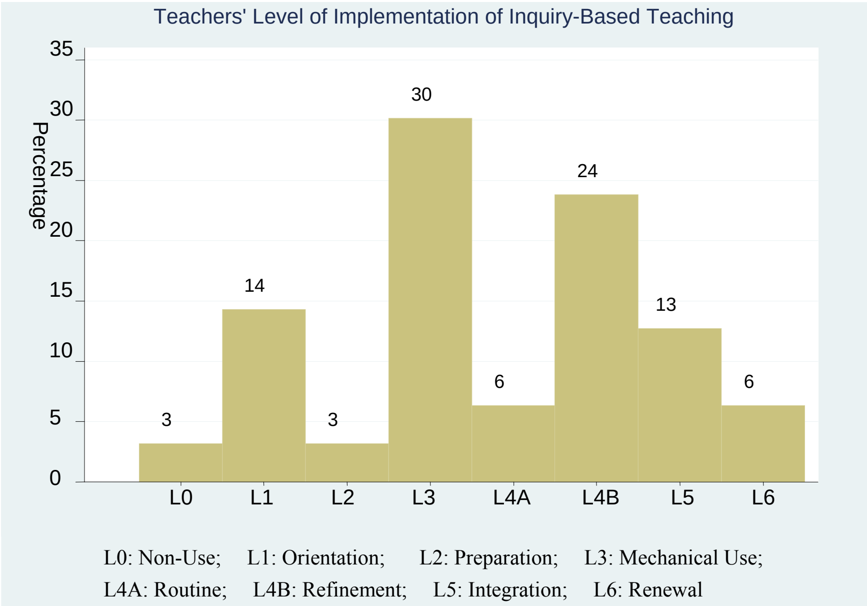
No participant merely chose "guiding students to conduct a literature investigation" (Item 3). "Group research projects on designated topics that takes one week or longer" (Item 4) was also an unpopular choice (3 %). Furthermore, very few participants chose to use the combinations including these two items.

Fisher's exact tests also reveal that district areas, school types, and levels of teaching experience did not make statistically significant differences in teacher's models of implementing IBT.

4.3 Levels of Implementation of IBT

The statistics show that teachers' self -assessment of their level of implementation of IBT (LoI-IBT) varied significantly (Fig. 4-3). Nevertheless, about 80% of these participants chose Level 3 and higher levels.

Figure 4-3 Teachers' levels of implementation of inquiry-based teaching (n=63)



The most frequently selected level is the Mechanical Use level (Level 3, 30%). It indicates that many teachers have implemented some activities of IBT, while with a primary teaching objective of achieving the requirements of the curriculum standards (see Fig.3-2 or Appendix for descriptions of levels). The next most frequently selected level is the Refinement level (Level 4B, 24%). At this level, teachers vary approaches to IBT to increase the expected benefits within the classroom.

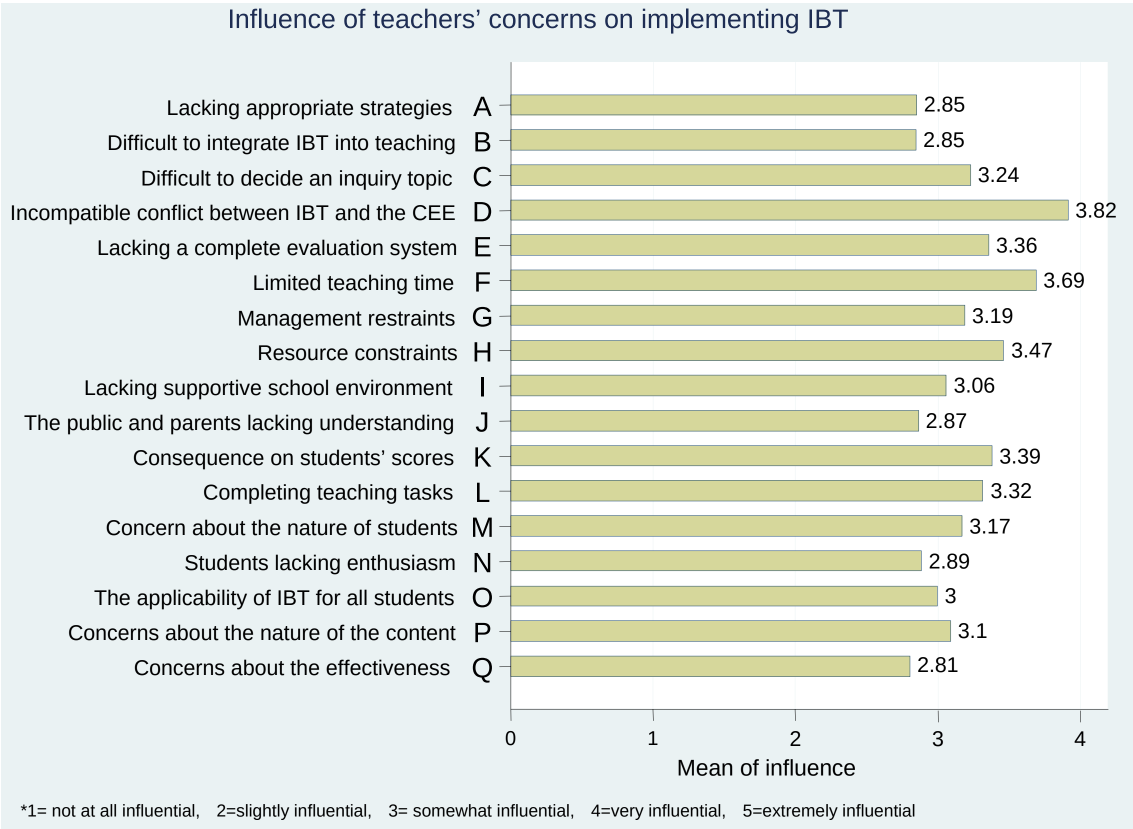
It appeared that most teachers were familiar with IBT and had been involved in some teaching activities of IBT. Moreover, 43% of them (choosing Level 4B and higher levels) claimed they were varying and refining approaches to IBT to maximise the benefit of IBT on their students. It seemed that these teachers not only felt comfortable using IBT, but also felt they were actively using different approaches to conducting IBT to maximise its benefit. The data paint an optimistic picture of these teachers' implementation of IBT.

The Rank-sum test reveals that there was no statistically significant difference in the teacher's level of implementation of IBT between district areas, between school types, and among teachers with different levels of teaching experience.

4.4 Teacher Concerns about Implementing IBT

The literature review found that Chinese physics teachers had different concerns about implementing IBT. This survey gauged the influence of these concerns on teachers' intentions to implement IBT. The influence of each factor was tested and represented by means (Fig.4-4). ANOVA tests were conducted to examine the effects of teaching experience (TE), school type (ST), and district area (DA) on the influences of these factors. The following sections report the results.

Figure 4-4 Influence of teachers' concerns on their implementation of IBT (n=63)



4.4.1 The influential concerns

The data reveal that 12 of 17 listed teacher concerns are more than somewhat influential on teachers' intention to implement of IBT ($M \geq 3$), and the rest of the items are slightly influential (Fig. 4-4). The three most influential factors are Items D (M= 3.82), F (M= 3.69) and H (M= 3.47). Item D is teachers' concerns about the conflict between IBT and the college entrance examination (CEE). The other two items (F and H) are pertaining to the limited teaching time and constraints of resource, space and facilities. The following three less influential factors are Items K, E, and L ($3.3<M<3.4$). They are related to the consequence of IBT on students' test scores, the assessment system, and completing teaching tasks. The next six factors are somewhat influential (3≤M<3.3). These include Items C, G, M, P, I, and O. They are associated with the difficulty of integrating IBT into teaching, management issues, the nature of students, the nature of the content, the school environment, and the applicability of IBT for all students. ANOVA tests found that TE, ST, and DA had some significant effects on the influences of some of the teacher concerns (see Table 4-1).

Table 4-1 The significant effects of TE, ST, and DA on the influences of teacher concerns (p< .05)

Teacher Concerns	ANOVA tests for the effects of TE, ST, and DA, and their interactions	Analysis of simple main effects for the two-way or three-way interactions
F Limited teaching time	TE ($F_{[3, 46]}$=3.40, p= .025)	
	TE#ST ($F_{[3, 46]}$=4.7, p =.006)	TE at (ST=0) ($F_{[3, 46]}$ =4.54, p=.003)
	TE#DA ($F_{[3, 46]}$=3.78, p =.017)	TE at (DA=3) ($F_{[3, 46]}$ =4.48, p=.004)
	ST#DA ($F_{[1, 46]}$=6.13, p = .017)	None
H Resource constraints	TE#ST#DA ($F_{[3, 46]}$ =3.38, p =.026)	TE at (DA=3 & ST=0) ($F_{[3, 46]}$=4.39, p=.004)
G Management issues	TE ($F_{[3, 46]}$=3.43, p= .025)	
M The nature of students	ST ($F_{[1, 46]}$=5.06, p=.029)	
I The school environment	ST ($F_{[1, 46]}$ =6.18, p = .017)	
	ST#DA ($F_{[1, 46]}$ =5.00, p = .030)	ST at (DA=3) ($F_{[3, 46]}$=9.05, p =.003)
O The applicability of IBT for all students	TE ($F_{[3, 46]}$=3.96, p= .014)	
	TE#ST#DA ($F_{[3, 46]}$ =2.97, p=.041)	TE at (DA=3& ST=0) ($F_{[3, 46]}$=5.03, p =.002)
J The public and parents lacking understanding	ST#DA ($F_{[1, 46]}$=4.57, p=.038)	None

*The # symbol is used by STATA to indicate interaction between variables.
DA=2: District A; DA=3: District B
ST=0: Key school; ST=1: Non-key school
TE=1: ≤5yrs; TE=2: 5-10yrs; TE=3: 11-15yrs; TE=4: >15yrs

The findings in Table 4-1are summarised as follows:

- Teaching experience (TE) had significant effects on the influences of limited teaching time, management issues, and the applicability of IBT for all students.
- School type (ST) had significant effects on the influences of the nature of students and the school environment.

- The interaction between teaching experience and school type (TE#ST), and the interaction between teaching experience and district area (TE#DA), had significant effects on the influences of limited teaching time.
- The interaction between school type and district area (ST#DA) had significant effects on the influences of limited teaching time, school environment, and the public and parents' understanding. However, further tests of simple main effects for the two-way interaction, combing with an adjusted critical value of *F* [3], found that the effect of ST at DA=3 was significant on the influences of the school environment (Item I); while the interaction between the effects of ST and DA on the influences of limited teaching time and the public and parents' understanding were assessed as non-significant.
- The interactions between teaching experience, school type and district area (TE#ST#DA) had significant effects on the influences of resource constraints and the applicability of IBT for all students.

The following section specifically analyses the three most influential factors (Items D, F, and H).

The incompatible conflict between IBT and the CEE (item D) caused the greatest influence on teachers' intention to implement IBT. There was no statistically significant difference in the effects of teaching experience (TE), school types (ST), district areas (DA), on the influence of this concern. This provided a piece of evidence that teachers commonly felt under pressure from the CEE, and this constituted a great obstacle to their implementation of IBT.

The next relatively strong influence was caused by limited teaching time (item F). It indicated that to more or less extent teachers felt that implementing IBT was time-consuming and therefore conflicting with limited teaching time. ANOVA tests show that there was a significant main effect of teaching experience (TE) on the influences of limited teaching time. In addition, there were significant interactions between the effects of ST and TE, DA and TE, and ST and DA, on the influence of limited time (see Table 4-1).

Simple main effects analyses for the TE#ST interaction (see Appendix E) show that for key school teachers (ST=0), the effect of teaching experience on the influence of limited teaching time was statistically significant ($F_{[3,\ 46]}$ =4. 54, *p*=. 003); but for non-key school teachers (ST=1), the teaching experience had no effect on the influence of limited teaching time. The follow-up Pairwise Comparisons (at ST=0) show that in key-schools, both group 1 teachers (≤5 years of experience)

[3] Since tests of simple main effects are a type of post-hoc comparison we need to use an adjusted critical value of F to assess statistical significance of F-ratios. This study used the smecriticalvalue command in STATA for this purpose.

and group 3 teachers (10-15years of experience) were significantly more influenced by limited teaching time, than group 2 teachers (5-10 years of experience) and group 4 teachers (>15 years of experience) at the .05 level of significance. All other comparisons were not significant (see Appendix E).

In addition, simple main effects analyses for the TE#DA interaction (see Appendix E) show that for teachers from District B (DA=3), the effect of teaching experience on the influence of limited teaching time was statistically significant ($F_{[3, 46]}$ = 4.48, p=.004); while for teachers from District A, the teaching experience has no effect on the influence of limited teaching time. The follow-up Pairwise Comparisons (at DA=3) show that in District B, group 4 teachers (>15 years of experience) were significantly less influenced by the limited teaching time, than group 1 teachers (≤5 years of experience), group 2 teachers (5-10 years of experience), and group 3 teachers (10-15years of experience) at the .05 level of significance, but there was no significant difference between groups 1, 2, and 3 teachers (see Appendix E).

The third relatively strong influencing factor was resource constraints (item H). Teachers' concerns about resource, space and facilities had a considerable impact on their implementation of IBT. A three-way ANOVA found that there was a significant three-way interaction between the effects of TE, ST, and DA ($F_{[3, 46]}$= 3.38, p=.026) on the influence of resource constraints (see Appendix F).

Further tests of simple main effects for the TE#ST#DA three-way interaction (see Appendix F) show that for key school teachers of District B (DA=3 & ST=0), the effect of teaching experience on the influence of resource constraints was statistically significant ($F_{[3, 46]}$=4.39, p=.004); while for non-key school teachers of District B or teachers of District A, the teaching experience has no effect on the influence of resource constraints. The follow-up Pairwise Comparisons (at DA=3 & ST=0) show that in key-schools of District B, group 3 teachers (10-15 years of experience) were significantly more influenced by the resource constraints than group 2 teachers (5-10 years of experience) and group 4 teachers (>15 years of experience) at the .05 level of significance. All other comparisons were not significant (see Appendix F).

4.4.2 The overall influence of teacher concerns

The data analysis found that the overall influence of all listed teacher concerns on their implementation of IBT was between somewhat influential and very influential (M=3.18). A three-way ANOVA shows that there was a significant two-way interaction between the effects of between teaching experience and school type (TE#ST) on the overall influences of teacher concerns

($F_{[3, 40]}$=3.51, p=.024, see Appendix G).

The tests of simple main effects for the TE#ST two-way interaction (see Appendix G) show that for key schools teachers (ST=0), the effect of teaching experience on the overall influences of teacher concerns was statistically significant ($F_{[3, 40]}$=4.98, p=.002); while for non-key school teachers, the teaching experience has no effect on the overall influences of teacher concerns. The follow-up Pairwise Comparisons (ST=0) show that for key-school teachers, group 3 teachers (10-15years of experience) were significantly more influenced by the overall influences of teacher concerns than group 2 teachers (5-10 years of experience) and group 4 teachers (>15 years of experience) at the .05 level of significance. All other comparisons were not significant (see Appendix G).

4.5 Relevant Professional Development Activities regarding IBT

The survey investigated the situation of relevant professional development activities on teachers' implementation of IBT. These included three aspects:

1. Relevant teaching and research activities regarding IBT
2. Strategies important to the successful implementation of IBT
3. Factors helpful to form or change views on IBT

The following sections report the results.

4.5.1 Relevant teaching and research activities regarding IBT

Table 4-2 shows the situation of participating teachers' relevant teaching and research activities regarding IBT in recent years.

Table 4-2 Relevant teaching and research activities regarding IBT (n=64)

	Teaching and Research Activities	Never %	Once %	Once a year %	Once a semester %	Many times %	Mean	Std. Dev.
A	Participating in academic conferences (international or domestic ones)	78	14	5	0	3	1.36	0.843
B	"Keli" (Exemplary lesson) research activities	22	28	14	11	25	2.89	1.513
C	Observing an excellent teachers' public class *	0	22	20	17	41	3.77	1.205
D	Research project on IBT	34	27	17	9	13	2.39	1.376
E	Workshops and expert lectures	34	28	20	3	14	2.34	1.359
F	Enrolling a short-term or long-term course of IBT in tertiary schools	78	11	6	3	2	1.39	0.866

*A public class is an important form of teacher professional development for Chinese primary and secondary teachers, which is organised by the school and/or the district professional community (the "teaching-study group" in school and/or the district "teaching-study office", see footnote 1). A public class allows a teacher to demonstrate his/her understanding of teaching and ability to teach. Other teachers/ experts/ school leaders/district research leaders/ assessors are allowed or invited to enter the teacher's class to observe, learn, and/or assess his/her teaching. A thorough related dissuasion is organised after the lesson.

The data show that the most frequently attended teaching and research activity regarding IBT is observing an excellent teachers' public class (item *C*, *M*=3.77, *SD*=1.21). 41% of the participants reported that they participated in this kind of activity many times. The rest of the participants sometimes participated in this kind of activity.

"Keli" (exemplary lesson) research activities were also reported to be relatively favourable activities (item *B*, *M*=2.89, *SD*=1.51). 25% of the participants reported that they were often involved in this kind of activity. 53% of the participants sometimes participated in this kind of activity. However, 22% of the participants described that they had never participated in this kind of research activity.

Research project on IBT (item *C*, *M*=2.39, *SD*=1.38) and workshops and experts' lectures (item *D*, *M*=2.34, *SD*=1.36) were much less popular research and teaching activities regarding IBT. Only 14% and 13% of the participants respectively claimed that they often participated in these activities. 34% of the participants respectively reported that they had never attended these two kinds of activities in recent years.

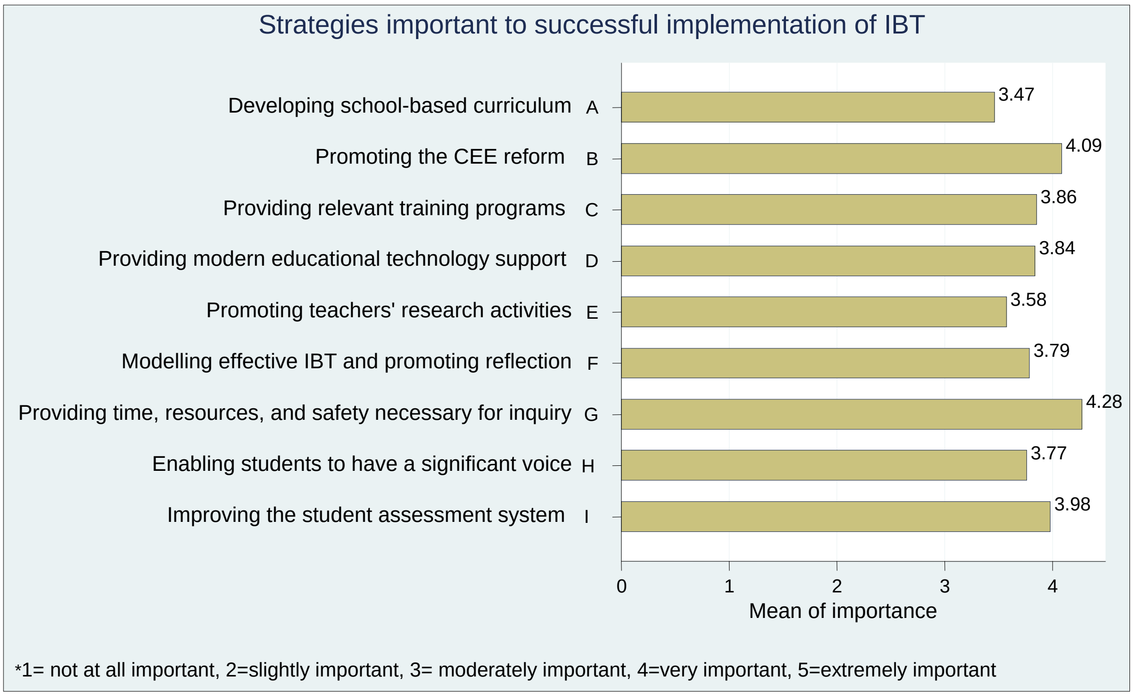
The most unpopular activities are participating in academic conferences (item *A*, *M*=1.36, *SD*=0. 84) and enrolling a short-term or long-term course of IBT in tertiary schools (item *F*, *M*=1.39, *SD*=0. 87). 78% of the participants respectively reported that they had never attended such activities in recent years. Very few participants (3% and 2% respectively) often involved themselves in these two kinds of activities.

Observing public classes and "Keli" research activities were much more popular than other kinds of activities. This is perhaps because they were more easily organised and carried out at the school level. In addition, they did not need too much money input and human resource, except for the participating teachers' time and energy, and school and district research leader's management. More importantly, these activities probably made more sense to teachers because they were connected with their day-to- day teaching practice.

4.5.2 Strategies important to successful implementation of IBT

The participants' opinions on the importance of strategies to successful implementation of IBT were presented in Fig.4-5.

Figure 4-5 Importance of strategies to successful implementation of IBT (n=64)



The data illustrate that the participants generally viewed that all these strategies are important to successful implementation of IBT (*M*>3).

The most perceived important strategy was providing students with necessary time, space, resources, and safety necessary for inquiry (item *G*, *M*=4.28). The strategies of promoting reform of the CEE (item *B*, *M*=4.09) and improving the student assessment system (item *I*, *M*=3.98) were also considered to be very important to teachers' success in implementing IBT. More importance was attached to these three strategies by the participants than to other strategies, such as providing teachers with relevant training programs (item *C*, *M* =3.86).

It was found that the three above-mentioned important strategies were highly consistent with the most influential teacher concerns found in this survey (see section 4.1.4). It suggests that, for these Chinese physics teachers, in order to boost their chances of successful implementation of IBT, these highly influential teacher concerns need to be appropriately addressed, rather than solely giving teachers relevant training.

4.5.3 Factors helpful to form or change teachers' views on IBT

Table 4-3 presents a summary of the participants' opinions on the degree to which the following factors were helpful to form or change their views on IBT.

Table 4-3 Factors helpful to form or change teachers' views on IBT (n=64)

	Factors	No at all helpful %	Slightly helpful %	Somewhat helpful %	Very helpful %	Extremely helpful %	Mean	Std. Dev.
A	Learning new textbook and teaching reference book	5	23	38	17	17	3.19	1.13
B	Communications and discussions among school colleagues	2	6	34	25	33	3.81	1.02
C	Discussing teaching methods with experts and excellent teachers	5	5	31	27	33	3.78	1.11
D	Instructions on teaching approaches from experienced teachers	2	9	22	30	38	3.92	1.06
E	Participating in workshops and expert lectures	3	17	40	14	25	3.41	1.14
F	Participating in research project on IBT	6	16	27	27	25	3.48	1.21
G	Enrolling a short-term or long-term course of IBT in tertiary schools	13	11	30	27	20	3.31	1.27

It was found that all these factors were reported to provide some help to the majority of the participants to form or change their ideas of IBT (M>3).

The three most commonly considered helpful factors were *Instructions on teaching approaches from experienced teachers* (item *D*, *M*=3.92, *SD*=1.06) and *Discussing teaching methods with experts and excellent teachers* (item *C*, *M*=3.78, *SD*=1.11), and *Communications and discussions among school colleagues* (item *B*, *M*=3.81, *SD*=1.02). There were 68%, 60% and 58% of the teachers respectively who considered these factors very, even extremely, helpful, to form or change their perspectives of IBT.

However, more than 20% of the participants felt that *Learning new textbook and teaching reference book* (item *A*, *M*=3.19, *SD*=1.13), *Enrolling a short-term or long-term course of IBT in tertiary schools* (item *G*, *M*=3.31, *SD*=1.27), *Participating in research project on IBT* (item *F*, *M*=3.48, *SD*=1.20), and *Participating in workshops and experts' lectures* (item *E*, *M*=3.41, *SD*=1.14) provided little help or no help at all to them to form or change their beliefs about IBT.

It appears that these teachers felt much more convinced when they directly communicated and discussed their teaching approaches with experienced teachers, experts and excellent teachers, and their colleagues. Research projects, workshops, and expert lectures, and attending tertiary courses seemed to have lower credits among these teachers. This is perhaps because when they directly communicated and discussed their ideas and teaching approaches, they have more opportunities to reflect on, and link IBT to, their own teaching practice, leaving more chances to build on an appropriate understanding of IBT. In addition, many of these teachers did not see new textbook and teaching reference book as helpful resources of information on IBT.

4.6 Summary

The data show that the participating teachers generally assessed that their implementation of IBT has reached, at least, the level of "*mechanical use* of IBT". It indicates that many teachers have implemented some activities of IBT, while with a primary teaching objective of achieving the requirements of the curriculum standards.

The majority of the teachers reported that they adopted a teacher-guided inquiry, and preferred not using open approaches, or seldom using teacher-student-cooperative approaches to IBT. It appears to the researcher that some teachers might lack experience, or felt uncomfortable, to use approaches requiring less teacher control.

In addition, the participants commonly reported they conducted IBT using student experiments or classroom activities such as group discussions or formula deductions, or a mixture of both, whereas seldom considering other models. These two commonly considered models indicate that the teachers were concerned about the teaching tasks and preferred to incorporating IBT into their regular teaching practice.

The data also reveal that the teachers had various concerns about IBT, which had affected their intention to implement IBT to different extent. Among these concerns, the influences of the conflicts between IBT and the CEE, limited teaching time, and resource constraints were prominent. Teachers' experience and school background were found to make significant differences in the influences of some of the concerns and the overall influence of these concerns.

Furthermore, it is found that observing public classes and "Keli" research activities were the most popular research activities. The participants generally reported that they seldom participated in research activities organised by institutions other than schools and districts, such as tertiary schools. Many of them also reported that these activities may not be helpful.

5. Phase two: Interviews

The interviews were intended to understand how the Chinese physics teachers perceive classroom inquiry and what factors influence their decisions regarding implementing inquiry-based teaching (IBT). It was found that teachers generally perceived that classroom inquiry was a process of thinking and doing science, while expressing diverse perceptions of the nature and value of classroom inquiry. Meanwhile, they demonstrated a considerable degree of theoretical understanding of inquiry. They proposed various methods to implement IBT in classrooms. However, they also identified a range of factors that influenced their decisions regarding implementing IBT. This chapter presents these key findings from the fifteen teacher interviews. The analyses of the interview data led to the answer for the following research question:

Q1: How do Chinese physics teachers perceive IBT?

More specifically, it answers the above research question from the following aspects:

1. How do teachers perceive the nature and value of classroom inquiry?
2. How do teachers think to implement IBT in their classrooms?
3. What factors do teachers perceive affect their decisions regarding implementing IBT?
4. What professional development do teachers require for implementing IBT?

The following sections report the results with respect to these questions. The relevant findings are presented and supported by selected teacher quotes. Pseudonyms have been used for teacher names. The quotes from different sources are referenced by marks noting their names and/or data sources[4], for example, Zhao-C, and Pan-I.

The last section of this chapter summarises the findings. A further discussion of the findings, linking with the findings from other data sources, is presented in the discussion chapter.

5.1 How do Teachers Perceive the Nature and Value of Classroom Inquiry?

The analysis of the 15 teacher interviews found that teachers generally described the nature of classroom inquiry as a process of thinking and doing science, with an aim of helping students understand physics laws and regularities. However, they expressed this perception from multiple,

[4] Abbreviation for data sources: C-informal conversation, E- email, F-field notes, I- interview.

interrelated aspects. These aspects included: (a) Inquiry is a process of exploring, investigating, and solving problems; (b) Classroom inquiry is a process in which students understand scientists' work, and (c) Classroom inquiry is a process of students' independent learning.

However, their opinions on the value of inquiry varied. These teachers attached different values to the elements involved in classroom inquiry, such as knowledge, methods and processes, results and conclusions, and the non-intellectual factors such as interest. These included: (a) Inquiry is an effective approach for learning methods and experiencing processes, (b) Inquiry is a better approach to acquiring knowledge and reaching the conclusions, (c) Inquiry intends to discover unknown knowledge, and (d) Inquiry fosters interest, thinking, and abilities.

Meanwhile, these teachers demonstrated some common knowledge of the process of classroom inquiry. Their descriptions were consistent with the statements of the curriculum standards.

In many cases, teachers reported multiple perceptions of classroom inquiry. Although these perceptions describe inquiry from different aspects, they are not mutually exclusive. In the following sections, teachers' perceptions and knowledge are all described and supported with selected quotes from teachers.

5.1.1 The nature of classroom inquiry

The interviewed teachers generally perceived that classroom inquiry was a process of thinking and doing science. However, they achieved this understanding from different perspectives. The following sections describe these perspectives.

Inquiry is a process of exploring, investigating, and solving problems.

Some teachers suggested that inquiry is a process of exploring, investigating, and solving problems, in which students ask questions, explore, investigate and then achieve understanding of the raised questions.

For example, Lin, Lu and Yao claimed that "inquiry is exploring and investigating". Through this process, students finally "acquire knowledge" (Yao-I) [5] and "discover the regularities of the nature" (Lu-I). Lu stated that exploring and investigating is a process that students achieve understanding through their own learning experience and life experience, such as experiments. He further explained what exploring and investigating meant in inquiry,

[5] In in-text teacher quotes, the teacher's name is specified if the interviewee cannot be identified from the context, or the quotes are from sources other than interviews.

> Explore what they don't understand, [investigate] through their own mind activities, or hands-on activities, or language or behaviour, think about, and then acquire the regularities of the nature. (Lu-I)

Lin stated that inquiry meant that students explore and investigate something that they feel interested in on their own. These could be something already known, or unknown, or that they doubt the result of it.

Jun asserted that inquiry is an activity in which students "investigate self-generated questions" and "really wanted to understand something".

Wen suggested that inquiry is "a process of finding a problem, investigating the problem, solving the problem, and then applying the solution".

Classroom inquiry is a process by which students understand scientists' work.

Some teachers indicated that classroom inquiry is a process in which students understand scientists' work. Li's response is typical.

> I always want my students to go back to the time point when the scientists have not solved this question. I want them to do inquiry from the same starting line with the scientists... When they are the same starting line to research problems, they will feel that everything is unknown… They will feel that they are [the scientists]. What are the entry points for research? And what are the research methods? They start to think about these (Li-I).

However, some teachers mix up classroom inquiry with scientists' inquiry. They indicated that classroom inquiry is a process of reproducing scientist's research work. Lu implied that in classroom inquiry, students were working like a scientist. He, therefore, thought that it was difficult for students to do so.

> It is impossible for them [students] to redo scientists' experiments and reconstruct laws. (Lu-I)

> Physics, starting from the senior high school stage, is based on models. It is therefore necessary to exclude external disturbances [from experiments to construct models]… It is fairly difficult for students to conduct such an experiment… I think it is impossible for students to discover an unknown law through inquiry, because it is impossible for them to construct many external conditions, such as the vacuum. (Lu-I)

Zhao held similar opinions to Lu. He advocated "a real inquiry starting from zero", and perceived more difficulties for student thinking activities involved in inquiry.

> There are too many factors that need to be taken into account. We have to keep getting rid of those factors influencing the experiments. Finally, we need to make idealised assumptions, and then achieve a certain conclusion… If only requiring students open their minds… they may not think through the question. Therefore, I think it may not be a scientific attitude to only rely on students' thinking to do inquiry. (Zhao-C)

Classroom inquiry is a process of students' independent learning.

For some teachers, inquiry meant that students independently accomplished learning tasks. In their opinion, inquiry-based learning was on the opposite side of traditional teaching. Because traditional teaching mainly consisted of teachers' lectures and students' receptive learning, they tended to perceive inquiry as a process of students' independent (or autonomous) activities where teachers gave minimal guidance or structure to students' learning. Min, Ding, Pan's and Wang's descriptions were typical.

Min stated that "for him inquiry was students' autonomous learning". Ding also emphasised students' independence by stating,

> Inquiry is [a process] that can foster students' interest and… allow students to complete a section of a learning task following their own train of thoughts. (Ding-I)

Wang's opinion was the strongest. He argued that IBT meant letting students do inquiry on their own. As he put it,

> I can only tell them the direction [for inquiry]. As for the theory, methods, equipment, and how to do it, they have to figure out by themselves. (Wang-I)

He maintained that "teachers only need to turn up once at an essential time" when students failed.

Similarly, Pan perceived that the nature of inquiry is a series of independent student activities through which students achieve understanding. He stated,

> In the nature, inquiry is [a process] that students acquire some physics laws or scientific inquiry methods through independent activities. (Pan-I)

He also suggested that teachers provide minimal structure to students:

> Set up an objective for student inquiry, and then offer them a small amount of help to design a rough process of inquiry- because a scientific inquiry should have a relatively complete methodology. (Pan-I)

It seems that these teachers thought that inquiry meant giving minimal guidance to students and students took most of the responsibility for their learning. In this sense, their perceptions of inquiry as independent student activities were close to what is defined as "open inquiry" (NRC, 2000) rather than other approaches to inquiry.

Other perceptions

In contrast, one teacher, Zhao, proposed a more general notion of inquiry. He stated,

> Inquiry can be any classroom activity as long as it fosters students' thinking. (Zhao-C).

He further gave an example. He suggested that students could participate in inquiry by "knowing or observing the process of others' inquiry". Students understood and acquired knowledge from others' [usually teachers'] descriptions and presentations of doing inquiry. He maintained that it was an inquiry.

These above findings show that teachers had different pictures of classroom inquiry in their minds, although they generally perceived that classroom inquiry was a process of thinking and doing science.

5.1.2 The value of inquiry

Although teachers generally viewed classroom inquiry as a process of thinking and doing science, they gave different weight to the elements involved in inquiry, such as knowledge, skills (methods and processes), results and conclusions, and the non-intellectual factors such as interest and abilities. Their opinions on the value of inquiry varied. The following parts explain these opinions.

Inquiry is an effective approach for learning methods and experiencing processes.

"Processes and methods" is one of three dimensions of the curriculum objectives (SHMEC, 2004). Teachers generally perceived that IBT was more effective than traditional teaching approaches in achieving this curriculum objective. They maintained that doing inquiry could help students focus attention on, and construct a better understanding of, the processes and methods of discovering physics laws and constructing physics concepts.

For some teachers, for example, Yao, Wen, Xiao and Lu, using IBT allowed students to experience the process, and learn the methods, of developing physics knowledge and constructing scientific laws. What students experienced in inquiry would reinforce their understanding. Wen stated,

> The biggest effect is that it allows students to learn scientists' research methods, go through a process of inducing scientific laws from physics phenomena and experiments, and experience the fun of scientific inquiry. (Wen-E)

Yao claimed that "a good inquiry is able to genuinely reflect the process of the development of knowledge".

Ding asserted that the most important benefit of conducting inquiry was that students understood methods and processes, which she considered was more influential on students' future lives than other curriculum objectives. She explained,

> In inquiry, they [the students] apply, reflect upon, and understand processes and methods... Using cramming, receptive learning may be good at acquiring knowledge and skills, but will be poorer in [developing] understanding of methods… With these processes and methods integrated in their minds, the students tend to be more flexible in the perspectives with which they think about questions. (Ding-I)

Zhao also admitted that "inquiry may be more useful than traditional approaches to help students better understand the processes and methods of constructing physics laws and concepts".

Some teachers attached more emphasis to the methods and the processes of inquiry than achieving results, such as Dong, Pan, Wen, Xiao and Xu. For example, Dong suggested that "the final conclusion of inquiry is subsidiary". He explained,

> If the research method and equipment are prescribed… for students, this degree of openness is not enough. I don't think it is a real inquiry-based teaching. It has a too strong purpose of pursuing conclusion... This kind of knowledge was not suitable for inquiry. For inquiry, different opinions should be allowed in most steps of inquiry, and there should be a process of screening [these opinions]. Since [we] emphasise the methods, the process of selecting methods is an important section, and the final conclusion of inquiry is subsidiary. (Dong-I)

Pan also suggested "it is not necessary to get the results. It is sufficient to embody the process of inquiry in IBT". Wen, Xiao and Xu admitted that experiencing the process was more important than reaching a conclusion for students.

> It was essential to allow students to experience a process from phenomena, to questions, to guesses, and to verification. (Wen-I)

> I think the process of doing inquiry is more important… Therefore, I would like students to achieve the conclusion through their inquiry, instead of telling them. (Xiao-I)

> I would like to place my emphasis on the thinking process of experiments. The conclusion is important, but not that important. (Xu-I)

Inquiry is a better approach to acquiring knowledge and reaching conclusions.

Some teachers stated that inquiry is a better approach to acquiring knowledge and reaching conclusions.

For Li, Liu, and Xiao, IBT provided a better way to acquire knowledge and achieve conclusion, rather than telling students directly. Liu, a key school teacher, emphasised that inquiry was a method that teachers chose to teach students knowledge while avoiding telling them the results directly. He explained,

> Our purpose is to let them know the physics theory, and thus inquiry is only a process. I hope they can achieve a physics theory and phenomenon through this process, instead of telling them directly… We should have a process of inquiry in teaching; however, direct instruction is still our principal method. (Liu-I)

Li, a private school teacher, also suggested that students had to acquire something in a lesson. He argued that for his students, "it is acceptable to let them have 'per gain per lesson' and then use it for practicing, calculating, and solving problems". He explained,

> These students can only master one or two key points in one lesson. Therefore, if they can consolidate these key points, they can acquire something in a lesson... Therefore, we go straight to these points, for example [leaning] one physics law, what are the phenomena in our daily lives, how to resolve [a problem], and what factors are related. (Li-I)

But Li realised that even these low-proficiency students needed inquiry. He stated,

> ... But we got to have some inquiries. You can't tell them directly... This is not good. (Li-I)

For him, inquiry was a better method to help his students acquire the knowledge in the textbook.

However, for some other teachers, arriving at a correct conclusion at the end of classroom inquiry was essential. Ding insisted that "IBT had to be implemented under the prerequisite that students were able to achieve the correct conclusion". She argued,

> Should they [students] believe in the knowledge in the textbook if they did not reach the correct conclusion? They would be suspicious of [the veracity of] the knowledge system. This situation was

> absolutely not allowed [to exist] at senior secondary education stage. (Ding-I)

Ding further explained her ideas by giving inquiry more distinctive characteristics. She compared "inquiry" with "research". In Chinese, the two synonymous words were easily mixed up. Ding asserted that inquiry-based learning was an approach to learning which could be carried out in day-to-day teaching, while research-based learning meant letting students do projects, which were conducted in an elective course. While students could learn physics using both inquiry-based learning and research-based learning, they should achieve the correct results in inquiry-based learning because "the content of learning was what students had to master". Whereas in research-based learning, it was not an important requirement that students had to achieve the correct conclusions or the same results with those of scientists, because "the content of learning was of students' own interest and was chosen by themselves".

Inquiry intends to discover unknown knowledge.

For some teachers, inquiry meant a process in which students discover unknown knowledge and this process could not occur in the classroom. For example, Jun asserted that inquiry was aimed to investigate the unknown. Students' own questions were a prerequisite for inquiry. He stated,

> The question should not have been investigated before. It must be generated by students themselves. It must not have a ready answer, or it should be difficult to find the ready answer. (Jun-I)

He argued that it was difficult for teachers to generate such a question to let students inquire about in a physics classroom since "the knowledge [of physics] was basically known by people". He explained,

> He (student) has already constructed concepts before learning the knowledge. He is not absolutely ignorant of it. (Jun-I)

> These conceptions already exist in their minds more or less. They know something. (Jun-I)

Therefore, he claimed that in order to conduct a authentic inquiry, students should be brought out of classroom to engage with an unknown context and develop their own inquiry questions. The teacher then "guided students and created conditions to help them realise their ideas". These kinds of activities were only able to be carried out once in a school semester.

Lin had similar ideas of inquiry. Although she indicated that she was not quite sure of it, she still suggested that inquiry meant students "generating new knowledge based on numerous experiments" using "new" methods and ideas which had not been previously considered and used. Due to this perception, she argued that "inquiry-based teaching, in a genuine sense, was quite rare".

In order to conduct inquiry, she suggested that

> Teachers must assure that students did not know any ready answer. In this situation, allowing students to inquire on their own, and don't even worry about the results. (Lin-I)

Inquiry fosters student interest, thinking, and abilities.

Teachers generally suggested that using IBT could foster students' interest, thinking, and abilities which would benefit their future lives.

Lu claimed that IBT fostered students' interest and abilities in learning physics because IBT "provided students with direct experience and hands-on opportunities". Min indicated that he would conduct IBT when he felt it "could foster students' interests, some aspects of abilities, or [their] qualities". Xu claimed that he preferred to use IBT because he felt IBT could make the class active and students interested in learning physics. Zhao asserted that inquiry could foster students' thinking. Lin suggested that IBT was a good way to foster students' creative thinking.

Pan agreed that "it was good for students to have inquiry abilities", as "they would benefit from these abilities when doing science or working in the future". He also asserted that "inquiry-based learning can [help students] develop diverse abilities, and it also can benefit diverse students". He explained,

> Take this school as an example, for those low-proficiency students, they would improve to some extent, and also understand some methods. This is much better than rote memorization… These students, even during exams – if the questions do not require just rote memory, but need some ability to answer, they will perform better, because, they have learned to extract and analyse information, and make an induction from the information. (Pan-I)

Zhao believed that students' understanding constructed in inquiry could develop into abilities which would positively affect their future lives. In this sense, he asserted that "these abilities meant more for the common people".

5.1.3 The process of classroom inquiry

The data suggest that these teachers generally had very clear knowledge of the process of classroom inquiry. For example, several teachers, for example Li, Min, Xiao, and Xu, gave specific descriptions of the process of classroom inquiry. Xiao described six steps of doing inquiry.

> Posing questions, formulating hypotheses, the third step is designing a plan, the fourth step is collecting evidence, the fifth step is analysing data, and the final step is communicating. (Xiao-I)

Min indicated that "clearly there is a mode of inquiry". He stated,

> First, let students identify the problem and pose questions. Then they formulate a hypothesis and design their experiments. They then conduct an investigation and achieve a conclusion. (Min-I)

Similarly, Xu suggested,

> [My thinking is] posing a question, letting students speak, analysing the causes, analysing the influencing factors, designing experiments, verifying [the influences], and then combining with some scientific experiment methods to achieve conclusions. (Xu-I)

Li claimed that students needed to consider a lot of issues in their process of doing inquiry, such as determining the related parameters, designing experiments and analysing data and conducting error analysis. As he put it,

> Generally speaking, first, [students] need to determine the related parameters… The second step is [to determine] what experiments should be used to precisely measure these parameters… After measuring, how to analyse data, what is the method… Finally, conducting error analysis. Only when all of these [steps] are completed can it be a precise and complete experimental inquiry. Therefore, there are many things students need to take into account. (Li-I)

Some other teachers did not give specific definitions of the process of classroom inquiry, but provided more general views with specific verbal examples, for example Ding, Dong, Jun, Wen and Zhao. The following are selected teacher quotes which explained what the teachers thought the process of classroom inquiry was.

> The process of inquiry is to define a train of thought, let students guess, or assume, what is relevant to [the investigated objectives], and then allow them to acquire a physics law, or achieve a result, through a series of independent activities. (Pan-I)

> As an inquiry experiment, it needs to have a step of posing a guess. After posing a guess, do some reasoning about what the possible phenomenon or result is, and then check whether this phenomenon or result exists. It is a process of verifying guesses. (Zhao-C)

Each of these teachers used verbal examples to explain their ideas about the process of inquiry. For example, Pan provided an example of "investigating the time period of a simple pendulum" to explain what he thought the process of inquiry was.

> For example, the objective is very clear, [to investigate] the factors affecting the time period of a simple pendulum. Then you design experiments –first predict what factors are related, then use these experiments to verify these relationships one by one, to find out regularities about the relationships between the time period and the related factors…… If some relationships could be identified, [we] go further to determine the quantitative correlation. This could be a complete process of inquiry. (Pan-I)

Comparing these teachers' descriptions with the process of scientific inquiry stated in the physics curriculum standards (SHMEC, 2004), it was found that they were highly consistent. According to the curriculum standards,

> The process of scientific inquiry includes identifying a question, formulating hypotheses, designing an investigation plan, using tools and collecting evidence, analysing data and developing explanations, and communicating. (p. 27)

The consistency between teachers' perceptions of the process of inquiry and the curriculum standards suggested that these teachers had clear knowledge about the key elements involved in scientific inquiry.

5.1.4 Summary

The data revealed that although the interviewed teachers described their perceptions of inquiry from different aspects, they generally perceived that classroom inquiry was a process of thinking and doing science. They paid considerable attention to the thinking and practical activities, and also attached importance to appropriate thinking abilities and practical skills involved in classroom inquiry. Inquiry as a process of thinking and doing science was an essential attribute they identified and attached to classroom inquiry.

In addition, these teachers demonstrated clear knowledge of the process of inquiry, which was consistent with the descriptions of the curriculum standards.

However, although these teachers generally agreed that doing classroom inquiry was a method to develop and understand physics laws and regularities, they assigned different levels of importance to the elements involved in inquiry, such as knowledge, methods and processes, and results and conclusions. In other words, they attached different values to IBT according to their beliefs.

5.2 How do Teachers Think to Implement IBT in their Classrooms?

The interviewed teachers demonstrated diverse opinions on how to conduct inquiry-based teaching (IBT) in their classrooms. These opinions were pertaining to two areas: approaches to inquiry, and methods of incorporating inquiry into teaching. Similarly, in many cases, teachers reported multiple perceptions of IBT. The following sections present the results with selected teacher quotes.

5.2.1 Approaches to inquiry

Table 5-1 summarises the approaches these teachers discussed in interviews. The discussed approaches to inquiry included four aspects: guided *vs.* open, experimental *vs.* speculative (or theoretical), partial *vs.* full, and in-classroom *vs.* outside-classroom.

Table 5-1 Teachers perceptions of approaches to inquiry (n=15)

Teachers	**Guided vs. Open inquiry**		**Experimental vs. Speculative (or theoretical) inquiry**		**Partial vs. Full inquiry**		**In vs. Outside classroom inquiry**	
	Guided	*Open*	*Experimental*	*Speculative (or theoretical)*	*Partial*	*Full*	*In*	*Outside*
Ding	✓	✓	✓	✓	✓		✓	
Dong		✓	✓				✓	
Li	✓		✓	✓			✓	
Lin		✓	✓				✓	
Liu	✓	✓	✓				✓	
Lu	✓		✓				✓	
Jun	✓		✓					✓
Min	✓	✓	✓		✓		✓	
Pan		✓	✓	✓	✓	✓	✓	✓
Wan		✓	✓				✓	
Wen	✓		✓		✓		✓	
Xiao	✓		✓		✓		✓	
Xu	✓		✓				✓	
Yao	✓		✓	✓			✓	✓
Zhao	✓		✓	✓			✓	

As the table shows, most of the teachers suggested a teacher-guided, experiment-based, and in-classroom approach to inquiry. Some teachers proposed open, speculative (or theoretical), outside-classroom approaches to inquiry. Teachers generally did not articulate how many features of inquiry should be embodied in one lesson, but some teachers clearly indicated that partial inquiry was more practical for classroom teaching. The following part describes each approach to inquiry, together with supporting quotes from several teachers.

Guided vs. Open inquiry

This aspect pertains to the responsibilities of teacher and students in classroom inquiry.

(a) *Guided inquiry*

The interviews found that most of the interviewed teachers gave more weight to teachers' guidance and structure than students' independence in inquiry. Meanwhile, they stressed the need to lead students to learn and cover the required content of curriculum for their teaching. Their perceptions of approaches to inquiry could be referred to as "Guided inquiry" (NRC, 2000).

Teachers attached importance to teachers' guidance in inquiry. They generally perceived the role of teacher as a guide and a facilitator of students' learning in inquiry. How they perceived guidance, and the amount of guidance they perceived should be provided to students, however, were varied.

Ding defined the role for teachers as a guide in student inquiry. More specifically, she stated,

> As a guide, the most important thing [for a teacher] is to decide a theme for this lesson. After that, the teacher should separate this theme into several easy-to-conduct steps for students as students would encounter variable difficulties in inquiry. When students encounter problems again in each step, [we] then apply discussion and collaboration between teachers and students [to solve them]. (Ding-I)

It seemed that she provided guidance for the purpose of managing and controlling her students' learning pace.

Similarly, Yao stressed the importance of teacher's guidance for the sake of leading students to take the planned pathway to do inquiry. She explained,

> I think that the teacher's role is a guide. In other words, you can't – it is not like that – let them [students] be. You have to guide them, as much as you can, to take the planned pathway. Because if [their thoughts are] too divergent, they probably handicap you to accomplish your teaching. However, you should give them a process of experiencing. For me, I will design numerous questions. Every question is actually a step. Once they answered my questions, their knowledge is developed basically (Yao-I).

Zhao advocates for teacher guidance due to the constraints of students' life experience and thinking ability. He put on that,

> If only requiring students open minds… they may not think through the question. Therefore, I think it may not be a scientific attitude to only rely on students' thinking to do inquiry… After all, limited by life experience and thinking levels, their questions may not hit the nail on the head, or may not be thorough. These [questions] need to be analysed… Teachers could give them guidance in the process of

> analysing… There has to be such a process, because it is really a process of developing students' thinking ability. It provokes students to think thoroughly. (Zhao-C)

Liu regarded teachers' guidance as important in inquiry because he was concerned about the efficiency of open inquiry to acquire knowledge. He stated,

> It is impossible that every student can conduct a successful inquiry in one lesson… If I leave them alone, let them do inquiry independently in a whole lesson, this [lesson] is very ineffective. Generally speaking, in an inquiry-based lesson, teachers should provide hints and control [the class] at appropriate times. Otherwise, what can I do if they can never figure it out?... After all... Our purpose is to let them know the physics theory, and thus inquiry is only a process. (Liu-I)

Wen preferred guided inquiry to open inquiry because she felt that "it is not feasible to stand by and let them go, given the ability level of the current senior secondary students and the teaching schedule". She further argued,

> An open inquiry is, after all, aimed to let students experience a process [of doing science]. If students can experience it under the teacher's guidance, the purpose is achieved. It is not a must to use open inquiry. (Wen-I)

In summary, these teachers noticed the importance of guidance in student inquiry from different aspects. The majority of the interviewed teachers demonstrated a common understanding that guided inquiry was a method teachers could use to control students' learning direction and pace to achieve their teaching objectives in classroom inquiry.

(b) *Open inquiry*

Several teachers suggested inquiry should be open, or that teachers give minimal guidance or structure to students and encourage students' independence in inquiry. These perceptions of approach to inquiry could be referred to or close to "Open inquiry" (NRC, 2000).

Dong emphasised the importance of openness of inquiry for students. He argued,

> If the research method and equipment are prescribed… For students, this degree of openness is not enough. I don't think it is a real inquiry-based teaching... I feel its objective and method are too monotonous. (Dong-I)

Therefore, he suggested,

> Different opinions should be allowed in most steps of inquiry, and there should be a process of screening [these opinions]. Since [we] emphasise the methods, the process of selecting methods is an important section, and the final conclusion of inquiry is subsidiary. (Dong-I)

The above descriptions show that his understanding of the approach to inquiry was close to the mode of "open inquiry".

As discussed earlier, some teachers attached much emphasis on student independence in inquiry. They considered classroom inquiry as a process in which students independently completed learning and solved problems to achieve understanding. Ding, Liu, Min, Pan and Wang held this kind of opinion. Wang's opinion was the typical. He argued that IBT meant letting students do inquiry on their own and "teachers only need to turn up once at an essential time" when students failed.

It seems that these teachers thought that inquiry meant giving minimal guidance to students and students took most responsibilities for their learning. In this sense, their perceptions of inquiry as independent student activities were close to what is defined as "Open inquiry" (NRC, 2000) or "Discovery learning" (Bruner, 1961) rather than other approaches to inquiry.

Experimental vs. Speculative (or theoretical) inquiry

This aspect discusses the importance of experiments in inquiry. The interviews showed that all teachers attached importance to experiments as the basis of inquiry. But several teachers argued that inquiry could also be conducted without experiments.

(a) *Experimental inquiry*

All teachers pointed out the importance of experiments in classroom inquiry. For many teachers, experiments were the basis of inquiry. The experiment was considered as the major method of verifying the predictions students made. As discussed in an earlier section, activities involved in experiments, including designing and conducting experiments, analysing and interpreting collected data, and error analysis, were considered by these teachers as important processes of doing inquiry (see section 5.1.3 for references and details).

Furthermore, it was suggested by the interviewed teachers that experimental inquiry could bring what students have learned alive. Lu indicated that inquiry meant "using experiments to discover physics regularity". Xiao also stated that "It is better to use inquiry to acquire experimental conclusions and regularities", because "students can directly experience the process of developing conclusions, and thus reinforce their impressions”. He further explained the role of experiment in inquiry:

> First, the development of many [physics] laws is based on experiments. Therefore, the experiment is a process of forming knowledge. Second, it is an effective method to foster student interest. Third, [since] scientist acquired this conclusion through this experiment, it teaches the students a research method. (Xiao-I)

Some teachers also considered that experiment lessons should be more appropriate for conducting inquiry, because inquiry was difficult to implement in other types of lessons, such as teaching theory or doing exercises. For example, Xiao did not see it a good idea to use inquiry in a “theory lesson” (teaching theory). He explained,

> I generally use inquiry in experiment lessons. While in a theory lesson, the key knowledge has to be covered. Furthermore… conclusions achieved from experiments can be clarified by students, but the key concepts cannot. I have to teach these. (Xiao-I)

Pan gave a different explanation for experimental inquiry. He argued that students could conduct an inquiry using second-hand data, and this approach to inquiry did not require experiment. He stated,

> Searching information, borrowing others’ regularities [results] from inquiry, and then verifying it, this is also an inquiry. (Pan-I)

He further explained that the aim of using this approach was “to preliminarily understand and learn a method of doing scientific investigation”.

(b) *Speculative (or theoretical) inquiry*

However, several teachers argued that IBT could also be conducted without experiments. Ding proposed a form of “Speculative inquiry” which only involves the thinking process. In Ding’s understanding, not all the content of physics was suitable for conducting experimental inquiry, for example, the Kinematics. She suggested that this kind of knowledge relies on mathematical tools to describe and is not well connected with other knowledge. Therefore, she argued that the form of “Speculative inquiry” was more appropriate in this circumstance. She further clarified two circumstances where speculative inquiry could be applied to:

> The first [circumstance] is pertaining to thinking, for example, concluding problem-solving methods, comparing models, [summarising] the applicable conditions of [physics] laws, and etc. The second is with respect to teaching some theorems, such as the kinetic energy theorem, the momentum theorem and ideal gas equation. These theorems are able to be derived from prior knowledge. (Ding-E)

Yao held a similar idea that inquiry could be a form of "thinking inquiry". She argued,

> Some people think that inquiry-based teaching must include experiments, but I don't think so. Actually, it is also an inquiry when you carry out exploring and investigating by thinking. Like… Using questions to urge students to think and allowing for their predictions, these are also inquiries. (Yao-I)

Li's opinion was slightly different. He asserted that an inquiry could be separated into two parts: a "Theoretical inquiry" and a following "Experimental inquiry". He explained,

> Theoretical inquiry was mainly focused on the gradual transition from a perceptual scenario to the theoretical [analysis]… In this process, [students] learn to analyse the parameters qualitatively and quantitatively. (Li-I)

Partial vs. Full inquiry

This aspect pertains to the "five essential features of inquiry" (see NRC, 2000). Interviews indicated that teachers generally did not articulate how many features of inquiry should be embodied in one lesson, but some teachers clearly indicated that partial inquiry was more practical for classroom teaching. Only one teacher suggested the possibility of bringing all these essential features of inquiry into teaching.

Several teachers suggested making a proportion of a sequence of learning experience inquiry-based is more practical for classroom teaching. This approach could be labelled as "partial inquiry" (NRC, 2000).

Ding stated that, for her IBT, meant "allowing students to independently finish one section of a learning task following their own thoughts". She clarified that "one section" meant teachers "designed one or several points at which students could engage in a relatively open-ended process based on their prior experience and achievement". She further explained the necessity of choosing "one section of a lesson" to implement IBT.

> After all – thinking about physics knowledge, even the construction of some concepts took hundreds of years. It is impractical for students to learn several concepts in one lesson using predecessor's methods completely. (Ding-I)

Wen and Min held somewhat similar perceptions with Ding. Wen argued that it was neither necessary nor practicable to let students experience the full circle of inquiry in one lesson.

> It is difficult to conduct a full inquiry in one lesson. One reason is that the time is limited. Another is that

> students differed in their abilities after all. Some students did not have this kind of ability. Therefore, considering the situation of the majority of the students, it is reasonable to choose to do one part, or one section, of inquiry. (Wen-I)

She further elaborated the criteria for selecting a part of inquiry,

> For one thing, this part is important for this lesson. For another, it is able to be accomplished by the majority of the students, and also by the "weaker" students under teachers' enlightenment. (Wen-I)

Min also suggested "focusing on a key point in one lesson and training students to conduct an inquiry to develop abilities". He explained,

> Pick one point and conduct inquiry around this point, because it is impossible to complete the whole process in a 40 or 45- minute- long lesson. It will be the focal point of the lesson that requires students to inquire about. There will be a particular emphasis each time. (Min-I)

Only Pan mentioned that full inquiry could be implemented. He defined different situations in which inquiry could be full:

> The inquiry process can be completed in several lessons, or part of it is completed in class and part of it completed after class, or it can be completed in one section of a lesson if it is a simple inquiry. (Pan-I)

Inside vs. Outside classroom inquiry

This aspect discusses the place to conduct inquiry. Only one teacher argued that inquiry must be conducted outside the classroom. Except for this teacher, the other teachers indicated that inquiry was conducted inside the classroom. Two of them mentioned that inquiry could be conducted both inside and outside the classroom.

Yao asserted that "the experimental inquiry could be conducted at any place". She further explained her ideas by giving examples of inquiry that she required her students to conduct outside classroom, such as experiencing and measuring hyper-gravity and weightlessness in a lift.

Pan pointed out that part of the process of inquiry could be completed outside the classroom, for example, "the process of sorting data, analysing data, and discovering regularity".

Jun's opinion was the strongest. He held that that "an authentic inquiry was impossible to conduct in the classroom". The reason he provided was that knowledge in the classroom was not unknown for students:

> He (student) has already constructed concepts before learning the knowledge. He is not absolutely ignorant of it. (Jun-I)

Therefore, Jun argued that in order to conduct an authentic inquiry, students should be brought out of the classroom to investigate “the questions generated by themselves”.

5.2.2 Methods of incorporating features of inquiry into teaching

The methods of incorporating features of inquiry into teaching discussed by the interviewed teachers could be classified into four categories: (a) integrating inquiry into regular classroom activities, (b) combining inquiry with extracurricular activities, (c) conducting IBT in “public class”, and (d) other unusual methods of conducting IBT.

Integrating inquiry into regular classroom activities

Many teachers indicated that features of inquiry could be incorporated into teaching by combining with regular classroom activities.

One common method discussed by interviewed teachers was using the textbook, extending prior knowledge, and adapting experiments in the textbook to conduct IBT. Li explained how he used the textbook to conduct IBT.

> Generally speaking, new topics [in the textbook] have content for inquiry. I usually check the source materials first. What materials do we have in daily life regarding this topic? How to explain these source materials or strange phenomena? What factors are possibly related? Then [we] can transfer qualitative questions, i.e. scenario, into these factors and then reduce parameters. Then we perform some experiments and demonstrations to highlight the influences of these parameters. After constructing the relationships… I organise a student experiment to [let students] investigate the relationships between these parameters quantitatively… Then [we discuss] what conclusion could be achieved using these results. (Li-I)

Dong considered extending knowledge in the textbook to be used in classroom inquiry. He stated,

> [The content that suits for inquiry should] allow students to acquire knowledge by reconstructing their prior knowledge… i.e. Choose some sections that have been dug into, [thus] students have firmly grasped basic knowledge, and then extend some divergent, but not too difficult, knowledge… Student could acquire extra knowledge as long as they think hard. (Dong-I)

Yao articulated how she would use the experiments in the textbook to conduct IBT,

> [Choose] the wonderful inquiry process of scientists from the history of physics, let students to re-experience it. I can slightly change it to be more reasonable, and make its experimental conditions simpler or improved, and then let them experience inquiry. (Yao-I)

Xiao also suggested "extending some experiments in the textbook and making a full use of their methods". He explained,

> I generally conduct inquiry-based teaching in experimental lessons. Because for a lot of experiments, for example, measuring the value of gravity acceleration, we [students] could figure out many methods for measuring… Students generally formulate [investigation] plans and methods using this approach. (Xiao-I)

Some other teachers suggested incorporating inquiry into regular teaching using partial inquiry or speculative inquiry.

As discussed earlier, partial inquiry was an approach that several teachers, Ding, Wen and Min, for instance, preferred to use in their classroom teaching. Using partial inquiry to make a proportion of a sequence of learning experience inquiry-based, these teachers suggested that they could incorporate inquiry into their regular teaching, and at the same time covering the required content of the textbook.

Several teachers also suggested using "speculative inquiry" to integrate inquiry into regular classroom activities. Ding claimed that "the ideas of IBT could be permeated in classroom teaching" as long as "teachers held clear objectives". She provided examples of how she would integrate inquiry into an exercise lesson.

> In the process of doing exercises, for example, analysing questions, constructing models, choosing suitable [formulae], I think there is something students can inquire into. This depends on how to set your questions, and your steps, or "traps". (Ding-I)

Yao also asserted that "thinking inquiry could be easily permeated into classroom teaching" which was "embodied in small activities", such as "using questions to urge students to think and allowing for their predictions".

Combining inquiry with extracurricular activities

Several teachers did not think the current textbook suitable for conducting IBT. Therefore, they proposed alternative methods for incorporating features of inquiry into their teaching.

Lu argued the experiments in the textbook were too difficult for students to complete using inquiry.

He suggested that the "physics textbook should be connected with students' life experience, and then let students do inquiry". If so, teachers could conduct IBT by combining students' daily life experience with physics. More specifically, he stressed,

> Having students be involved more in extracurricular activities, and then letting them explain their life experience and solve problems in their daily life, teachers could integrate [students'] life experience into physics [to conduct IBT]. (Lu-I)

Jun also suggested taking advantage of extracurricular activities to conduct IBT. For him, the knowledge in the textbook was difficult for inquiry because "they were not unknown". Therefore, he insisted that students should be brought out of the classroom to conduct inquiry because in extracurricular activities, students can "generate genuine questions for inquiry", and teachers could "combine physics with science and technology activities" to conduct IBT.

Implementing IBT in "public classes"

Several teachers suggested that IBT was mainly conducted in "public classes". For many teachers, a "public class" provided a chance to conduct IBT with colleague's support and best material support. Meanwhile, due to the speciality of "public class" – outsiders came to observe the lesson and had a discussion afterwards – teachers were more motivated and willing to demonstrate their best understanding of IBT than usual.

Lin indicated that she would use IBT in "public classes", but would not use it at other times, because she felt her teaching time was too limited to use inquiry.

Pan also suggested that he would conduct IBT in "public class". However, he saw IBT as a way to demonstrate that he "was capable of doing it".

Yao and Wen also confirmed that they would definitely conducted IBT in "public class", but they did not exclude other circumstances in which they could conduct IBT when the content was suitable for inquiry.

Other unusual methods of conducting IBT

Zhao proposed an unusual method of conducting IBT: offering students a vicarious experience of inquiry. He articulated his idea,

> I may not let students to do inquiry to investigate some [physics] laws, but I will tell them [the stories]:

> how people investigated previously, how we do inquiry today, and what problems will possibly emerge during inquiry. (Zhao-I)

This idea originated from his experience as a university student. His teacher told the students his own stories of doing inquiry and Zhao found that he understood the content. Therefore, he indicated that his students could also participate in inquiry by knowing or observing the process of others' inquiry.

Zhao called it an "eclectic approach to IBT". Using this approach, he hoped that he could incorporate inquiry into his regular teaching and give considerations to both developing student ability and improving students' test scores.

Dong also proposed an unusual method for incorporating inquiry into teaching: combining labour skill lesson with physics lesson. He explained it as a way of combining theory and practice. As an example, he explained how he would conduct IBT using this method,

> For example, when I teach the topic of torque… If I can combine physics lesson with labour skill lesson, I can bring them a bicycle to the classroom. I let them to dismantle it and reassemble it, and observe the process of operation. Paying attention to… frames and pivot points, and how it relates to knowledge [in the textbook]. (Dong-I)

However, Dong realised that the method he proposed may be just an ideal because it was difficult to put into practice.

5.2.3 Summary

These teachers demonstrated diverse understanding of approaches to doing inquiry. Although many teachers agreed that classroom inquiry should be guided, experimental and conducted in the classroom, some teachers suggested that classroom inquiry could (or should) be open, speculative (or theoretical, partial (or full), and conducted outside the classroom.

Furthermore, these teachers varied significantly in their opinions of how IBT could be implemented in physics classrooms. The suggested methods included: (a) using the textbook and adapting experiments in the textbook to conduct IBT, (b) combining inquiry with extracurricular activities to implement IBT; (c) integrating inquiry into regular classroom activities, (d) conducting IBT in "public class", and (e) unusual methods of conducting IBT, such as offering students a vicarious experience of inquiry by telling stories.

In all, teachers painted diverse pictures of incorporating IBT into their teaching practices in their minds. This implied that they understood classroom inquiry from a theoretical perspective, but perceived IBT from a more practical perspective. This was understandable because how teachers would conduct IBT was related to their individual considerations of what quality IBT actually looked like in their unique classroom contexts.

5.3 What Factors do Teachers Perceive Affect their Decisions regarding Implementing IBT?

The interviewed teachers reported diverse factors that affected their decisions regarding implementing IBT, as well as their choices of approaches to, and frequency of, conducting IBT.

5.3.1 Factors affecting teachers' implementing IBT

These influencing factors cross three aspects. The first aspect is pertaining to teachers' beliefs about the nature of physics, the curriculum, the content and their perceptions of the nature of inquiry. The second aspect is concerned with teachers' understanding of the requirements of IBT for teaching and learning. The third aspect is about contextual factors. It not only included the practical factors to which teachers passively responded, but also the cultural factors in the teaching context which teachers contributed to. Table 5-2 summarises these factors. Sample quotes for each factor from selected teachers, are included in the table.

Table 5-2 Factors reported to influence teachers' decisions regarding implementing IBT

Factors		Descriptions	Sample quotes
Physics, curriculum, & Inquiry	F1	**Nature of physics**	• Physics, starting from the senior high school stage, is based on models. It is therefore necessary to exclude external disturbances [from experiments to construct models]… It is fairly difficult for students to conduct such an experiment… I think it is impossible for students to discover an unknown law through inquiry, because it is impossible for them to construct many external conditions, such as the vacuum. (Lu-I)
	F2	**Curriculum**	• Its [the experiments in the textbook] purposes are to develop student experiment skills and to meet the requirements of the examination. It is not suitable for student inquiry. (Zhao-I)
	F3	**Content**	• I generally use inquiry in experiment lessons. While in a theory lesson, the key knowledge has to be covered. (Xiao-I) • If a specific content, I feel, can develop students' interests, or some aspects of abilities, or qualities, I will use it. (Min-I)
	F4	**Nature of inquiry**	• Inquiry is investigating the unknown… It was impossible to conduct inquiry in the classroom… I want inquiry, but inquiring about the unknown... [Senior] physics is hard to inquire about, because it has been basically known by people. (Jun-I) • I don't like inquiry very much… You can't do inquiry in one lesson, because inquiry needs a long period of time and has a complete system. (Wang-I)
Requirements for teaching and learning	F5	**Requirement for teachers**	• Because we were educated by traditional educational beliefs, we cannot step out of them completely. IBT poses a high requirement for teachers. (Xiao-I) • Probably because I am not capable enough, I did not consider the student situation well and analyse it thoroughly. Therefore, my designs of IBT have been always unfit for the students' actual situation. (Pan-I) • The biggest constraint is myself, is whether I would like to use this approach. (Zhao-E)

	F6	**Teacher's energy**	• The inquiry-based learning is relatively open… The teacher has to prepare several plans in advance, or provide some guidance to students. Therefore, the amount of preparation is huge. It is not feasible to do so (Dong-I).
	F7	**Requirements for students**	• Students need to have the initiative. That means, they can pose questions; they can divide the work in group activities; they have initiative; and finally… they can reach an agreement on… at least one or two, relatively mature research methods and conclusions. (Dong-I)
Contextual factors	F8	**Assessment system**	• The College Entrance Examination [CEE] acted as a "baton" conducting all teachers' work. (Lu-I) • The CEE did not, and could not, assess students' abilities to inquire. (Pan-I) • The teachers who used IBT might be misunderstood [because their students' scores were not high enough]. (Zhao-I)
	F9	**Limited time for prescribed teaching tasks**	• If I use inquiry in this lesson, the possible consequence is that [they] only complete very little content and acquire quite a few results. If so, my future teaching schedule will be affected because the total teaching time is not enough. (Liu-I) • There has to be someone, who is implementing inquiry-based teaching, and whose students not only have their abilities developed, but also demonstrate their own advantages, and also score highly on tests… So there must be many cases showing that both students' short-term and long-term interests could be guaranteed using this approach. (Ding-I) • I doubt, how useful these things are, in the Chinese context emphasising a high-level academic training. (Zhao-I)
	F10	**Experiment conditions/ Resource**	• I want to do experiments, while there is nothing in the labs. We can't use it. They [other teachers] haven't used the DIS system… And then I want to install one, but all the computers, including the one in the classroom, don't allow it to be installed. (Min-I)
	F11	**Class size**	• If only half of my students come to the labs, the interactions between the teacher and the students will be better. I can observe students at any time and discuss with students.(Ding-I)
	F12	**Nature of students**	• The development of their inquiry abilities is inhibited by the current teaching models from childhood, and therefore, poorer than those of the prior students (Lin-I). • These students can only master one or two key points in one lesson. Therefore, if they can consolidate these key points, they can acquire something in a lesson... Therefore, we go straight to these points, for example [leaning] one physics law, what are the phenomena in our daily lives, how to resolve [a problem], and what factors are related. (Li-I)
	F13	**Classroom culture**	• The classroom climate in this class is that they do not respond to my questions… I have to elicit their answers because they don't respond. If they still don't respond, I have to speak the answers… Then I may not use this approach in the next lesson. I will not ask them, and I may use declarative sentences rather than sentences to elicit their answers. (Xu-I)
	F14	**School culture**	• Our school [administrators] know that these students can't learn physics well. The teaching time [for physics] has been cut down, and that for Chinese, math, and English are increased, because the CEE could not count on students' scores of [physics]… Even spending much time on physics, it is difficult for the students to learn physics well. Considering these, they don't pay much attention to physics. (Min-I) • The atmosphere in our school is relaxed… Every day, when we plan lessons, we speak out when we have ideas. We discuss together each other's ideas and give suggestions. This is the case in the same teaching group, even in different teaching groups. (Yao-I)
	F15	**Collegial influences**	• I really want them (the students) to learn such a process of posing a question and then solving this question using experiments… while as a student teacher, I should place the focus on the concept of free-fall and the law of its motion. Only doing so, will my mentor feel it (the teaching) is focused. Otherwise, he will say that I haven't made the concept clear. (Xu-I)
	F16	**Wider sociocultural context**	• They (students) would never use so difficult physics and maths in their whole life. They learn so difficultly because they need to compete with others. In the current social context of our country, only when they score higher, go to better universities, could they get better jobs, and have better lives in the future. They have to. This is a social phenomenon. (Liu-I) • In our country, it is almost impossible to use IBT to foster students' sense of creativity, or independent ideas... The biggest constraint... on the surface, it is a problem of the examination and assessment system. Fundamentally, it is the problem of the country system. (Zhao-I)

The above diverse factors demonstrated that teachers considered a wide range of issues when deciding whether there was a need to implement IBT in their practices. It is worth noting that there are more contextual factors than other factors identified by the teachers which affect their decisions regarding IBT. These contextual factors include: the assessment system, limited time for prescribed teaching tasks, experimental conditions/resources, class size, the nature of students, classroom culture, school environment, collegial influences, and the wider sociocultural context.

Among these factors, some of them were frequently reported to constitute constraints for teachers' intentions to implement IBT, such as limited teaching time, the assessment system, and the nature of students. However, for some of the other factors, for example, classroom culture, school environment and collegial influence, their influences were perceived very differently by teachers. These perceptions could positively or negatively contribute to individual teachers' decisions to implement IBT. The following table summarises how differently the interviewees perceived these factors (see Table5-3).

The influences of the teaching context are further discussed, combining with findings from the surveys and the case studies, in the discussion chapter.

Table 5-3 Summary of the different influencing factors reported by teachers

	Lu	Pan	Zhao	Jun	Ding	Yao	Liu	Xiao	Dong	Lin	Wang	Li	Min	Xu	Wen	*N*
F1	-							+	✓				+			**4**
F2	-		-	✓	-			-				✓	✓			**7**
F3		✓			✓	✓		✓	✓				✓		✓	**7**
F4		✓	+/-	✓	+	+				-	-				✓	**8**
F5	-	-	-		-			-					-			**6**
F6			-			-			-							**3**
F7		-							✓						-	**3**
F8	-	-	-		-		-	-	-	-		-	-			**10**
F9	-		-		✓/-	-	-	✓	-	-	-	-	✓/-		✓/-	**12**
F10		-			-				-				-		-	**5**
F11					-				-							**2**
F12	-	-	-		-		✓	-	✓	-		✓/-	-		-	**11**
F13						+				+/-		+/-	-	+/-	+/-	**6**
F14					+	+							-		-	**4**
F15		+			+	+							-	-	+/-	**6**
F16	-	-	-				-		-	-						**6**
n	7	9	8	2	11	7	4	7	10	6	2	5	11	2	9	

\+ positive influence - negative influence
✓ influencing pedagogical choices in implemeneting IBT
Teachers are sorted by teaching experience level in descending order.

The above table explains what constitutes difficulty/motivation to individual teachers when implementing IBT. Teachers' considerations varied. Some teachers, for example, Ding, Dong, and Min, had more considerations than other teachers. But some other teachers, for example, Jun, Wang, Li, and Xu, only indicated a few factors that influenced their decisions regarding implementing IBT. Meanwhile, the influences of individual factors were also perceived differently. For example, the influence of the nature of inquiry was positive for Ding, Yao and Zhao, negative for Lin and Wang; but for Jun, Pan, and Wen, it was neutral while influencing their pedagogical choices such as the approach to inquiry.

The discrepancies among teachers' considerations indicate that teachers perceived and interpreted IBT in their specific teaching contexts. Teachers' instructional choices are related to their understanding of the essential components of the classroom (Hewson & Kerby, 1993). Their instructional decision-making process around IBT was a deliberate process in which teachers weighed the challenges, personal costs and benefits (Fernandez et al., 2008) of conducting IBT, as well as a process in which they "acknowledge their capacity for change in terms of their disposition, energy, and social support" (p.196).

Nevertheless, there are several factors that were frequently reported as influential, including (a) Limited time for prescribed teaching tasks, (b) The assessment system, and (c) The nature of students. There was no significant difference among teachers from different types of schools, or with different levels of teaching experience, in their opinions on the former three factors. The following sections further describe these factors, along with selected teachers' quotes.

Limited time for prescribed teaching tasks

The most commonly reported factor to constrain teachers' use of IBT was the limited time for completing prescribed teaching tasks. Teachers reported that physics was generally only given four teaching hours a week (three in some schools). The course content was predetermined and prescribed by the municipal educational commission, and every teacher must accomplish it on time to prepare for the unified mid-term and end-of-term examinations [6]. In addition, individual schools set their own tests from time to time to examine students' learning outcomes. Therefore, teachers commonly indicated that the content of the syllabus had to be covered on schedule to meet the requirements of examinations. As Ding explained,

> After all, we are encountering examinations administered by others. Therefore, the content of the syllabus,

[6] Each district usually organises its own unified examinations for their students. For Grade 12 students, the final exam (College Entrance Examination) is organised by the municipal educational commission.

> at the dimension of knowledge, must be acquired by all students. (Ding-I)

In this situation, the teachers' feelings of being pressed for time and commitment to coverage of required content were understandable due to the pressure of examinations.

In many teachers' opinions, IBT was time-consuming work. It is, therefore, not surprising that teachers were concerned about the efficiency of IBT for acquiring required knowledge in limited time. Liu's explanation was typical.

> If I use inquiry in this lesson, the possible consequence is that [the students] only complete very little content and acquire few results. If so, my future teaching schedule will be affected because the total teaching time is predetermined. (Liu-I)

Several teachers also indicated that IBT was not as efficient as the traditional approaches to help students acquire knowledge. For example, Zhao was "very sceptical about the usefulness of IBT in a Chinese context that emphasises high-level academic training". Ding suggested that the traditional methods of teaching may be more practicable and effective in helping students "acquire knowledge and skills" and improving students' test scores in a test-oriented assessment system.

Therefore, some teachers stated that IBT could not be used as a regular teaching approach. Zhao argued that IBT is not practical to implement in day-to-day teaching, because "teaching tasks are hard to complete if using IBT in a whole lesson". Yao and Wen claimed that they could only spend limited time on conducting IBT. Lin indicated that she implemented IBT only in public classes. Lu suggested that he had no time for IBT because he had to "complete a certain amount of teaching tasks". Liu claimed that he had to cover the required content of the syllabus first and suggested students go to the laboratory to do some inquiry after class.

In contrast, some teachers advocate adapting the approaches to implementing IBT to be more practical. Ding, Wen, and Min suggested doing partial inquiry in one section of a lesson. Xiao reported that he might adjust his teaching mode to be more structured. He explained,

> If I allow the lesson to be open to students' discussion, I can't control the time. I find it is impossible to have students discuss and do experiment [in one lesson]. (Xiao-I)

In a case a complete student inquiry has to be done in one lesson, he decided to "decrease time in communication, but maintain the time spent on experiments" because he thought that "experiment is more important".

Clearly, limited time for prescribed teaching tasks greatly affected these teachers' intention to implement IBT in their regular teaching practice, as well as their choices of instructional strategies and frequency of conducting IBT.

The current assessment system

Teachers generally perceived that the current assessment system did not provide them with incentives to implement IBT. Most of them saw there was a conflict between IBT and the current assessment system.

Teachers generally considered that the current assessment system was test-oriented, while it could not effectively assess students' learning outcomes from IBT. Zhao commented that "the school assessment did not assess students' understanding of process and methods". Pan stated that "the College Entrance Examination (CEE) did not, and could not, assess students' abilities to inquire". Therefore, "teachers felt under pressure" because "it was impossible to ignore students' test scores in the current CEE system".

When the assessment system could not assess the effectiveness of IBT, teachers tended to see risks associated with conducting IBT. As Lu argued, "teachers always hoped to see positive feedback when they tried new things". Teachers wanted to see their efforts rewarded, while the results might be "the teachers who used IBT might be misunderstood" (Zhao-I) because "the effect of IBT was hard to assess by the school examinations" and "their students' scores were not high enough" (Zhao-I).

For many teachers, "the College Entrance Examination (CEE) acted as a 'baton' conducting all teachers' work" (Lu-I). The official syllabus of examination had to be followed completely in order to prepare students well for the CEE. How to prepare students well for the examinations was an overarching concern of most teachers.

However, teachers were not convinced of the effectiveness of IBT in improving students' test scores. Although teachers generally indicated that inquiry was a better way to foster students' understanding, they did not see a picture that IBT could allow students to develop inquiry abilities and score high in tests at the same time. Ding explained that,

> The current assessment methods are mainly written tests in which students rely more on their experience that are acquired from doing exercises to answer questions. (Ding-I)

Therefore, Ding argued that "to acquire higher test scores, teacher could simply give students more drill training", instead of using IBT to achieve this end.

Pan and Lin indicated that if teachers spend too much time on the IBT, students may be "weak in examination skills" because they did not "acquire the relevant knowledge and develop appropriate abilities for the CEE" (Lin-I).

Therefore, some teachers, for example, Lu and Zhao, indicated that they were not willing to conduct IBT; and some teachers, such as Xiao and Wen, suggested that they dare not use IBT regularly because they had to give consideration to students' test scores. Ding argued that it was hard for teachers to handle the relationship between teaching for exams and teaching for developing inquiry abilities in the current teaching context. Therefore, she appealed,

> There has to be someone, who is implementing inquiry-based teaching, and whose students not only have their abilities developed, but also demonstrate their own advantages, and also score highly on tests. So [teachers are convinced]… So there must be many cases showing that both students' short-term and long-term interests could be guaranteed using this approach. (Ding-I)

The nature of the students

Many teachers suggested that the nature of their current students posed a challenge to their implementation of IBT. More specifically, they referred to students' learning styles, inquiry abilities, and attitudes towards learning.

Pan argued that using IBT with the current students would raise issues in students' learning because these students had never been trained to conduct inquiry. He explained that IBT advocated a new approach to learning, which was different from the way that students were taught in their prior schooling. He continued by saying,

> To use another approach to learning, students have to be trained from starting primary schools. Human thinking cannot be switched in one step... If students do not have such a habit of learning, such a way of thinking, in their prior schools, they would be confused by using this [learning approach] in senior secondary schools, they would not make progress, and they would feel completely in the dark. (Pan-I)

Dong, Li, Liu, Pan, Wen, and Xiao, articulated that students' thinking ability and habits affected their way and/or frequency of implementing IBT. Xiao reported that he often implemented IBT in his advanced class, but much less in his normal classes, because he found that "the students in normal classes could not achieve the same requirements with those in his advanced class". Liu and Wen claimed that they would not adopt an open mode of inquiry because of the nature of their students. Liu argued that the discrepancies in abilities among students would make an open inquiry ineffective. Wen stated that her students "were not competent enough to conduct inquiry activities without teachers' guidance". She further explained, "A match between IBT and students' levels of thinking and abilities is essential". Pan claimed that it was difficult for his students to do inquiry because "they did not know how to think" and "their abilities differed significantly". This affected his decisions about the frequency and approaches of conducting IBT. As he put it,

> Students in our school are low-proficiency students, having some problems in learning habits and classroom behaviours. Therefore, I seldom implement IBT. (Pan-I)

> I have to consider students' abilities in my implementation of IBT, giving them appropriate enhancement. It has to be centred on students and learning. (Pan-I)

Ding, Lin, Lu, and Zhao, found that their students held somewhat utilitarian views of learning, and these views affected teachers' intentions to use IBT. For example, Ding found that the students wanted "instant solutions rather than thinking deeply". Lu stated, "They are learning for the CEE… I have never seen a student who likes this learning method [IBT]". Lin reported that

> The students do not necessarily like hands-on activities… because of the CEE… They want the teacher to explain examination questions more; and if luckily these questions were tested in the CEE, [they can] improve their test scores immediately. (Lin-I)

The above examples demonstrate that teachers felt that the nature of their students caused a challenge to their implementation of IBT.

5.3.2 Summary

As stated in the previous section, these teachers saw the benefits and values of inquiry for students' learning, while at the same time they tended to perceive risks associated with implementing IBT in the current teaching context of China. Teachers considered a wide range of issues when deciding whether there was a need to implement inquiry in their practices. They reflected on the subject matter, the curriculum, the nature of inquiry, their teaching, their students, and their teaching context. These factors were reported to affect their decisions regarding implementing IBT, as well as choices of approaches to, and frequency of, conducting IBT. These perceptions showed that teachers perceived and interpreted IBT in their specific teaching contexts.

For teachers, to conduct inquiry was not a simple process of implementing a theoretical understanding in practices, but a practical process of relating inquiry with their teaching contexts. In order to improve teachers' implementation of IBT, effective strategies should be taken to maintain and foster the positive influences, and meanwhile address issues appropriately to decrease the negative influences.

5.4 What Professional Development do Teachers Require for Implementing IBT?

The teachers reflected upon the status quo of their professional development and posed various demands for professional development to plan and implement IBT successfully. They demanded professional development include three aspects: practice support, theory support, and information support. The following section described the various demands of these teachers for professional development.

5.4.1 The status quo of teachers' professional development

Teachers reported that teaching and observing "public classes" were the main strategies that provided teachers with professional development.

For many teachers, teaching a "public class" provided a chance to conduct IBT with collegial support and material support due to the speciality of "public class". Teachers planned and prepared their lessons with more information, collegial support, help from experienced teachers and/or the researcher leader and experts. Meanwhile, because outsiders came to observe the lesson and had a discussion afterwards, teachers were not only more motivated and willing to demonstrate his best understanding of IBT than usual, but this also provided a chance to reflect on what they did and challenge what they thought and then update and modify practice later on. Therefore, teaching a "public class" was an important strategy that enabled teachers to develop pedagogical understanding and knowledge about IBT.

However, for these teachers, the chance of teaching a "public class" was much less than observing a "public class". The reality was that on average all teachers in this district had one or two chances of teaching a "public class" at a school level per semester, but only a few teachers had the opportunity to teach a "public class" at a higher level (e.g., at a district level). This meant that, except for colleague support, teachers seldom receive professional support from experienced teachers, the research leaders, and experts. Therefore, observing "public classes" and participating in discussions became an alternative method for these teachers to foster professional development.

However, teachers expressed different opinions on the helpfulness of observing "public classes" for implementing IBT. Although some teachers, for example, Wen, Liu and Pan, mentioned that observing a "public class" was useful for them to improve teaching and plan IBT, many indicated that this approach was not very helpful for them. They gave different reasons. For example, Lu explained,

> [Those lessons] may give me some ideas, but they are basically making shows... It is impossible to teach like that in every lesson. (Lu-I)

Zhao argued,

> In public classes [we] can only observe the external, demonstrated, stuff, but we can't understand the designer's ideas, starting points, and intention. These may be known from the discussion and comments after the class, yet they are still superficial, even the comments from the experts barely skimmed the surface of the subject. (Zhao-C)

Xiao stated that he regretfully found that "many open lessons, even those national ones, were still traditional, although the students were actively thinking".

Teachers' perceptions indicated that professional development should link with teachers' specific teaching practice to be meaningful. Observing public classes, therefore, should be combined with teachers' own teaching practice, promoting teachers' self-reflection upon, and participation in, IBT.

5.4.2 Demands for professional development

Teachers demanded professional development for implementing IBT from different aspects: practice, theory, and information.

Dong, who had seven years of teaching experience, suggested that in order to develop an effective instructional model for implementing IBT, he needed appropriate practical advice from experts, instead of theoretical advice. He explained what constituted practical advice to him,

> He (the expert) should prepare some, for example, a list [of topics], that are readily used for inquiry. And then he has a [sample teaching plan] for one of them. It explains the general design, including the methods to be used, such as how to group [students], how to cover the knowledge, and how to prepare, and so on. It is like a sample teaching plan. On this basis, he gives us advice and discusses with us, and then we prepare, or re-create, plans for other topics [of this list], following this model. One or two weeks later, [he] organises another similar training… After discussions, all teachers should basically have a consistent understanding before they go to teach. (Dong-I)

Dong's demands highlighted the importance of relating professional development with teachers' teaching practice, and the importance of the communication between colleagues, for their success in implementing IBT.

Ding, an experienced teacher who had utilised IBT many times, had different requirements for professional development. She realised that, " most of the time, she might understand the [teaching] matter through experience". Therefore, she expected to find "a core theory" to support her instructional practice and judgements about teaching and learning". She stated,

> Having a core theory to support my judgements on, or implementation of, teaching, I can compare each section or everything that I did [in teaching] with the requirement of this theory. This means improvement in two aspects: for one thing, my experience develops into a theory; meanwhile, I can direct my practices using a theory that I accept. (Ding-I)

Due to this reason, Ding suggested that researchers in universities should come to observe secondary teachers' classrooms and provide appropriate theory advice to teachers.

Some teachers indicated requirements for information support for implementing IBT. Teachers generally reported that they planned IBT mainly based on the curriculum standards and the textbook. Although some of them, for example, Xiao, Li, Pan, and Wen, referred to the reference book, different versions of textbooks, books including U.S.A textbooks, and information from the internet for planning IBT, these sources were generally isolated, piecemeal, and sometimes confusing. As Pan described, "The reference materials are bits and pieces. I can't remember." This situation entails systematic and sufficient information support for teachers' success in implementing IBT.

Although many teachers suggested that professional development was important for implementing IBT, some teachers could not specifically articulate what they exactly needed. Liu explained,

> Because I am not very clear about the better way to conduct such kind of lesson, I don't know what kind of training I need. (Liu-I)

Wen also reported that she did not fully understand the theory of IBT. Therefore, she searched sample teaching lessons from the internet, but she could not articulate what else she needed to help her implementation of IBT.

The data also show that the interviewed teachers demanded professional development for planning and implementing IBT. Their demands varied from person to person, however, some teachers could not specifically articulate what they exactly needed.

5.5 Summary

Teachers demonstrated diverse understanding and knowledge of inquiry and how to conduct IBT. Regarding inquiry, teachers generally perceived that classroom inquiry was a process of thinking and doing science, while from different perspectives. They attached different values to the elements involved in inquiry. Meanwhile, they showed clear knowledge of the process of inquiry, which was consistent with the descriptions of the curriculum standards. These perceptions indicated that these teachers had developed a considerable degree of theoretical understanding of inquiry.

Teachers proposed various methods of conducting IBT in their classrooms. Their ideas reflected their thinking about how IBT would possibly work in their classrooms. However, most teachers preferred using guided inquiry and implementing IBT by incorporating features of inquiry into their regular teaching practice.

Teachers reported a range of factors that influenced their decisions regarding implementing IBT. The commonly reported factors were related to the current assessment system, the efficiency of IBT to acquire knowledge in a limited time, and the nature of the students. They also articulated different demands for professional development in the aspects of practices, theory, and information, to successfully implement IBT. These perceptions show that teachers perceived and interpreted IBT in their specific teaching contexts.

The interviews also reveal several issues in teachers' understanding of IBT. First, some of the teachers demonstrated misconceptions about inquiry. Second, teachers were generally not convinced of the efficiency of IBT in acquiring knowledge, particularly for the low-proficiency students. Third, some teachers did not see that the experiments in the textbook could not be used for IBT. Finally, several teachers could not articulate what professional development they needed to implement IBT. These findings and their implications are further discussed in later chapters.

6. Phase three: Case studies

The interview findings suggest that teachers held diverse perceptions of inquiry and inquiry-based teaching (IBT). The case studies described in this chapter were designed to find out how teachers implemented IBT in their specific teaching contexts. In addition, the case studies explored the influences of teachers' beliefs, perceptions of inquiry, and other factors, as identified in the interviews, on teachers' instructional decisions and practice regarding IBT.

The five teachers were carefully selected to represent a range of contexts and levels of teaching experience. These teachers were interviewed and invited to demonstrate how they implement IBT in their classrooms. For the purpose of comparison, the researcher intended to observe the same topics conducted in the same type of lesson (conceptual teaching) whenever possible. Table 6.1 shows the selected topic of each teacher with which they implemented IBT.

Table 6-1 The selected lessons that teachers implemented IBT

Taught topics	Ding	Min	Pan	Wen	Zhao
1. The motion of an object in free fall			√ (L)	√ (C)	
2. The Parallelogram Law (resultant of forces)	√ (C)	√ (C)			
3. Factors affecting the magnitude of induced emf *					√ (L)*

√ using IBT to teach (C) classroom (L) laboratory

* Zhao did not implemented IBT in his Grade 10 class, instead he provided a sample IBT in his Grade 12 class.

The following sections represent the findings from the case studies, and include selected teacher quotes (referenced noting their names and data sources, e.g. Zhao-I), and classroom vignettes (T stands for the teacher, and S refers to the student). The chapter begins with a description of each teacher's profile, followed by the major findings from both within-case analysis and cross-case comparisons of teachers' beliefs, perceptions of inquiry, and inquiry practices. In all, this chapter intends to provide rich, contextualised descriptions of the relationships among teachers' beliefs, perceptions of inquiry, and their implementation of IBT in their unique teaching contexts.

The last section of this chapter provides short summaries of each case and concludes the findings. A further discussion of the conclusions is presented in the discussion chapter.

6.1 Case Study Teachers' Profiles

Ding

Ding, a senior secondary physics teacher, teaches at Phoenix Senior High School that attracts the best students in the district. This school is a municipal key school in this district that enrols a large number of senior secondary students. It is also a boarding school and all its students are required to board. It has a strict timetable for student study and rest.

As a municipal key school, Phoenix has priority in enrolling students over other schools. The cut score of this school in the Senior Secondary School Entrance Examination (SSSEE) each year is much higher than other schools in this district. Therefore, the students in this school are publicly considered as the top students of this district. In addition, Phoenix receives more educational funds from the government than other type of schools in this district. It has the biggest campus, best equipped library and laboratories, and best sport gymnasium and living infrastructure. Phoenix is publicly considered as one of the top schools in Shanghai also because of its high enrolment rates in the Colleague Entrance Examination (CEE). Students here are very proud of themselves and teachers of this school are well-respected by students, parents, and the public.

This school attaches particular importance to the school subjects of mathematics and physics, giving much attention to experiments as well. The laboratory staffs work collaboratively with science teachers by scheduling time, preparing and maintaining equipments, and helping carry out experiments and resolve students' problems (technically) in experiments.

Ding is a leading teacher in her school, publicly recognised for excellence in teaching, her students' good academic performance, and her high rank in several national teaching competitions. Ding has been working at this school for more than 10 years. Besides the teaching duty, Ding also undertakes a position as the coordinator of the physics department of the school.

Ding taught two Grade 10 classes. Both classes consisted of 35 top students who were selected from the Grade 10 cohort when they were admitted to this school. In a sense, Ding taught the best students of the year level in this district. According to the researcher's observation, these students had better learning abilities and habits than most students in other types of schools. They were serious, studious, and always willing to cooperate with their teacher and make an effort to achieve the teacher's requirement. Misbehaviours were rarely observed in classrooms.

Min

Min is a serious young teacher of Rainbow Senior High School in this district. Min had recently graduated with a Masters Degree in Physics Education from a famous normal university[7] of China. This was his first year of teaching after graduation. But he had taught for four years in a key school in another province before he went for his three years of full-time Masters' study.

Rainbow Senior High School is a private senior high school. This school normally admits students who cannot reach the cut score of the public schools in the SSSEE. The students' average academic level is supposedly at the bottom of the cohort of students in this district at the same year level. The teachers in this school are much concerned about their students' learning abilities, learning habits, and misbehaviours in classrooms.

This school gives less importance to physics than to Chinese, English, and mathematics. Physics are only given 3 lessons a week (4 lessons a week in other schools), because the students are considered to have difficulties in learning physics and thus generally will not choose physics at Grade 12. In addition, physics teachers in this school do not often organise student experiments and the laboratories are not well equipped.

In this school, students' family backgrounds differ widely. Besides the local students, this school also enrols some foreign students, typically from Taiwan, South Korea and Japan, who come to China to experience the Chinese classroom culture. In Min' classes, there are several foreign students who sat in the last row of the classrooms.

Min taught four Grade 10 classes in this school. All classes had about 33 students. He is the only physics teacher of Grade 10. Although he had been teaching for four years, his previous teaching experience in a key school seemed not to help him much. He constantly mentioned he had no experience with his current students and had to "test each step before taking it" and had no colleagues to consult with.

Pan

Pan, a veteran teacher with 20 years teaching experience, teaches at Whitestone Senior High School, a non-key public school in this district. As a normal public school, this school admits students who reach the cut score on the SSSEE set for the normal public schools, which is lower than that of the key schools. The teachers in this school are much concerned about their students' learning abilities

[7] A "Normal University" in China, are teachers' colleges at which teachers receive higher education and training.

and learning habits as well. In the researcher's observation, misbehaviour was observed from time to time and it was sometimes seen as an interruption by Pan.

This school has recently applied for an upgrade from a normal public school to a district demonstrating school. In order to achieve the requirements of the assessment, this school makes every effort to demonstrate its best features. All teachers in this school were required to give at least 20 minutes for student talk or discussion in a lesson (Therefore, if the assessors come to observe teachers' classes, teachers could demonstrate somewhat new teaching style). Pan did not like this school policy, but indicated that he would and could do it when the outsiders come to his classrooms.

Pan taught two Grade 10 classes containing 33 and 35 students respectively. He is passionate about using information technology and different resources to facilitate teaching. He also actively participates in the research and teaching activities organised by the district research leader.

Wen

Wen is an amiable and a lively student teacher. She was doing her teaching practicum in Phoenix Senior High School when she was interviewed. She taught three Grade 10 classes.

As a student teacher, she was given plenty of time to prepare for teaching. She was required to observe her mentor's teaching, and other teachers' teaching if possible, check and correct students' homework, prepare lesson plans and do trial teaching, before her formal teaching. Meanwhile, she needed not take as much responsibility as a regular teacher, for example about the text scores. In a sense, she had more freedom than regular teachers to choose favourite instructional approaches which she thought were appropriate for her students. In this situation, she concentrated herself on designing lessons and thinking about the content to be taught. Meanwhile, she seemed to be confident, happy and relaxed.

Zhao

Zhao, a senior secondary physics teacher, teaches at Fourseason Senior High School, a non-key public school in this district. This school has been recently relocated to its current address by the district government, being given larger land to build its campus. The new campus is bigger, refurnished, and better equipped. Moreover, it is built next to the district library and its students can share the library resources.

This school is set as an exemplary school by the district government. It is publicly recognised as one of the good schools in this district, although not as excellent as the municipal key schools. It admits students whose test score are lower than the municipal key schools, but higher than other schools.

Zhao holds a masters degree in physics education and has been teaching physics for 18 years. He taught in a municipal key school in a suburban district of Shanghai before he was employed by this school two years ago. Besides the teaching duty, he also coordinated the physics teachers at Grade 12 level of his school.

Zhao is concerned much about science education. He also spends much time on writing journal articles. Recently, he has published one journal paper regarding the design of inquiry-based teaching in the physics textbook.

Zhao taught two Grade 10 classes and a Grade 12 class. All classes had about 30 students respectively. In Zhao's description, his Grade-10- students' learning habits were "on the opposite side of those of successful learners". In the researcher's observation, most of his Grade 10 students were willing to cooperate with the teachers. They followed Zhao's instruction and behaved as he required. But misbehaviours were sometimes observed. Some male students seemed to be more active than other students. Their behaviours were sometimes seen as serious interruptions by Zhao.

Zhao told the researcher that he stopped writing teaching plans a couple of years ago. He explained that it was because he was too busy to do so. Nevertheless, it seemed that he was very confident in his expertise in teaching physics.

6.2 What are Teachers' Beliefs about the Nature of Science, Teaching, and Learning?

Case studies found that teachers held diverse beliefs about the nature of science, teaching, and learning. Meanwhile, they shared some common understandings. Their beliefs were found to be closely aligned (or nested) and sometimes conflicting. The following sections describe the five case study teachers' beliefs, together with selected teacher quotes.

6.2.1 Beliefs

Ding

Ding regarded science as "a systematized body of knowledge that accurately reflects the laws of nature". She emphasised the "systematicity" and "veracity" of the knowledge that students learned. This was reflected in her views on the reformed curriculum, new textbook and student experiments.

For example, for the reformed curriculum, she argued that if teachers treated the extended curriculum [8] as an elective course, "problems would emerge in the connection between the basic and extended parts", and it would "affect students' formation of a system of knowledge and teaching efficiency as well". For the reformed textbook, she pointed out that deleting some content from the earlier version of the textbook "made the system of knowledge incomplete".

She felt, therefore, that she had to cover those deleted topics and the content in the extension curriculum in order to allow students to link knowledge together to form a complete system of knowledge.

She also stressed the importance of achieving the "correct conclusion" in student experiments and stated,

> Should they [students] believe in the knowledge in the textbook if they did not reach the correct conclusion? They would be suspicious of [the veracity of] the knowledge system. This situation was certainly not allowed at senior secondary education stage. (Ding-I)

Regarding effective teaching, Ding claimed that it should "inspire students' interest" and "have specific objectives". To do so, teachers employ some important teaching skills to keep students on tasks such as "using demonstrations", "interacting with students using questioning", "observing students' discussions", and "designing appropriate questions". In the long run, she suggested that an effective teaching should help "students develop a good and open habit of mind" that "enables them to conduct inductive and divergent thinking".

She also asserted that an effective lesson must achieve the teaching objectives. She argued that the content of the examination syllabus "had to be mastered by all students" because "students were finally assessed by examinations".

With respect to learning, Ding stated that the students' initial impetus to learn science comes from their observations and reading. For senior secondary students, they acquire knowledge from teachers' transmission more than from other methods. Ding also held that experiments are important for learning physics, because by doing experiments students can "improve experimental skills", "apply scientific methods", and "construct links between theory and practice".

Considering her students, Ding felt her students did not have good habits of mind and held

[8] The new physics curriculum consists of three parts: basic curriculum, extended curriculum and research curriculum (). If students do not want to choose physics at Grade 12, they only need to learn the basic curriculum. Otherwise they have to learn both the basic and extension curricula. The research curriculum is used for students' autonomous learning.

somewhat utilitarian views of learning.

> I particularly feel the current students seem to be over-impatient. This gives me a headache. They want instant solutions rather than thinking deeply. They prefer to be told a conclusion and copy it down. This is the way they learn, and I feel it is a nuisance… Students' learning habits in recent years, I mean habits of mind, are relatively backward… They seem to, as I just said, like to acquire knowledge from spoon-feeding, not thinking. Although we encourage inquiry, they prefer to be told what is correct, no matter if it is inquiry or not. (Ding-I)

She stated that in order to learn physics well, students should develop good habits of mind. They also need

> [develop] logical thinking ability and ability to construct models. Continuously try to ask themselves questions in learning and answer by themselves. (Ding-E)

In addition, she suggested that drills on problem-solving with standard procedures are really helpful to "improve the orderliness of student thinking", and this ability helps students improve the accuracy of solving examination questions.

Min

Min stressed that physics is a science subject based on experiments. He attached particular importance to teacher demonstrations and students' experiments. He stated,

> The experiment, firstly, can enhance students' understanding of the nature of physics. Secondly, it can foster students' interest in learning physics. If students' interests were enhanced, other aspects of learning could be improved naturally, including test scores and passion for science. (Min-I)

Furthermore, he suggested that through experiments "students are at least able to develop manipulative skills and abilities to collaborate with others". He felt this was particularly important for his current students as he found the latter were lacking these abilities. Therefore, he emphasised the importance of performing demonstrations, doing student experiments, and designing better student hands-on activities for "more student involvement".

Regarding his current students, Min found they "were lazy and had low learning autonomy". He felt that he had to concentrate more on basic concepts and skills and there were many things he could not do with these students. He also felt that his students "had bad learning habits". For these students, he argued that "developing good learning habits was essential".

In order to learn physics well, he suggested that the students should "actively participate in learning" and "communicate with the teacher" to achieve a good understanding. He stated,

> If they [the students] don't communicate with the teacher, the teacher will follow his own train of thoughts to teach… Then what they do in the lesson is just taking notes.... Soon after, they will find they don't know how to solve problems, [because] their thoughts haven't been trained. (Min-I)

Min hoped that his students could "develop abilities rather than improve test scores" through his teaching. He did not want his students to be "test machines".

Pan

Pan stated that physics was a science subject based on phenomena and experiments. He felt that experiments were very important to teaching and learning physics. "Without experiments they [teaching and learning] produce little effect, and lose connections with reality", he asserted. The functions of experiments were "reinforcing students' manipulative skills, and mastering the method of scientific inquiry".

Regarding teaching, Pan claimed that the teacher role was "spoon-feeding students with teachers' ideas". For him, teachers only make a difference to "the percentage of the knowledge which they could cram into students' head".

He also stressed the influence of teacher personality on student learning. This influence depended on teachers' approach to teaching, their "understanding of students' psychology", and their "attitudes towards, and ways to communicate with, students". He asserted that "the most successful teachers were those whom the students adored, respected, or liked. Students would like to follow these teachers' instruction".

Regarding learning, Pan claimed that knowledge was acquired from a chain: theory (concept) – examples (problem-solving) – applications (doing exercises). If the textbook uses this chain to represent knowledge, students could follow it to acquire knowledge. For this reason, Pan did not like the reformed textbook because "it was hard to read and follow for students". In Pan's opinion, the best physics learners could "follow the textbook to study on their own". Otherwise, if students did not have such an ability to learn on their own, they should carefully listen to their teacher's instruction, successfully master the knowledge, and initiatively apply it to the new circumstances.

His current students were obviously not seen by him as good physics learners. Pan stated that his students had low motivation and ability to learn.

> Our students' basic abilities to study were low, and they had problems in learning habits and obeying school discipline. (Pan-I)

He also tended to perceive most students as passive learners.

> They [my students] do whatever the teacher tells them, and they dare not have ideas. In addition, they do not have ideas, and do not know how to think. (Pan-I)

Considering this situation, Pan held that for his students, effective teaching was to provide them with very specific instruction. Otherwise, his students would "lose their direction in learning". He argued that teachers should consider the students' situation and the best way to teach was the one suitable for students.

Meanwhile, Pan stated that it was impossible to ignore the test scores in the current CEE system. He, therefore, indicated that it was essential to cover the content of the examination syllabus. In addition, he suggested that it was an "indispensable section" that students repeatedly practise drills for solving questions and consolidating knowledge. He emphasised,

> It does not mean that they [students] can solve problems by taking my notes. They need repeatedly practice afterwards. This section cannot be omitted, just like thousands and millions of times of drills training for a gymnast. (Pan-I)

Wen

Wen stated that the nature of science is that science is able to be revised because "science has limitation and biases, and it is not right in any condition".

She suggested that the purposes of experiments were to allow students to understand the importance and function of experiments in physics, and also master the basic experimental skills.

With respect to teaching and learning, Wen held that "it is more important for students to experience the process before achieving the results". Therefore, she defines a good physics learner as a student,

> Who forms a clear train of thought through a thinking process, not only wants answers or replicates teacher's sample solutions. (Wen-I)

Correspondingly, she described that the role of a teacher is "to guide students to experience such a process in which students could understand the train of thought in problem-solving". She highly valued "a heuristic method of teaching" using elaborately designed questions to guide students to "form good habits of learning".

Furthermore, she stated that effective teaching should consider on a long term basis. She further explained, "Teaching may be effective in the short term by teaching students the drills so that they can do their work right away. But it might not work in the long term".

Regarding the nature of her students, Wen held a naive opinion, to some extent, that "the knowledge of physics learned in junior secondary schools has little effect on student learning at their senior secondary level", and therefore senior secondary teachers can treat students as "blank papers" and design instruction accordingly.

Concerning her students, she reported that many of them do not have good habits of mind, and "are accustomed more to spoon-feeding". She stated,

> Some students do not think, and do not like to think. They are just waiting for teachers to tell them [the answer]. They do not think even in inquiry activity. They wait for other students to tell the answers. (Wen-I)

In addition, she found that many students were not interested in learning physics and "took a perfunctory attitude towards learning this school subject".

She, therefore, stressed the importance of teachers guiding students to change their learning habits.

> It is a process of transition. If teachers guide them from the very beginning, slowly inspire them, and provide them with better support, it will work when students get accustomed to [this teaching style]. It is impossible for them to change instantly, as they have long been accustomed to test-oriented education. (Wen-I)

Zhao

Zhao demonstrated a set of competing beliefs. When discussing the nature of science and physics, on the one hand, he perceived science as "explanations of objective phenomena. It was therefore objective". "However, not everything could be explained", he stated, "Some knowledge was uncertain. Some laws were just something [accounting for] facts or events whose possibility of recurring was greater than others".

On the other hand, Zhao tended to conceive science as a body of knowledge that students needed to acquire. Consistently, he considered that teaching is transmitting knowledge and learning is a process of receiving knowledge.

It is therefore not surprising that Zhao stated that the conventional teaching approach –transmissive teaching– was a highly effective approach to teaching, although it was not able to satisfy all teachers. As he argued,

> We have tried whatever we can teach during the last several decades. Why [do] we still choose such a teaching approach that could not satisfy all of us? It is thus clear that this teaching approach is not only effective but also highly efficient. Compared with others, it had a "lower input" but with a "better outcome". (Zhao-I)

Regarding learning, Zhao pointed out that students developed two kinds of knowledge in their learning: declarative knowledge and procedural knowledge. Procedural knowledge allowed problem-solving skills to be executed intuitively. More specifically, he explained that if students' knowledge was declarative,

> Students cannot identify the problem-solving scenarios to which the knowledge could apply. They have not developed automatic behaviour sequence, too. (Zhao-E)

In order to achieve this purpose, he insisted that students need "*variant training*". "*Variant training*" was a vocabulary he used to describe a large amount of drills training with variant forms. He argued that through "*variant training*" students would "be familiar with variant forms of questions, and develop their knowledge from declarative into procedural", and thus they are able to use these drills freely.

However, Zhao did not have such a belief a couple of years ago. He formed this opinion since he found that his students' test scores were always lower than other teachers' students who had a large amount of drill training. He concluded, "Although this may not be the best method, it may be the most efficient method [to acquire knowledge and improve students' test scores]".

Zhao also showed more conflicting beliefs regarding the purpose of education. On the one hand, he attached the highest importance to "student thinking" and suggested "developing ability was more important than gaining knowledge". On the other hand, he suggested that "the major purpose of imparting knowledge was to pass on culture" and "students were carriers of social culture". He argued that "students took more responsibility for this social role than their personal roles" in schooling. For example, he regarded that developing ability "relied more on students themselves".

Regarding his students, Zhao judged that "at least two thirds of the students [in his Grade 10 class] did not have high expectations for their own learning". He stated that his students "only had very low aims and never exerted themselves to accomplish these aims". He complained, "Their learning habits were the opposite of those of successful learners". Furthermore, he stated that his students did not "have a sense of active learning and inquiry". Therefore, "without such senses, they cannot give full play to their abilities". For these students, he felt that his teaching was sometimes ineffectual.

6.2.2 Summary

It was found that the case study teachers shared certain basic beliefs about the nature of the science and demonstrated common understandings about the means used to develop scientific ideas. Linking to physics as a secondary school subject, teachers perceived that physics was a school subject based on phenomena and experiments. Giving priority to phenomena and experiments and focusing on scientific methods to develop scientific understandings were their major perspectives of physics as a senior school subject.

Teachers' beliefs about the nature of science, teaching, and learning were found to be closely aligned (or nested) and sometimes conflicting. On one hand, most teachers indicated that science is a body of existing knowledge students need to acquire. To acquire knowledge, students needed a lot of instruction and drill training. Teaching was regarded as transmitting knowledge and task-centred. Meanwhile, to prepare students well for the final examination (CEE) was the overarching goal of teaching and learning. On the other hand, teachers generally suggested that, for effective learning to take place, students need good habits of mind and interest. Students needed experiments and observations to develop understanding of scientific methods and manipulative skills. Students also need to develop inquiry abilities and good habits of mind which will benefit their future lives.

Teachers differed in their beliefs about what constituted effective teaching. These beliefs, concerning how senior secondary physics should be taught to their students in their schools, were content-dependent and contextualised. The significantly influential contextual factors seemed to be the student assessment system and the nature of their students. Teachers' beliefs about effective teaching reflected their views about what was the most appropriate way to teach in their specific teaching contexts.

6.3 How do Teachers Perceive IBT?

It was found that the case study teachers held diverse understanding of inquiry and posed different methods to implement IBT. Associating their ideas of IBT with teaching practices, teachers articulated a range of factors that influenced their instructional choices regarding the use of IBT. The following sections present the five case study teachers' perceptions of IBT and their instructional decisions regarding the use of IBT.

6.3.1 Perceptions of IBT

Ding

Ding stated that inquiry is a type of learning method which "can foster students' interest very well and allows students to independently complete a section of learning task following their own train of thoughts". She explained that she laid emphasis on "a section of the learning task" because "it is impossible to require students to acquire quite a few concepts in one lesson totally adopting the method of our predecessor".

This given explanation indicated that Ding tended to view student inquiry as independent student activities that replicated the precedents. For her, inquiry was time-consuming and difficult to apply to a whole lesson. She, therefore, proposed an alternative solution for this situation,

> [What we can do is that] we can possibly design one or two points in a lesson, based on students' prior experience and knowledge, giving students a participating process with a certain degree of openness. (Ding-I)

Ding elaborated her ideas of a typical lesson applying inquiry-based teaching (IBT) by giving descriptions and examples. She stated that in this type of lesson, her role as teacher was to choose appropriate content and design the points for student inquiry, decide the theme, plan steps easily carried out by students, and discuss with students when they had difficulties in each step.

She further elaborated that a typical IBT lesson consisted of three sequential components: *"Constructing problem-solving Scenario"*, *"Classroom inquiry"*, *and "Applying knowledge*". Problem-solving Scenarios were generally constructed to formulate a main question for the lesson. These could be a scene from real life, or a question to, or deep thinking of, a problem. In the section of inquiry, students participated in inquiry activities to answer the questions proposed by the teacher. The classroom inquiry could be conducted either in the form of "*Experimental Inquiry*" or in the form "*Speculative Inquiry*" (see Section 5.2.1 for details). With these two forms of inquiry, Ding claimed that the ideas or methods of IBT could be "infiltrated" into any type of classroom teaching, "provided that the teacher held clear teaching objectives". For example, even in exercises lessons, Ding asserted that IBT could be implemented when "examining questions, constructing models, and choosing appropriate problem-solving strategies".

However, Ding emphasised that

> Regarding the basic and extended curricula, IBT should be enacted on the premise that students are able to acquire a correct systematized body of knowledge (Ding-I).

She also maintained that "it is acceptable to use inquiry, but only one conclusion can be drawn from that", because

> Reaching the conclusion is more important in most cases because this law is the one that students have to master. (Ding-I)

Clearly, these opinions of IBT were tightly connected with her beliefs about teaching and learning.

The above descriptions demonstrated that Ding had developed a clear idea of how IBT could be implemented in her classroom. It was worth noting that Ding stated that she developed understandings of inquiry mainly from her experience of teaching. She noted,

> I have been teaching for more than ten years. Maybe I understand this matter [teaching] through my experience, most of the time. (Ding-I)

Min

Min suggested that "inquiry meant students' autonomous learning". He defined that "students are the master of learning". More specifically, he stated,

> Students are able to autonomously discover problems and solve them, this is inquiry… Allowing students to be the master of learning, and therefore in many cases teachers should not take the place of their students. The students should be allowed to complete [learning] on their own in order to experience the process of a scientific inquiry. (Min-I)

The above statement demonstrated that in Min's understanding, the learner in inquiry was an active agent in his own learning process.

Correspondingly, he defined the teacher's role as a "guide". However, he was perplexed with some pedagogical issues of giving guidance to students. He indicated that his very low-proficiency students were the source of his perplexity. He felt that it was very difficult for him to lead his student to design an investigation plan.

> It is very difficult for our students. It is almost impossible [for them to design an investigation plan] if you tell them nothing except a small clue. However, if you give them targeted and detailed suggestions, you almost tell them everything. It is very difficult [for me] to handle this situation. (Min-I)

In addition, Min realised that implementing IBT posed higher requirements for his teaching than using the regular teaching methods, because “unexpected situations in classrooms occurred more often” which “increased the degree of difficulty of teaching”.

Nevertheless, he believed that IBT can benefit students more than traditional teaching approaches in “fostering students’ autonomy, and abilities to solve problems and collaborate with others”. In addition, “teachers benefit from the gained experience as well”. Therefore, he indicated that he would continue to try IBT in his classroom.

In order to implement IBT, he suggested it was necessary for teachers to develop a model of inquiry.

> First, let students identify the problem and pose questions. Then they formulate a hypothesis and design their experiments. They then conduct an investigation and achieve a conclusion. (Min-I)

However, he argued that it is not necessary to complete the whole process of inquiry in one lesson.

> Pick one point and concentrate on this point. Because a lesson is 40 or 45 minutes long, it is impossible to complete the whole process. It will be the focal point of the lesson that requires students to inquire about. There will be a particular emphasis each time. (Min-I)

Pan

Pan classified inquiry activities into two different types. The first kind is to investigate a question that is “feasible to be delved into” for students, for example, to investigate factors affecting the period of a simple pendulum. He suggested that students conduct this kind of inquiry activity “to acquire physics laws through independent investigations and experiments”. He stated,

> The process of inquiry is to define a train of thought, let students guess, or assume, what is relevant to [the investigated objectives], and then allow them to acquire a physics law, or achieve a result, through a series of independent activities. (Pan-I)

Another type is to investigate a question that is "difficult to achieve results", for example, to prove that the resultant of forces complies with the Parallelogram Law. For this type of question, he suggested that students conduct an inquiry in which they "draw on the experience of others through searching for information and then verify it independently". He concluded,

> Inquiry is in the nature of [a process of] independent activities through which students acquire some physics laws or scientific inquiry methods. (Pan-I)

He drew attention to the difference between experience and inquiry.

> Experience is what you feel, while an inquiry is a rational process which has an objective and procedures. (Pan-I)

More specifically, he suggested that,

> An objective for inquiry is a determined topic... The designed processes are the procedures of inquiry. These should include the process of conducting the experiment, the process of sorting data, and the process of analysing and interpreting data to achieve results". (Pan-I)

Therefore, to implement IBT in the classroom, Pan suggested that the teacher should "set up an objective for students' inquiry, and offer them a small amount of help to design a rough process of inquiry". Pan also argued that "the points set for inquiry should suit student situation". Otherwise, the inquiry was "meaningless" and "resulting in classroom chaos". Pan achieved this understanding from his unsuccessful experience of implementing IBT.

In addition, Pan asserted that "the key to IBT was to guide students to find relationships" between the observed phenomena and the question they were investigating. He advocated that a teacher should "teach students to observe phenomena" before requiring them to investigate the question. Students should "observe the phenomena and investigate them and then find out their essential relationships".

However, regarding the provision of guidance for student inquiry, Pan demonstrated some misconceptions. He gave an example that a teacher used demonstration to show students several possible relationships (students did not pose these possible relationships) and then asked the students to design their own experiments to verify them. He then commented that the students' inquiry activities in this example were "only replicating what the teacher did". He argued,

> If there is nothing done by the teacher before students investigate, it is inquiry. (Pan-I)

In seemed that in Pan's understanding, IBT should be a process through which students independently accomplish their investigations with little help from the teacher. If a teacher facilitated too much, students might not do a real inquiry.

Meanwhile, Pan asserted that inquiry set "high requirements" for students.

> The process of inquiry requires students to have, first, a good sense of discipline; second, a good learning habit, and third, certain basic abilities to inquire. (Pan-I)

Furthermore, Pan stressed that IBT advocated a new approach to learning, which was different from the way students were taught in their prior schooling, inevitably causing problems: "They would not make progress, and thus feel completely in the dark".

Therefore, for his students who "had low proficiency in learning, and problems in learning habits and sense of discipline", he perceived that "it was very difficult" for them to conduct a successful inquiry, particularly when they had not been trained to do inquiry in their prior schooling.

Wen

Wen's description of IBT was close to the definition of inquiry in educational books, although she reported that she did not fully understand it. She described IBT as "a process that engages students to find questions, do research, solve problems and apply conclusions".

In her understanding, the crucial thing in implementing IBT was to allow students to "experience the process from phenomena, questions, and guesses, to verification". Therefore, she suggested that teachers should pay attention to "questioning and guidance" when designing IBT in order to achieve a good result. As she stated,

> Teachers' questioning and guidance are important [in student inquiry]. Giving them more guidance and clues in the key sections, and allow them to experience a process from the phenomenon, questions, and guess to verification… If they experienced such a process, even if the time for inquiry is very short, it (IBT) is effective. (Wen-I)

Regarding implementing IBT, she suggested that "it was not necessary to experience a complete process of inquiry in one lesson". She stated,

> It is difficult to conduct a full inquiry in one lesson. One reason is that the time is limited. Another is that students differed in their abilities after all. Some students did not have this kind of ability. Therefore, considering the situation of the majority of the students, it is reasonable to choose to do one part, or one

> section, of inquiry. (Wen-I)

Furthermore, she argued that "it was not practical to employ an open inquiry" in classroom teaching. This perception was based on several considerations. First, Wen considered that "a match between IBT and students' levels of thinking and abilities is essential". Although the students' learning ability seemed not to be of a great concern to her, she felt that her students were not competent enough to conduct inquiry independently. Second, she pointed out that teaching time was limited and students were very busy with study. An open inquiry needed more time in class than other approaches to inquiry. It also posed a requirement for more of the students' time after class, while these students were "too busy to do their own research after class". Therefore, she determined that "it was not suitable for the current teaching schedule". And particularly, Wen considered that,

> The final purpose of an open method is to let students to experience the process. If students can experience the process under the teacher's guidance in the lesson, the purpose is achieved. (Wen-I)

It seemed that Wen's understanding of IBT was somewhat incomplete. As discussed earlier, the approach to inquiry that the teachers employed depended largely on the intended teaching objectives they set for their students. But on the other hand, scientific inquiry should be designed and implemented with increasing complexity to meet students' needs at different stages. Therefore, Llewellyn (2011) suggested that science teachers should take into account their students' prior experience of inquiry and their differences in inquiry abilities to decide when and how to introduce different inquiry-based opportunities to their courses. But Wen seemed not to have achieved this understanding.

Zhao

Zhao described inquiry as "a process of testing hypotheses", including "formulating hypotheses", "reasoning", "predicting phenomena and results", and "testing them".

However, he seemed to be somewhat confused by the difference between classroom inquiry and scientists' inquiry. For example, he suggested that some experiments were too complicated to be designed for IBT, because the students had to consider and continuously exclude many affecting factors, and then formulate idealised hypotheses, to be able to achieve some conclusions. Therefore, he argued that these experiments designed for inquiry activities could exhaust his teaching time.

Zhao asserted that "inquiry-based teaching (IBT) could be any classroom activity as long as it fosters students' thinking". For example, he asserted that observing or knowing the process of others' inquiry activity should be considered as a kind of inquiry activity. Such a belief originated from his prior experience as a university student when he achieved understanding through his teacher's description of experiments.

This prior experience brought him to the conclusion that students could understand knowledge through knowing the process of teachers' inquiry activities. He thus decided that by listening to stories of others' inquiry his students could also experience inquiry. He claimed that the stories he told – "how scientists do inquiry, how we inquire today, and what problems can possibly emerge during inquiry" – could engage the students in inquiry. He believed that he was actively implementing IBT using this approach.

Although Zhao asserted that IBT could be any classroom activity, he did not see that the student experiments in the textbook were appropriate for conducting IBT. He argued that "the experiments in the textbook are designed to verify conclusions, and the students will only know the processes and results."

Meanwhile, Zhao suggested that IBT may be more useful than traditional approaches to help students better understand the processes and methods of constructing physics laws and concepts. Furthermore, IBT would "have positive influences on students' future lives". He believed this meant a lot to the public.

However, Zhao indicated that IBT was not as effective and efficient as the traditional way of teaching. This perception was consistent with his beliefs about the nature of science, teaching, and learning. To him, an effective and efficient teaching approach should "require lower input but produce better outcome", which seemed to mean that his students were able to acquire more knowledge and achieve higher test scores in exams.

To Zhao, IBT was obviously not such an effective approach to achieving this end. He indicated that IBT was time-consuming, and thus it was not practical to implement IBT in his regular teaching, as "teaching tasks were difficult to complete if using IBT in a whole lesson". Furthermore, "the existing school assessment criteria do not assess student understanding of process and methods", and thus the teachers using IBT "may be misunderstood", because "their students' scores may be not high enough".

It is clear that Zhao interpreted IBT to be consistent with his teaching beliefs and in his teaching context. It was noteworthy that he pointed out that his life experiences had significant influences on his perceptions of IBT. These antecedent events formed an important resource of beliefs, and affected his interpretation of IBT. He himself realized that he tended to teach using the methods through which he was taught.

6.3.2 Instructional decisions regarding IBT

Ding

Ding claimed that IBT was a good approach to teaching. She asserted that IBT facilitated students to "understand the process and methods" and also "develop emotion, attitude and values", which she described as students' long-term interests. The most important benefit of IBT was helping students understand the processes and methods, which she considered was most influential on students' future lives. She explained,

> In inquiry, they [the students] apply, reflect upon, and understand the processes and methods... With these processes and methods integrated in their minds, students tend to be more flexible in the perspectives with which they think about problems. (Ding-I)

On the other hand, Ding identified several constraints for implementing IBT. The main consideration she articulated was the inconsistency between IBT and the assessment system. She pointed out that nowadays teaching and learning were confronted with an assessment system which "used written tests as a main tool", while "in written tests students relied more on their experience in drills training to solve questions". Therefore, she stated that, in this situation, it was difficult for teachers to strike a balance between teaching for students' immediate interests (improving test scores) and teaching for long-term interests (developing understanding of the processes and methods). In short, Ding considered there were risks associated with implementing IBT because "IBT was not in step with tests".

Other contextual constraints Ding pointed out for her implementation of IBT included her concerns about her students, the class size, and the experiment resources and conditions. For example, considering her students, she felt that her students did not have good learning habits and held somewhat utilitarian attitudes towards learning, and these caused difficulties in her implementation of IBT.

Nevertheless, Ding was enthusiastic about implementing IBT in her classroom. She figured out that IBT can be conducted in a section of a lesson and can be "infiltrated" into any types of lessons if teachers could use *Experimental Inquiry* or *Speculative Inquiry* according to different situations.

Meanwhile, Ding did not condemn of the value of the traditional methods of teaching. She indicated that the traditional methods of teaching may be more practicable and effective in helping students "acquire knowledge and skills" and "improving students' test scores".

Therefore, Ding suggested that she would like to use conduct inquiry in one section of her regular teaching.

> [What we can do is that] we can possibly design one or two points in a lesson, based on students' prior experience and knowledge, giving students a participating process with a certain degree of openness. (Ding-I)

However, she argued that IBT "should be enacted on the premise that students are able to acquire a correct systematized body of knowledge", because "reaching the conclusion is more important in most cases because the [physic] law is the one that students have to master".

Min

Min articulated that his teaching was greatly affected by the school environment, his colleagues, and the classroom climate. He reported that in his school, the purpose of education was preparing students for examinations. Physics was not ascribed much value by the school administrators due to considerations of the tertiary enrolment rates. Teaching hours were very limited. Few public classes were organised. Science teachers gave little attention to student experiments. Students were not interested in learning physics and generally did not have appropriate learning objectives. Min perceived a great amount of difficulty to sustainably implement IBT in this teaching context.

In addition, Min was particularly concerned about the nature of his students. He said,

> These students' proficiency levels are unimaginably [low]. Therefore, it is really difficult to give them a high level of IBT. In fact, we can only take it slowly if we want to realise our ideas in the classroom... And it is impossible to be completely consistent with our beliefs. We really cannot make it. I have a lot of ideas, and I really want to teach following my own ideas… However, the situation is really tough and I can't continue. (Min-I)

Therefore, Min decided that his teaching was conventional teaching, which gave his main attention to developing students' learning habits.

But he indicated that giving up IBT was not necessary for these students. For his students, he claimed that it was not appropriate to implement IBT in every single lesson. However, the elements of inquiry could be incorporated into teaching when starting a new topic, using a partial approach to inquiry. As he stated,

> I certainly will [implementing IBT in my classroom]. There is a lot of content suitable, but it is not necessary to complete the whole process of inquiry in one lesson. Pick one point and concentrate on this point. Because a lesson is 40 or 45 minutes long, it is impossible to complete the whole process. It will be the focal point of the lesson that requires students to inquire about. There will be a particular emphasis each time. (Min-I)

Min indicated that he would make efforts to try IBT when there was content he felt able to "develop students' interests or some aspects of abilities, or qualities". However, he admitted that he had to give up his plan sometimes because he found "it did not work". He attributed this to his "lack of experience in conducting IBT". In addition, sometimes he had to change his plan under outside pressure. He said, "I have to change my ideas because I have no choice but to be compared [with other teachers] by test scores".

Nevertheless, Min stated that he would persist in trying IBT because he believed that IBT was a good teaching approach that "fosters students' autonomy and abilities to solve problems and collaborate with others".

Pan

Pan indicated that he was not interested in implementing IBT in his classrooms. His beliefs about teaching and learning, his perceptions of inquiry, and the nature of his students and the assessment system, exerted intertwined influences on his instructional decisions regarding the use of IBT.

Pan perceived that teaching was spoon feeding, and his students were passive learners with "low proficiency in learning and problems in learning habits and sense of discipline". He reckoned that these students needed to take detailed notes about the basic steps and repeatedly practice them, otherwise "they would have nothing left in their minds after class".

Pan alluded this was the effective way to teach his students. Regarding his instructional decisions, he argued, "The best way to teach was the one most suitable for your student situations".

Regarding the prospect of implementing IBT in classrooms, he suggested it was difficult for his students to conduct a successful inquiry, because doing inquiry set "high requirements" for his students, and his students "had not been trained to do so" in their prior schooling. He further expressed his unwillingness to implement IBT as he found that his prior experience in implementing IBT with his students was always "ineffective".

In addition, Pan stated that he felt under pressure in the current CEE system as it was impossible for him to ignore students' test scores. He pointed out that the CEE does not, and is not able to, assess students' abilities to inquire. He was, therefore, concerned about the students' academic performance in the CEE if they spent much time on inquiry.

Nevertheless, Pan claimed that he would conduct IBT when "the content of teaching was easy to organise considering the student situation". In addition, he argued,

> I can guarantee I can teach using this approach, but not every lesson is appropriate for this approach. I mean it. However, if you come to check up on work, I will show you this type of lesson. I can do it. I am not incapable of doing this. Instead, I can do it well or acceptably at least. (Pan-I)

It seemed that Pan also treated IBT as something to demonstrate the teacher's "ability to teach", and this teaching method would possibly be employed when outsiders came to observe his teaching.

Wen

Wen held positive attitudes towards implementing IBT and indicated that she would use IBT as much as possible when she became a regular teacher. This consistency between her understanding of inquiry and her beliefs about teaching and learning, positively affected her intention of, and attitudes towards, implementing IBT.

Wen articulated that the limited teaching time and students' abilities and their differences in abilities were two main constraints to her intentions to use IBT regularly in her practice. She also figured out that it was not always feasible to carry out IBT, because "some inquiry required various equipment or were too troublesome to be conducted".

Wen stated that she preferred to use "a stratified, progressive, and heuristic method of teaching" as a regular teaching approach in the future. Nevertheless, she claimed that she would surely employ IBT in her teaching when she became a regular teacher. She stated,

> I will implement IBT as much as I can, but not as much as in a "public class"... It is not like an open inquiry, but [an inquiry] under guidance. (Wen-I)

She suggested that a partial, guided inquiry was an appropriate approach to be included in her teaching model. She suggested that "a match between IBT and students' levels of thinking and abilities is essential". Although the students' learning ability seemed not to be of a great concern to her, she felt that her students were not competent enough to independently conduct inquiry.

Zhao

Although Zhao claimed that inquiry may be more useful than traditional approaches to help students better understand the processes and methods of constructing physics laws and concepts, he was not interested in trying more IBT in his classroom. He posed several reasons to explain his decisions.

First, although he claimed that IBT would benefit students' learning, he identified that IBT was not as effective and efficient as the traditional way to impart knowledge to students. Particularly, he was suspicious of the applicability of the "imported" theories to the Chinese context. He explained that "the current teaching context of China laid particular emphasis on a high level of academic training", therefore "the 'school factories' only want to manufacture one kind of standard product – student with high test scores". Therefore, he was skeptical of the efficiency of IBT for acquiring high test scores in this situation.

Zhao was also concerned about the influences of the conflicts between IBT and the CEE, because he found that "the teaching effects [of IBT] may be misunderstood" because "the students' scores may not be high enough".

Second, Zhao suggested that implementing IBT required a lot of input. It not only took the teacher a large amount of energy and time, but also involved "knowledge and techniques" and thus a design of lesson plan using IBT may be complicated.

He further pointed out that "unlike the unidirectional instruction in the lecture-mode of teaching, IBT required face-to-face interaction between teachers and students". He articulated that his unwillingness to cooperate with students was the greatest obstacle to his intention to implement IBT, and this unwillingness was related to his mood, and how he felt about the students in teaching. For his students, he felt that his teaching was sometimes ineffectual. This situation disappointed him and in turn negatively affected the relationship between him and his students. As he stated, "Their behaviours disappointed me… At the end of the day I just finish the teaching and don't want to give them a second glance".

Finally, Zhao held a very pessimistic view of the larger social context in which Chinese teachers were teaching. He asserted that it was impossible to use IBT to cultivate students' creativity or independence in the current social situation. He attributed students' passivity and lack of creativity to the consequence of school high-level academic training, which was seen by him as an endemic of this country, and teachers could only passively react to it. He stated,

> What we are doing is trying something new in a very limited space. These… are not fundamental solutions. (Zhao-I)

> I think, in our country, it is almost impossible to use IBT to foster students' "sense of creativity", or independent ideas. I could not see there is a time point when things can change. We cannot make it. It is fundamentally the problem of the country's system. (Zhao-I)

Consequently, Zhao was not passionate about using more IBT in his classroom. He stated that he was in favour of transmissive teaching because of its effectiveness and efficiency.

However, Zhao indicated that he hoped to give consideration to both developing students' inquiry abilities and improving test scores. Therefore, he decided to use a compromise method to incorporate IBT into his teaching practice: offering his students a vicarious experience of inquiry by telling them scientist' stories of inquiry or observing the process of others' inquiry. In his notion, students could experience inquiry through knowing the process of others' inquiry without direct participation. He believed that he had been actively implementing IBT using this approach.

6.4 How do Teachers Implement IBT in their specific teaching contexts?

In order to reveal how teachers implemented IBT in their specific teaching contexts, this study closely examined the nuances of inquiry practice in five case study teachers' classrooms. This included teachers' instructional models of implementing IBT, the processes of classroom inquiry, their approaches to inquiry, and the strategies they employed to manage and guide student inquiry. The case studies reveal that the real classroom situations in teachers' implementation of IBT were very complicated. The teachers implemented diverse inquiry practice in their unique teaching contexts. At the same time, their inquiry practices shared some common characteristics. The following sections present the main findings from classroom observations.

As discussed previously in the methodology chapter, the analyses of teachers' inquiry practice started with identifying the teachers' instructional models of implementing IBT. By drawing the pedagogical components and sequences of them, together with a built-in schema representing the inquiry process, each teacher's instructional model was able to be depicted. The basic pedagogical components were extracted from an initial examination of all the five teachers' instructional practice according to their main pedagogical functions. Then the analysis further examined the strategies teachers used to guide and manage student inquiry. Particular attention was given to teachers' questioning strategies.

The following sections first describe each teacher's inquiry practice in the observed lesson, followed by the distinguished basic pedagogical components, and then present teachers' instructional models of implementing IBT in their specific contexts, their approaches to classroom inquiry, and the strategies they used to guide and manage student inquiry.

6.4.1 Instructional practices

Ding (The Parallelogram Law of Forces)

This observed lesson in which Ding implemented IBT was to teach the Parallelogram Law of forces. The main objectives of this lesson were to introduce the concept of resultant force, and to guide students to find the law of calculating the resultant force (the Parallelogram Law).

The textbook encouraged students to acquire this knowledge from inquiry. It introduced an inquiry activity that students could follow to investigate the relationship between the resultant force and its two component forces. But the physics teachers generally did not use this inquiry activity. The traditional[9] way of teaching this topic was organising a verifying student experiment in a follow-up lesson after the Parallelogram Law had been taught. Ding did not adopt this inquiry activity too. However, she designed a different approach to student inquiry.

This lesson was conducted in a classroom. Ding started her lesson in a traditional way: reviewing old knowledge by doing exercises. She then created a problem-solving scenario using an analogy and linking this with students' life experience. This scenario was used to introduce the concept of resultant force, leading to the question for student inquiry.

After giving the definition, Ding guided students to go through the process of science inquiry. She required students to make a guess how to calculate the resultant force and questioned their explanations. She asked them how to test this idea using the materials she provided, and how to collect and record data. Based on students' answers, she involved students in an ongoing process of designing experiments. At the same time she conducted the designed experimental procedures to collect data, had students analyse and calculate data, demonstrated their work, and required them to further develop the methods of recording and analysing data. This is an iterative process occurring

[9] In the laboratory, the students were assigned very specific tasks and instructed in the detailed experimental procedures and requirements. Students followed these instructions to collect required data and analyse them.

between designing experiments and collecting/analysing data. In this process, Ding purposefully stopped at some points to remind the class of the necessary knowledge, for example, how to use the spring scale and how to graphically represent a force. This process ended when all data were collected and graphs were drawn, students were then required to interpret graphs.

This lesson did not end in a conclusion due to the time limit. Ding finished this lesson by a simple explanation and reminding the students of the experimental errors. The application part had to be arranged as a form of students' homework.

Ding used demonstrations to facilitate her teaching in this lesson. For the topic of "The Resultant of Forces", the textbook provided examples and pictures, but no sample demonstration, to show that two forces can be replaced by one force that has the same effect. Ding created her own demonstration and used it to verify that the resultant of forces can be calculated using the Parallelogram Law. The apparatus Ms Ding used seemed to do a good job for her.

After class, the researcher asked Ding why she decided to use such a demonstration, instead of the examples and pictures in textbook. Ms Ding explained, "I can use it to give my students a direct and fresh impression".

Ding' effort to do so was admirable because the Parallelogram Law is abstract and difficult for students to understand. It is helpful to give students chances to observe, touch, and feel real apparatus, rather than simply observe pictures and examples, to learn such an abstract concept. It is apparent that Ding's effort had an effect because her students were interested in the demonstration and followed her questions to think. Her students also commented after class that they liked the demonstration and performing demonstration was better than direct lectures.

Min (The Parallelogram Law of Forces)

Min also implemented IBT to teach the Parallelogram Law of forces. He adopted the student inquiry activity in the textbook to implement IBT in this lesson. Instead of taking students to the laboratory, he brought apparatus into the classroom and let students do inquiry in the classroom. In addition, he used PowerPoint slides and the multimedia classroom teaching system to facilitate his teaching.

At the beginning of the lesson, Min grouped the students into small groups and required each student to take a responsibility. He started the lesson with a quick review of prior knowledge of the effect of a force. He then constructed a problem-solving scenario by representing examples (pictures shown on a big screen) and linking these with students' life experience. The scenario was used to introduce the concept of the resultant force, leading to the main question for investigation.

Min led the students to formulate an initial hypothesis that the resultant of forces is not a simple arithmetic addition, and required them to design a small experiment to test it. However the class was inactive. Min then demonstrated how to test this hypothesis. Min concluded his demonstration and continued leading the students to think about the main question again. Instead of asking students to make a further hypothesis, he suggested they find the relationship through experiments with the materials he provided.

Finding that the students could not accomplish this task appropriately, Min divided the task into several small iterative tasks. A loop between formulating hypothesis, designing the experiment and collecting/analysing data occurred. In accomplishing these small tasks, Min found that the students still did not actively respond to his questions, and manipulated badly in the experiment. He then demonstrated the procedures of doing the experiment, analysing data and drawing graphs, and required the students to do so. Min walked around to check all groups and sometimes gave very specific instructions. However, some students still could not successfully accomplish it.

Min did not require students to communicate their results and draw a conclusion. At the last section of this lesson, most students stopped working and the classroom became noisy. Min summarised and gave the conclusion at the last minute of this lesson.

This lesson had a bad ending. After the class, the researcher asked Min how he felt. Min said that he was unwilling to assign any more tasks to his students at the last section of this lesson, because he found that they had not done a good job. It was originally planned that Min would do a demonstration when the students finished their work, and compare his explanation with students'. However, he decided to give it up as he felt frustrated.

Pan (The free fall motion)

This observed lesson in which Pan implemented IBT was to teach the free fall motion. The main objectives of this lesson were to guide students to investigate the factors affecting the rate of fall, and to determine the nature of free fall motion. The textbook encouraged the teacher to use IBT to teach this topic and provided a learning package which specified the procedures of student inquiry. According to the textbook, these procedures would be accomplished in three lessons.

Pan did not use the learning package, but generated his teaching plan based on the textbook. This lesson mainly consisted of two sequential student inquiries: the first is aimed to find out the factors affecting the rate of fall, and the second used to determine the nature of the free fall motion and measure the magnitude of the acceleration of gravity.

This lesson was conducted in a DIS (Digital Information System) laboratory. Pan used the DIS experiment system, multimedia resources, including videos, animations, and PowerPoint slides, together with the laboratory multimedia teaching system, to facilitate his teaching. The multi-media resources were sought by him from the internet, making a good supplement to his demonstration and experiments. In addition, the DIS experiment system made the process of collecting and analysing data easier than the traditional experiment, and saved much time. Students were also able to generate more satisfying data and spend more time on thinking about the data and generating their explanations.

Pan started this lesson by creating a problem-solving scenario using demonstration, examples, stories and video. This scenario led to the first question for student inquiry. Pan broke this question down into two sub-questions, and then required the students to design experiments to answer these two sub-questions using the provided materials.

The students worked in groups to answer these two questions. Pan worked around to check the progress. However, in many groups the students did not attain appropriate solutions. And many students did not actively participate in discussions and work collaboratively. One group of students was called to demonstrate their experiments and required to explain. Pan drew a conclusion based on student work. He further verified this conclusion using a video of the Newton Tube Experiment.

After defining the free fall motion, Pan posed the second question for the student inquiry. Using questions, he guided the students to formulate a hypothesis that the free fall motion is a uniformly variable motion. The following process of inquiry was very structured. Pan first led students to review prior knowledge of using a *v-t* graph to determine a uniformly variable motion. He then introduced the DIS equipment and demonstrated the whole procedures of collecting, analysing, and interpreting data. Pan introduced the acceleration of gravity. The students were then required to do the DIS experiment to measure the magnitude of the acceleration of gravity. They were busily engaged in experiments, but not all groups obtained results by the end of the lesson. One group of students was chosen to report their results when the bell rang.

Pan drew a brief conclusion and continued to teach. He derived three related formulae on the blackboard and told the students to use it in homework. The lesson was finished by assigning student homework.

After the lesson, Pan showed his frustration. He commented that his implementation of IBT was unsuccessful and ineffective because he found that the classroom was in chaos and his students were "lost" in inquiry. He reflected and concluded,

> … In inquiry-based teaching, the crucial point is that inquiry should fit the students' situation. If it does not fit the students' situation, it is meaningless. This lesson is meaningless. Furthermore, the inquiry [activity] caused classroom disorder. I have to use several lessons to rebuild my classroom routine. (Pan-C)

Although he mentioned that his "designs of IBT were always unfit for students' actual situation", he mainly attributed these consequences to his students' low abilities rather than his lack of pedagogical knowledge of inquiry. As he argued,

> If they are more capable of thinking, they will know what to do next when I direct them here. But most of them are not able to follow my train of thought. They can only tamper with the equipment. (Pan-C)

Wen (The free fall motion)

Wen also implemented IBT to teach the free fall motion.

Wen showed a great passion for teaching in teaching practicum. In order to prepare a good lesson, she spent much time on planning. Wen did not use the learning package in the textbook. Instead, she gathered information from a wide range of sources, including: observing other teachers' lessons, observing another student teachers' lessons, searching for online resources (sample lesson plans and videos of lessons), and looking for suggestions from her mentor and the researcher. She then synthesised the information to form her draft teaching plan. Then she had modified it several times after discussions with her mentors before formally used it in her classes. In addition, she reflected on her teaching for improvement after each lesson. She also asked her mentor and the researcher for suggestions. She then adjusted her teaching plan and applied it to another class.

This lesson was conducted in a classroom. Wen used one set of DIS experiment apparatus, PowerPoint slides, and the multi-media classroom teaching system to facilitate her teaching. This lesson mainly consisted of three sequential student inquiries: the first aimed to find out the factors affecting the rate of fall, and the second and third used to determine the nature of the free fall motion and measure the magnitude of the acceleration of gravity.

Wen started this lesson by creating a problem-solving scenario using several demonstrations and examples, leading to the first question for student inquiry. Engaging the students in a discussion with her, Wen then demonstrated and modelled the process of inquiry from phenomena, hypotheses, experiments, to conclusions.

After defining the free fall motion, Wen posed the second question for student inquiry. Next, she guided the students to formulate a hypothesis, and develop methods to collect data using DIS and methods to interpret data. Wen demonstrated the DIS experiment and required students to interpret data. Wen supported the students' conclusion and reinforced the necessity of collecting more groups of data.

Wen reminded the students that there were alternative methods to test their hypothesis. She then introduced a method using second-hand data (stroboscopic pictures). She asked the class to look at a stroboscopic picture of a falling ball in the textbook, and required them to find ways to verify their hypothesis using this picture and calculate the value of acceleration.

Students worked hard and put forward several solutions. Wen engaged the students in discussions on their solutions, but did not respond actively until they finally achieved the expected answer. She then elaborated the procedures of verifying and calculating and required the class to recalculate the value of acceleration.

Later, Wen drew a conclusion and provided the method for reducing error. She further gave the value of the acceleration and defined the concept of acceleration of gravity. She then guided students to derive the related formulae of the free fall motion.

At the end of this lesson, Wen led the class to review the inquiry process in which they participated to arrive at conclusions. She reminded the class, "This method is indeed a scientific research method, although it is relatively simple. In real science it is impossible to achieve a conclusion by only one experiment. It needs numerous trials and experiments."

Wen finished this lesson with a story of scientists and a small student hands-on activity. She also posed questions for students' discussion after class.

Zhao (Factors affecting the magnitude of induced emf *)

Zhao did not implement IBT in his Grade 10 classes. He used the traditional approach of teaching in his classrooms, and arranged student experiments to verify the knowledge. In the experiment lesson, the students were provided with specific experimental procedures to collect data and analyse them, leaving no chances for designing their own experiments to test their ideas.

However, Zhao gave the researcher a copy of a videotaped lesson in his Grade 12 class to show how he implemented IBT. This lesson was videotaped for a teaching competition. Because of this, it was very different from what he did in his regular teaching. Nevertheless, his inquiry practice in this videotaped was worth analysing since it reflected his understanding of inquiry and his pedagogy in implementing IBT. The following section describes his inquiry practice in this videotaped lesson.

This lesson was conducted in a laboratory. Zhao used one set of DIS experimental apparatus and the multi-media classroom teaching system to facilitate his teaching. The main objectives of this lesson were to guide students to investigate the factors affecting the magnitude of induced emf, and to introduce Faraday’s Law of Electromagnetic Induction. This lesson consisted of two main activities: a small student hands-on activity to find out the factors affecting the magnitude of induced emf, and an inquiry activity to determine their relationships.

Zhao started his lesson by creating a problem-solving scenario using a small demonstration. He then proposed the investigated question: “What are the factors affecting the magnitude of induced emf?” Students were then required to find out the factors by using the materials provided.

This small hands-on activity engaged students in a process of linking observed phenomena with prior knowledge, and proposing further explanations. Zhao used questions to challenge students about what should be observed, and required them to explain their findings. This hands-on activity, together with Zhao’s questions, successfully led the students to reach a conclusion that the rate of change of magnetic flux affects the magnitude of induced emf.

Zhao then led a teacher-students conversation to discuss the relationship between the rate of change of magnetic flux and the magnitude of induced emf. He guided the students to formulate a hypothesis that the magnitude of induced emf was directly proportional to the rate of change of magnetic flux.

Zhao introduced the experiment apparatus and the software to be used for the experiment to test the hypothesis. He then engaged his students in an iterative process between designing the experiment (developing the methods to collect data, generate graphs, analyse data, and interpret graphs), collecting data, analysing data and interpreting graphs. However, in this process, the students were not provided with experiment apparatus to conduct the DIS experiment. Zhao performed the DIS experiment and collected data for students. Finally, a student was chosen to report their results calculated using the provided data.

Zhao interpreted the students' results and drew the conclusion. He then finished this lesson by defining the mathematical formulation of Faraday's law of electromagnetic induction and posing a question for student discussions after class.

This lesson showed that Zhao was able to implement IBT in his classrooms. However, he lacked enough motivation to implement more IBT in his regular teaching practice.

6.4.2 The instructional models of implementing IBT

The initial examination of these five teachers' inquiry practice distinguished several basic pedagogical components according to their main pedagogical functions. These include:

a. Reviewing knowledge (R)

This component is generally used to review the relevant prior knowledge that has been learned recently. Often, teachers use questioning and exercise to achieve this objective. This component provides an opportunity for teachers to assess students' prior knowledge and help students attack misconceptions. This phase is consistent with teachers' regular teaching models, on which teachers may spend much time. For example, Ding spent considerable time on reviewing prior knowledge by assigning student exercises and correcting their mistakes on the blackboard.

b. Building a problem-solving scenario (S)

The main function of this component is to create a problem-solving scenario that leads to the new topics and the essential question for inquiry. Teachers may use a variety of methods to create this scenario, such as demonstration and discrepant events, student activities, life experience, history of physics, and so forth. For example, to build a problem-solving scenario, Min used examples and linked them to students' life experience; Wen used demonstrations and examples; and Pan employed demonstrations, stories, and videos. The problem-solving scenario arouses students' interest, curiosity, questions, and also sets the stage for inquiring about a particular phenomenon.

c. Preparing necessary knowledge for inquiry (P)

In this section, teachers prepare students with the necessary knowledge for inquiry. It is different from the phase of *Review knowledge*, in that this section has a more specific function of serving and maintaining the student inquiry. The necessary knowledge for inquiry includes both "conceptual knowledge and procedural knowledge" (Millar, Lubben, Got, & Duggan, 1994) needed for conducting investigation. It could be prior knowledge that students need to recall, or new knowledge that they need to acquire before continuing the inquiry. Therefore, the *P* phase can occur before and at any time during the process of inquiry whenever the teacher feels it is necessary to do so. For example, Pan lectured the concept of free fall motion before student inquiry. During the inquiry, he introduced the DIS system and provided procedural knowledge of manipulating it before the student experiments. He also guided the students to review the prior knowledge of using a *v*-*t* graph to determine the nature of a uniformly variable motion.

d. Constructing knowledge through classroom inquiry (I)

This phase is the main component of teachers' IBT. In this phase, teachers engage students with questions, and guide them to go through the process of inquiry: identifying questions, making predictions and/or formulating hypothesis, designing experiments, conducting experiments, analysing and interpreting data, generating explanations, and communicating results. Students take more responsibility for their own learning in this phase. Teachers guide and evaluate student learning in the whole process.

It is the most complex phase of the whole lesson because how teachers structure and manage the essential elements of inquiry varied significantly. The loops between different elements occurring in the process of inquiry contributed to its complexity.

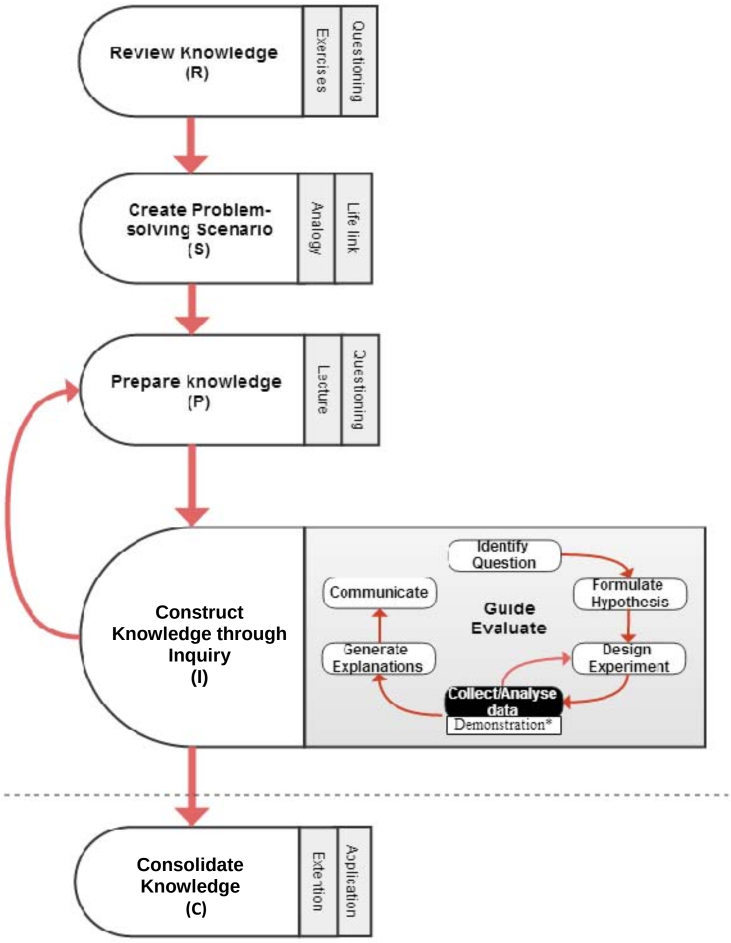
e. Consolidating knowledge (C)

This pedagogical component is scheduled at the end of the lesson. Teachers generally organise two different types of activities in this phase. One is helping students synthesise what they have learned in this lesson, and link this to their prior knowledge. Another is students' applying knowledge to new situations and extending understanding. For example, Wen led students to review the whole process of inquiry and engaged the students in hands-on activities in which students applied the new knowledge to new situations. Pan gave a lecture on deriving formula, which was then assigned to be used in the students' homework.

In all, these five basic pedagogical components and their sequences consist of the frame of a lesson in which teachers implemented IBT. Each phase has a specific function and contributes to the teacher's coherent instruction.

By depicting the components and their sequences in each teacher's inquiry practice, together with a build-in schema describing the process of classroom inquiry, the following diagrams (see Fig.6-1-Fig.6-5) respectively represent each case study teacher's instructional model [10] of implementing IBT. Explanations with respect to each component are also given in the figures.

Figure 6-1 Ding's instructional model of implementing IBT (based on the lesson observed)



Ding spent much time on helping students *review prior knowledge* by assigning exercises and correcting their mistakes on the blackboard.

Ding created a *problem-solving scenario* using analogy and students' life experience, she then introduced the new topic, posed the question for investigation.

The *Knowledge preparation* sections occurred both before and during the process of classroom inquiry when Ding found that her students needed some particular knowledge to keep going.

In the section of *classroom inquiry* (See the built-in schema), Ding led students to go through the process of inquiry. She, however, did not include student experiments in this lesson. Instead, she conducted the designed experiments and the students analysed data. (Student experiments were organised as traditional experiments in a follow-up laboratory lesson.) Iterations between stages of *design experiment* and *collect/analyse data* repeatedly occurred during the process of classroom inquiry.

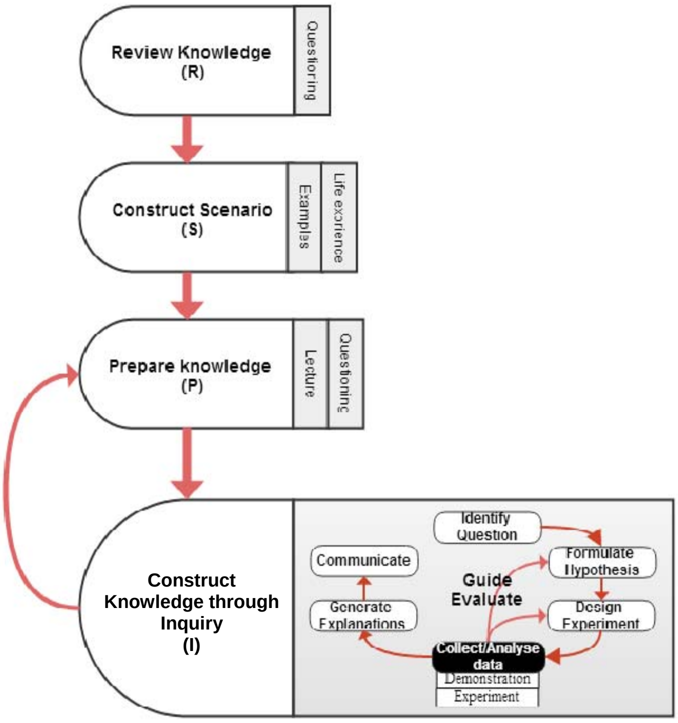
A component of *Application of knowledge* took a form of assigned homework that students accomplished after class.

The arrows show the sequence of classroom activities that were observed.
The dotted line separates this lesson from after-class activities.

* Demonstration: The student experiments are scheduled in a follow-up laboratory lesson. The purpose of a laboratory lesson is generally set to verify the physic law taught in the previous lesson conducted in a classroom. This is a typical way, and the traditional way, to organise student experiments in the Chinese secondary schools.

[10] Because Zhao did not implement IBT in his Grade 10 classes, his instructional model of implementing IBT was generated using the videotaped lesson conducted in a Grade 12 class.

Figure 6-2 Min's instructional model of implementing IBT (based on the lesson observed)



Min gave a short *review of prior knowledge* by asking related questions.

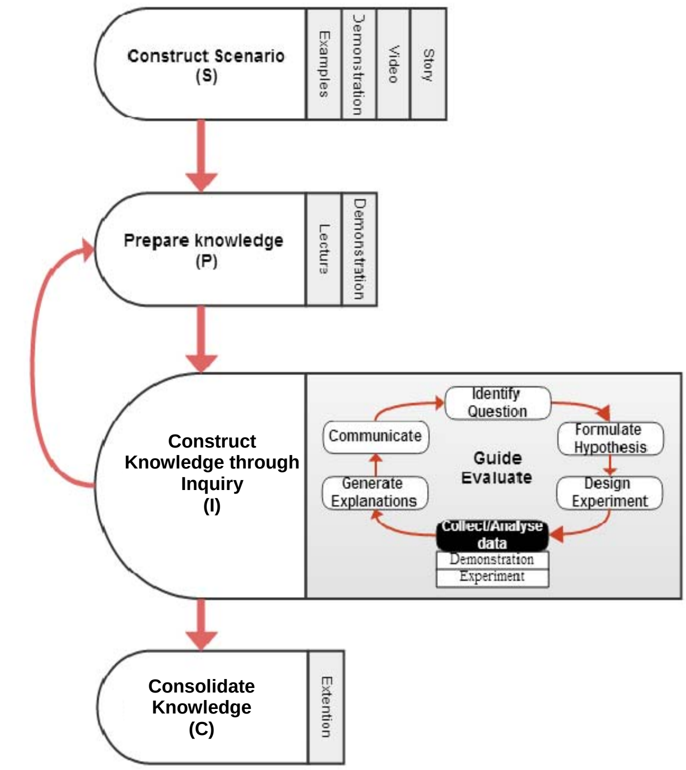
Min used examples and students' life experience to *create a problem-solving scenario* leading to the main question for investigation.

The *Knowledge preparation* section occurred both before and during the process of classroom inquiry when Min found that the students needed some particular knowledge to keep going.

In the section of *classroom inquiry*, Min. initiated a guided inquiry and later adapted it to a structured inquiry. He guided students to form hypotheses and used demonstration and student experiments to test them. Iterations between stages of *formulate hypothesis*, *design experiment* and *collect/analyse data* occurred during the process of classroom inquiry.

The arrows show the sequence of classroom activities that were observed.

Figure 6-3 Pan's instructional model of implementing IBT (based on the lesson observed)



Pan *created a problem-solving scenario* by using demonstration, examples, stories and video. This scenario led to the questions for student inquiry.

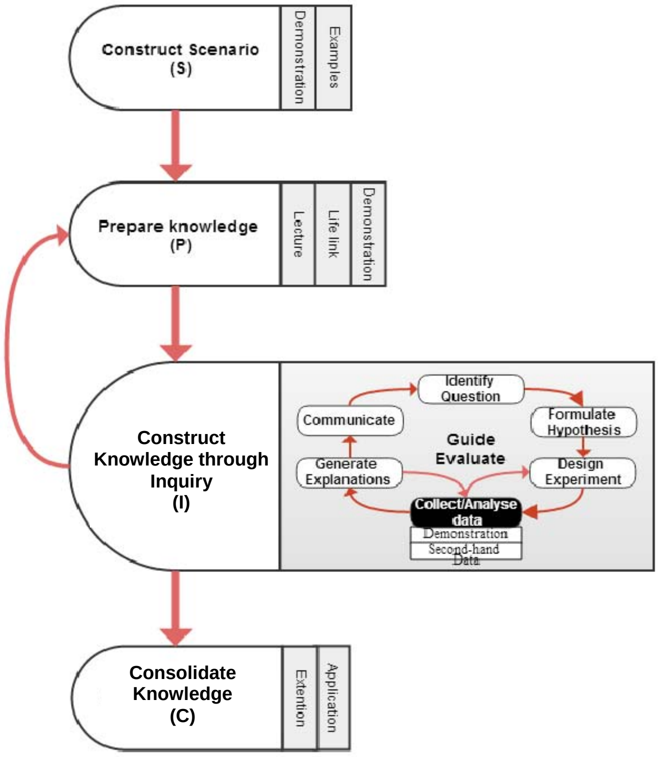
The *Knowledge preparation* section occurred both before and during the process of classroom inquiry when Pan decided that the students needed some particular knowledge to keep going.

In the section of *classroom inquiry,* Pan organised two sequential inquiries: a guided inquiry and a structured inquiry.

A brief application section followed the section of inquiry. In this section, Pan delivered lecture on the related formulae, which were assigned to be used in homework after class.

The arrows show the sequence of classroom activities that were observed.

Figure 6-4 Wen's instructional model of implementing IBT (based on the lesson observed)



Wen created a *problem-solving scenario* using a simple demonstration and pictures, to introduce the topic and formulate an initial question for investigation.

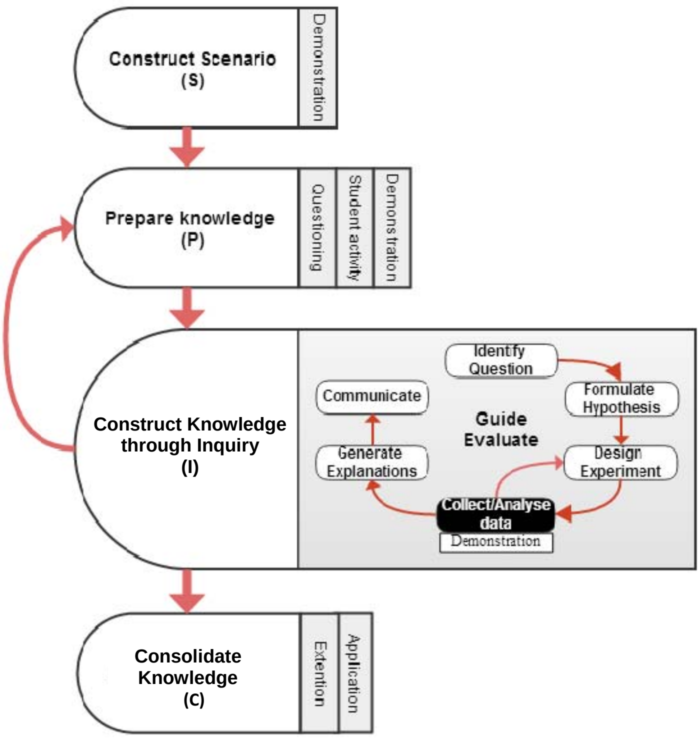
The *Knowledge preparation* section occurred both before and during the process of classroom inquiry when Wen decided that the students needed some particular knowledge to keep going.

In the section of classroom inquiry, Wen organised several sequential inquiries: a demonstrated inquiry and two guided inquiries. She did not include student experiments in classroom inquiry. Instead, she conducted the designed experiments and the students analysed data. In the guided inquiry, she led students to use different methods to test their hypothesis. Iterations between stages of *design experiment*, *collect/analyse data,* and *generate explanations* occurred during this process.

An *application* section followed the section of inquiry. In this section, Wen delivered a small lecture on the related formulae and led the students to review the process. She also engaged the students in a small hands-on activity to use the knowledge that had been learnt.

The arrows show the sequence of classroom activities that were observed.

Figure 6-5 Zhao's model of implemented IBT (based on the lesson observed)



Zhao *created a problem-solving scenario* by performing a demonstration and engaging students in observing and hands-on activities, leading to the investigated question.

The *Knowledge preparation* section occurred both before and during the process of classroom inquiry when Zhao decided that the students needed some particular knowledge to keep going.

In the section of *classroom inquiry*, Zhao guided students to go through the process of scientific inquiry, but he did not include student experiment in inquiry. Instead, he conducted the experiments and let the students analysed data. Iterations between stages of *design experiment* and *collect/analyse data* occurred during the process of classroom inquiry.

A brief *application* section followed the section of inquiry. In this section, Zhao delivered lecture on theories and mathematical formulation, and posed additional questions for student discussions after class.

The arrows show the sequence of classroom activities that were observed.

Teachers' instructional models clearly demonstrated how they incorporated inquiry into their day-to-day teaching practice. All of their instructional models included three basic pedagogical phases: *Build problem-solving scenario* (*S*), *Prepare knowledge* (*P*), and *Construct knowledge through* inquiry (*I*). Some teachers' models also included the *Review knowledge* (*R*) phase, or/and the *Consolidate knowledge* (*C*) phase, depending on their classroom situations.

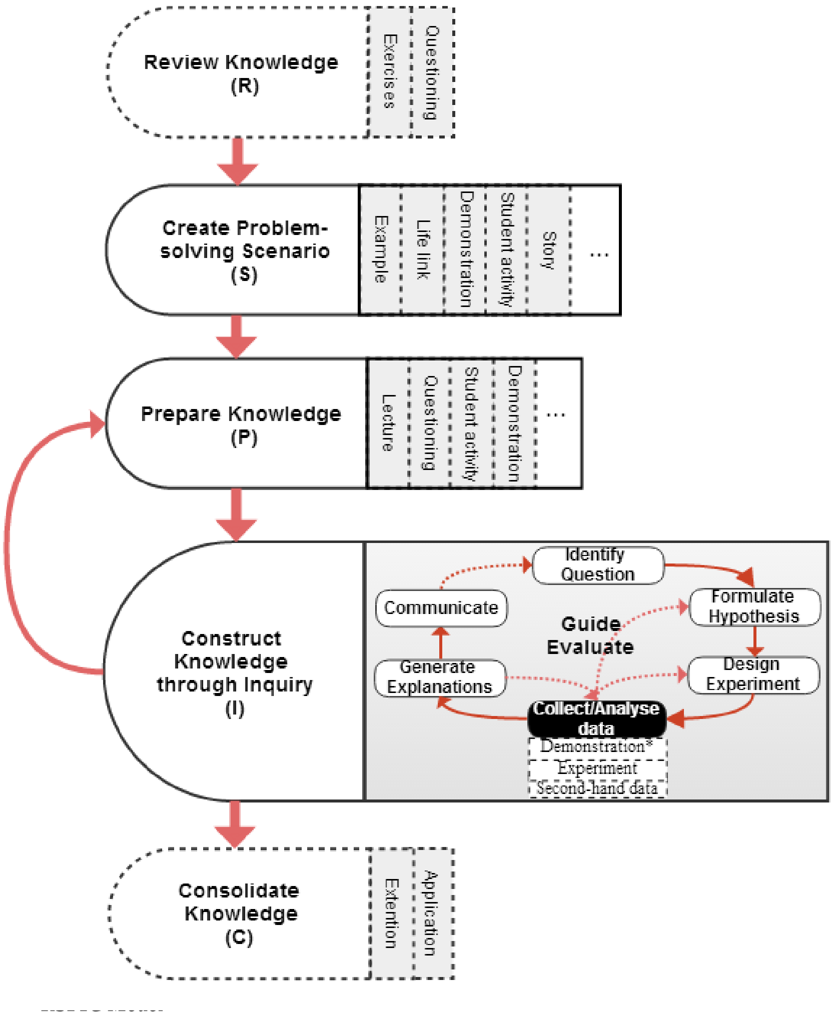
In each phase, teaching activities varied from teacher to teacher. The choices were decided by the teachers' intended teaching objectives and the pedagogical strategies they preferred. For example, in order to create a problem-solving scenario, teachers might use examples, student life experience, stories, demonstrations, or hands-on activities. To prepare students for inquiry with necessary knowledge, they might use a lecture, questioning, demonstration, or hands-on activities to make the students ready for inquiry. In the *I* phase, teachers employ different approaches and questioning strategies to guide student inquiry, manage the classroom, and achieve intended teaching objectives. However, they generally employed the lecture style of teaching when drawing conclusions. In the *C* phase, depending on the teacher, the classroom activities could be reviewing knowledge, doing exercises, problem-solving, or hands-on activities. Some teachers may go further to do extended teaching such as deriving formulae.

The most significant differences were found in the *I* phase, as shown in the built-in inquiry schema of each teacher's instructional model. For example, Wen taught the same topic as Pan, and their instructional models contained the same pedagogical components. However, the inquiry schema in Wen's model was more complicated than Pan's (see Fig.6-3 and Fig.6-4). The whole process of classroom inquiry in Wen's lesson occurred in a circular form which included several sequential inquiries. Loops occurred between *designing experiments, collecting/analysing data* and *generating explanations*. Teachers' inquiry schemas are further discussed in the discussion chapter.

By summarising and generalising the five teachers' instructional models of implementing IBT, a general *RSPIC* instructional model was generated (Fig.6-6). While it is a general model, individual teachers' models may lack the *R* or/and the *C* components depending on their classroom situations. Using this model, the reader may form an overall impression of how the Chinese physics teachers incorporated IBT into their regular teaching practice.

Fig.6-6 presents the general *RSPIC* model by depicting the sequence of these pedagogical components and the built-in schema of classroom inquiry. The arrows show the sequence of classroom activities that were observed in all teachers' lessons. The dotted arrows indicate teaching sequences that were observed in some teachers' lessons. The dashed frames represent classroom activities that were observed in some teachers' lessons. The important characteristics and issues in teachers' instructional models of implementing IBT are further discussed in the discussion chapter.

Figure 6-6 The *RSPIC* instructional model of implementing IBT (based on the lesson observed)



The arrows show the sequence of classroom activities that were observed in all teachers' lessons.
The dotted arrows indicate teaching sequences that were observed in some teachers' lessons.
The dashed frames represent classroom activities that were observed in some teachers' lessons.

* Demonstration: The student experiments are scheduled in a follow-up laboratory lesson. The purpose of a laboratory lesson is generally set to verify the physic law taught in the previous lesson conducted in a classroom. This is a typical way, and the traditional way, to organise student experiments in the Chinese secondary schools.

6.4.3 Approaches to inquiry

By examining each teacher's inquiry practices in the observed lessons, it was found that they generally adopted guided approaches to student inquiry, while they deployed their approaches differently in their classrooms. Ding, Wen and Zhao [11] adapted the guided inquiry to a special version which did not include student experiment. Student experiments were turned into a teacher demonstration. Min initiated a guided inquiry, but later he adapted it to a structured inquiry. In Pan's lesson, the whole process of classroom inquiry included two sequential inquiries: a guided inquiry and a structured inquiry. Wen started her lesson with a demonstrated inquiry, and then conducted two modes of guided inquiry based on experiments and second-hand data respectively. But no teacher tried open inquiries. The following table summarises the approaches to inquiry that these five teachers have employed in their lessons (see Table 6-2).

Table 6-2 The five teachers' approaches to inquiry in observed lessons

<table>
<tr><th>Teachers</th><th>Ding</th><th>Min</th><th>Pan</th><th>Wen</th><th>Zhao**</th></tr>
<tr><td rowspan="3">Approaches to Inquiry</td><td rowspan="3">Guided inquiry *</td><td rowspan="3">Guided inquiry
↓
Structured inquiry</td><td>Guided inquiry</td><td>Demonstrated inquiry</td><td rowspan="3">Guided inquiry*</td></tr>
<tr><td rowspan="2">Structured inquiry</td><td>Guided inquiry *</td></tr>
<tr><td>Guided inquiry</td></tr>
</table>

* It was a special version of guided inquiry in which student experiments were not included. Student experiments were replaced by a teacher demonstration.

** Here refers to Zhao's Grade 12 lesson in which he implemented IBT.

→ A guided inquiry was transformed into a structured inquiry.

6.4.4 Strategies used to manage and guide student inquiry

The case study teachers used diverse strategies to manage and guide student inquiry. The diversity was observed in the aspects of how these teachers managed students' learning, presented and explained the investigated phenomena and questions, structured student inquiry, questioned students and gave feedback, and assessed students' learning process. Meanwhile, their strategies demonstrated some common pedagogical features. Table 6-3 describes the teachers' strategies used in implementing IBT with respects to the above mentioned aspects.

[11] This refers to Zhao's Grade 12 lesson in which he implemented IBT.

Table 6-3 Teachers' strategies used to manage and guide student inquiry

	Teachers' strategies used to manage and guide student inquiry
Manage students' learning	• The whole-class activities, such as lectures, videos/demonstrations, exercises/tasks, and teacher-class conversations, were the most frequently used strategies to engage all students in learning. • Multimedia educational technology was often used to facilitate teaching. • Teachers had a strong control of the time for student inquiry. But sometimes they did not effectively manage the time.
Present the investigated phenomena and questions	• All teachers focused the class' attention on the phenomenon by creating a problem solving scenario using demonstrations, examples, student life experience, videos, stories, and etc. They posed the questions for investigation based on the scenario. • The teachers guided students to form hypotheses, based on observations, and linking to students' prior knowledge.
Structure student inquiry	• Teachers provided materials, and generally used whole-class instruction, questions and teacher-student conversations (occasionally using student discussion) to guide the students to design an experiment (including methods to analyse and interpret data), conduct data analysis and develop explanations. But the guidance varied among different teachers. • Min and Pan required students to work in groups to follow specific steps to collect data. Ding, Wen, and Zhao replaced the student experiments by a teacher demonstration. They collected data for students. • Teachers synthesised the results of inquiry at the end of student inquiry, but often drew conclusions by themselves. Teachers seldom required students to justify their explanations, and seldom required the students to communicate the procedures and the results of their inquiry.
Question students and give feedback	• All these teachers used questions to provoke students' thinking and guide them to go through the process of inquiries. Their questions were generally targeted at the majority of the students. • Teachers demonstrated different expertise in questioning and giving feedback (see details in the following sections)
Assess students' learning process	• These teachers generally used questions and observation to check student progress and used homework and classroom exercises to assess students' understanding and conceptual knowledge, but seldom employed other formative assessment strategies.

As the above table shows, the strategies that the case study teachers used to manage and guide student inquiry shared some common pedagogical features. These features included:

1. Teachers liked to focus students' attention on the investigated phenomena by creating a problem solving scenario, using multi-media resources and/or hands-on activities. This scenario stimulated students' interest, and led to the formulation of the question for student inquiry.
2. Teachers provided different levels of structure for student inquiry, with students generally having more initiation in designing experiments and analysing data, while engaging in more structured ways of collecting evidence, developing explanations, and communication. They

downplayed the functions of student experiments, teamwork, and communication.

3. Whole-class activities, such as lectures, videos/demonstrations, exercises/tasks, and teacher-whole class conversations, were the most frequently used strategies to engage all students in learning.
4. These teachers generally used questions and observation to check student progress and used homework and classroom exercises to assess students' understanding, but seldom employed other formative assessment strategies. The common features and related issues are further discussed later in the discussion chapter.

A significant diversity was found in teaches' use of questioning strategies to guide student inquiry. The following section specifically discusses each case teacher's questioning strategies respectively.

Ding

Ding used questioning throughout the lesson to probe and lead students' thinking, communicate with her students, lead students to experience the process of scientific inquiry, and to achieve the "right" objective. Her demonstration, questions, and quick responses created a friendly and active classroom atmosphere. The following is a small, but typical, episode of the conversation.

Vignette1: Ding posed questions to the whole class, and guided students to think about what should be recorded in the experiment.

26'25	T:	What need to be recorded? We want to find whether the effect of two forces is the same as the effect of a single force.
26'33	S:	The stretch length of the spring.
26'35	T:	The stretch length of the elastic band. Now I have another question. The elastic band is currently stretched to this length. Is it enough to stretch the elastic band to the same length each time?
		(Ding was stretching the elastic band at the same time, but did not stop for students' responses and continued questioning).
		I can stretch it to this side, or to that side, to the same length, and I can stretch it to the same length in a circle.
		(Ding demonstrated at the same time).
		So, what factor was not taken into account if I do so?
26'53	S:	The angle *(unclear voice)*-
26'54	T:	If I only consider stretching the rubber band to the same length, what factor I have not considered?
26'58	Ss:	*(most students)* The angle.
26'59	T:	The direction of the resultant force has not been considered. The direction the effect (of the resultant force) hasn't been considered. So, which position do I have to record, considering the effect of the force, including the direction?
27'09	S2:	The two forces *(unclear voice)*-
27'11	T:	How long is this rubber band? In which direction should I stretch it? This end (the common point of the two forces) is single and fixed. So what do I really need to record?

The above excerpt shows that Ding was good at using questioning to make her teaching flow smooth. She was very clear about her teaching objectives, and always asked appropriate questions at the appropriate levels. Every time students achieved an expected understanding, she posed new questions. These questions were organised in a logical sequence which made the lesson progress in the expected direction. In addition, to lead students' thinking, she generated impromptu questions and adapted the degree of difficulty based on students' responses. Clearly, Ding successfully drew her students' attention to the right direction and engaged them in thinking and communicating.

However, some issues could be identified in this small episode of conversation. The biggest problem was that Ding did not give her students enough wait-time to think about and respond her questions. Each time the students were given only a few seconds to respond to the questions. The students did not have enough time to elaborate their ideas clearly and completely. Whether they answered the questions or not, Ding soon announced the answers and posed another question.

Sometimes Ding gave students more than one question at once, which confused the students. For example, in 27′11″, Ding asked the student three questions at the same time, "How long is this rubber band?", "In which direction should I stretch it?", and "What do I actually need to record?". It seems that Ding tried to use questions to explain her original question and probe the student's thinking. However, the student was confused and did not give her any answer.

Furthermore, Ding did not intend to give students questions for the purpose of initiating discussions and encouraging student curiosity. She seemed to expect the student to answer the question in simple words. In order to do so, she gave a series of closed questions, and announced most of the answers but left a few key blanks for the students to fill in. Although Ding posed some deep questions at the beginning to require students to think about, she used more closed questions to explain them immediately.

Meanwhile, Ding seemed not be very concerned about the students' answers. Sometimes she ignored students' responses, and sometimes she changed the students' words, in order to match with the correct answers (see conversation from 26'52"-27'11").

As the above typical episode of teacher-student conversation shows, the quality of Ding's questions seemed not to be very high. This might be understood considering the time pressure because she had spent a lot of time on reviewing prior knowledge before trying to deliver a difficult and abstract concept in the remaining 28 minutes. However, it seemed that the content, rather than the students, was the centre of Ding's instruction in this lesson.

Ding used questions to control the pace of teaching and learning. Students were urged to think and respond to her questions, but sometimes they were not given enough wait-time. When students did not respond on time, Ding broke a question down to several small questions, or adapted her questions' difficulty into a lower level, such as fill-in-the-blank-type questions, although it was not always necessary to do so. Ding seemed to rush her students into results, even when they were not ready for it. The opportunity for learning from making mistakes was substantially curbed.

Min

Min probed and guided students' thinking by asking different questions. These questions were generally generated based on his thinking about the content. He also reflected on students' questions raised in their previewing and recorded these in a special notebook. His questions challenged students about how investigation might be conducted and how data should be recorded and analysed. He adapted the questions' difficulty to a lower level when he found that the students did not actively respond to him.

Min employed some strategies to make up for his lack of experience. He reviewed students' questions before teaching and used part of them in the lesson to clarify students' understanding. He also reflected after class to update his questions for use in another class. These strategies helped him improve teaching to some extent.

On the other hand, there were several issues in his questioning strategies. It was found that Min did not give sufficient feedback to students whose answers were not expected. It seemed that he did not accept all sincere student answers as valuable contributions. The following is an example.

Vignette2: Min required students to design the experiment to verify the Parallelogram Law.

T:	Student 1, can you tell me how you would design this experiment?
S1:	Using two spring scales to pull a hook weight at 45-degree angle, and then record the readings of the two scales--
T:	A hook weight? Where is the hook weight? You have to use the materials I provided. Of course you can use a hook weight, but how do you design with these materials?
S1:	(silent) I have to think about it.
T:	Does anyone have some ideas? Student 2, do you know?

The above example shows that Min interrupted this student because he gave an unexpected answer.

He did not further probe the students' thinking, but turned to another student. His response inevitably discouraged the students' initiative to participate in discussions.

In addition, Min was not good at asking "trigger" questions. He attempted to use open questions to engage students in inquiry, but did not succeed. When students did not respond, he turned the question to simpler closed ones. When students still could not answer, he gave the answers. The following is an example.

Vignette 3: Min required students to make a prediction about the relationship between the two forces and their resultant force.

T:	Can you predict the relationship between the two forces and their resultant force?
S:	(silent)
T:	For example, two forces, one is 200 N and another 300 N, how big is the resultant? Is it like the arithmetic rule of "1+1=2"?
S:	No.
T:	Is the resultant force equal to 200 N plus 300 N, and equal to 500 N? Is it like this?
S:	No.
T:	If not like this, could you design a small experiment to disprove this assumption?
S:	(silent)
	(20 seconds later)
T:	It's simple. How can we get the value of forces? I can use two spring scales to disapprove it…
	(Min took out two spring scales and then demonstrated how to conduct this experiment.)

The above excerpt shows that Min did not use quality "trigger"questions to probe students' thinking and engage his students' interest in inquiry. He started with an open question, but did not develop appropriate impromptu questions to trigger students' responses based on their response level and the level of critical thinking skills that students had. Instead, he turned to closed questions, which did not allow his students to elaborate their explanations, and also did not successfully engage his students' interest.

Furthermore, he did not give much wait-time for students' discussion, nor make an effort to stimulate students' discussion. It seemed that he lost patience when the students could not respond to the open questions. However, it was more important to encourage the low-achievers to clarify questions and participate in discussions to clearly express their thinking than achieving answers, because by doing so, these students could gradually develop fundamental abilities and understanding of inquiry.

Therefore, although Min was concerned about his student situation, he had not developed effective questioning strategies to guide his students, and he seemed unprepared for his students' reaction to his instruction.

Pan

In the observed lesson, Pan used questions to probe students' thinking and guide the student inquiry. Although he had more than twenty years of experience in teaching physics, he seemed to lack pedagogic expertise in using questioning strategies and giving feedback.

Pan used questions to guide students' thinking, but his questions were not always phrased appropriately, and were sometimes unnecessary, unrelated, and confusing. Furthermore, although he asked students open questions, he always rephrased them to closed questions. One big issue was that he did not respond well to students' answers. The following excerpts illustrate a couple of drawbacks in the strategies he used to question and give feedback.

Vignette 4：Pan required students to make predictions about the nature of the free fall motion.

T:	What type of motion is the free fall motion? Let's think about this question. First, whether it is uniform or variable?
S1:	Variable.
T:	Starts from rest and speeds up. Right? It is variable. Second, whether it is uniformly or non-uniformly variable?
Some Ss:	Uniformly variable.
Some Ss:	Non-uniformly variable.
T:	Non-uniformly variable? Someone said it's uniformly variable. Can you tell me why it is uniformly variable?
S2:	Because it is only under the influence of gravity, it is dependent on gravity. Gravity is a constant force. Therefore, it is uniformly variable.
T:	Oh, gravity is a constant force. Therefore, it is uniformly variable. Right? So, do you have any method to determine it?

The above example shows that, instead of requiring the student to justify their explanations, Pan gave explanations for the student's answer, and then moved to another question. Although Pan started with an open question, he did not use this question to initiate a discussion, nor did he go further to probe students' thinking or elicit their explanations even when they gave unexpected or strange answers. He tended to tell students information and begin implementing a solution before students could construct adequate understanding of the investigated phenomenon.

It could also be identified from the above dialogues that Pan was not well prepared for the unexpected situations which might occur during inquiry-based teaching. He chose favourite answers and ignored students' misconceptions that emerged from students' answers to the questions. He did not show effective strategies in dealing with the unexpected situations, but gave students simple, unrelated, and not so accurate feedback and shifted students' attention from this situation.

Wen

Wen probed students' thinking and guided their inquiry by asking different levels of questions. She asked questions at the appropriate opportunities for the purposes of initiating discussions and encouraging student curiosity. Wen used questions to challenge students' thinking and required them to justify their proposed explanations. These questions challenged students about how investigation might be conducted and how data should be analysed, and encouraged them to develop appropriate explanations based on evidence.

Wen also tried some strategies to make up for her lacking experience in teaching. After each lesson she updated her teaching based on students' responses and other teachers' suggestions, and applied the update to another class.

On the other hand, being a novice teacher, Wen was less proficient in using questioning techniques. There were several issues with her questioning skills. One big issue in Wen's questioning was that sometimes she asked open questions, but did not expect students to answer. The following classroom vignette shows this issue.

Vignette 5: Wen was guiding her students to make a prediction about the nature of the free fall motion.

T:	Why do you think it is a uniformly accelerated motion?
S:	(*Students murmured, and the classroom was full of vague voices*)
T:	It starts from rest, so its initial velocity is zero. Does its speed increase when falling? So it is accelerated. And is its falling path a straight line?
S:	(*Low voices)* Yes.
T:	Well, in fact, we have specified it as an accelerated linear motion with zero initial velocity. We have specified that. Is it a uniformly accelerated motion? This is what we should predict.

The above example shows that Wen asked an open question, but gave students information right away.

Another issue was that she did not give sufficient feedback to those students who gave unexpected answers. The following excerpts are examples.

Vignette 6: Wen required her students to analyse a stroboscopic picture of a falling ball to verify their hypothesis that the free fall motion is a uniformly accelerated linear motion. Students posed solutions and Wen gave them feedback.

T:	Student 2, can you tell me what method you used?
S2:	I used (the equation of) $v_0t+1/2at^2$.
T:	You used $v_0t+1/2at^2$?
S2:	Because its initial velocity is zero-
T:	Here we can't determine its initial velocity is zero. This picture may be shot after the ball has already fallen for a while. Right? So we cannot use [this method].
S3:	Teacher, I did not use his method.
T:	What is your method?
S3:	I calculated the average velocity of the ball over each interval (between two positions)… Since the time interval is equal… if the acceleration is constant, the velocity increases equally.
T:	(*In a low voice)* Keep on working. Your method is alright.
	(*She quickly turned to another student.)*

As the above excerpts show, Wen interrupted the first student's self-explanation because he gave an inappropriate answer. She did not take this opportunity to ask further questions to help students attack misconceptions, but gave her explanation. Wen also did not allow the second student to explain her solution clearly to the class, nor gave enough feedback, because it was not her expected answer.

The dialogues between Wen and her students illustrate that Wen did not realise the great power of students' self-explanation in constructing understanding and improving learning. She asked open questions, but did not encourage students to formulate and justify their explanations. Instead, she tried to give students information directly to fill gaps or correct misconceptions in their knowledge.

Clearly, Wen lacked appropriate questioning skills in her inquiry practice. She needed time and some support to develop the necessary questioning techniques.

Zhao

Zhao was proficient at using questioning strategies to engage students in thinking. He asked well-constructed, clear, unambiguous questions at the appropriate opportunities for the purposes of initiating critical thinking and teacher-led discussions, and leading students to form a hypothesis, and develop methods to collect, analyse and interpret data. He asked a series of questions to check students' understanding, elicit the explanations they had developed based on evidence. The students were prompted to develop scientific understandings and clearly express their explanations in teacher-students conversations.

He also asked students questions for alternative answers, asked questions that seek comparisons or contrasts, and asked additional questions after students' had answered to enable student to continue thinking. Sometimes he used Socratic question-and-answer chains to challenge students' thinking. The following classroom vignette shows Zhao's usage of questioning to guide students to develop explanations based on evidence.

Vignette 7: Zhao questioned the class how to read the graphs and how to use the graphs to obtain the wanted data.

T:	How to choose the initial position and the final position in this graph?
S7:	The initial one is the position where this line starts to rise.
T:	Why is this position?
S7:	Because, at this position magnetic flux starts to change, indicating that emf is induced.
T:	… So where is the final position?
S7:	The final position should be… in the middle where its value changes from positive to negative.
T:	Where its value changes from positive to negative. I want to know, why does the emf change from positive to negative?
S7:	Because when the bar magnet just insert into a coil of wire, magnetic flux increases continuously; while flux decreases when it leaves.
T:	Good… (*Pointing to the graph, and repeats the student's answer*)
	(*Zhao continued to question this student to check his understanding of the graph.*)

The above vignette shows that Zhao used questions to probe students' thinking and challenged the student to justify the proposed explanations. Students were required to explain their ideas clearly. They were also required to demonstrate their processes of reasoning.

However, Zhao tended to direct his instruction to the majority of the students, that is, the middle-ability students. Therefore, the students were engaged in the same questions. Individual questions were also not encouraged.

6.4.5 Summary

The case study teachers implemented diverse inquiry practice, which shared some common pedagogical characteristics. Teachers' instructional models of implementing IBT could be summarised by a general *RSPIC* instructional model, with the most significant differences found in the process of classroom inquiry. Teachers generally adopted guided approaches to student inquiry, while they deployed their approaches differently in their classrooms.

These teachers used diverse strategies to manage and guide student inquiry. The significant differences were found in teachers' expertise in using questioning strategies. Their strategies also demonstrated some common pedagogical features. Teachers seemed to provide a high level of structure to students' inquiry to keep students' learning under control. They generally used whole-class activities to engage all students in learning, and often employed questions and observation to check student progress. In addition, these teachers, regardless of age and experience, had pedagogical issues in their questioning and giving feedback. These characteristics and relevant issues of teachers' implementation of IBT are further discussed later in the discussion chapter.

6.5 Summary

This chapter provides five different cases to show how Chinese senior secondary physics teachers perceive and implement IBT in their unique teaching contexts.

The case studies reveal that the five physics teachers differed significantly in their beliefs about the nature of science, teaching, and learning. Their beliefs were complex, nested, and sometimes conflicting. Teachers also varied in their understandings of inquiry and IBT. Their beliefs and perceptions of inquiry exerted complex influences on their instructional decisions regarding the use of IBT.

The teachers pointed out the influences of a number of factors on their instructional decisions regarding the use of IBT. These considerations reflected that they understand the subject matter, the curriculum, their teaching, their students, and the nature of inquiry, in their specific teaching contexts. It indicates that although these teachers were receptive to IBT, they generally faced challenges and lacked adequate motivations for implementing more IBT in regular teaching practices.

Consequently, teachers made different compromises to accommodate their ideas of IBT into their regular teaching practices. Ding decided that she could implement IBT in one section of class, and created a form of "speculative inquiry" without involving students in hands-on activities. Min chose to use partial inquiry when there was content he felt was interesting and able to foster students' abilities. Pan indicated that he would implement IBT when outsiders came to observe his classrooms, to demonstrate that he was able to do so. Wen made a decision to use partial and guided approaches to inquiries in her teaching. Zhao decided to employ a method to offer students a vicarious experience of inquiry activities instead of a direct experience of inquiry.

Nevertheless, in the observed lessons, they made great effort to make IBT work in their classrooms by incorporating the features of inquiry into their regular teaching practices that centred on accomplishing teaching tasks. They developed diverse inquiry practices, which shared some common pedagogical characteristics. A general model of implementing IBT could be identified in these teachers' teaching. Teachers preferred to use guided approaches to classroom inquiry, but some of them also tried other approaches to inquiry. They managed different processes of classroom inquiry, and employed different strategies to guide and manage student inquiry, engaging students in all or some aspects of classroom inquiry. However, issues were also identified in their inquiry-based instruction. The characteristics and issues of teachers' inquiry practice are specifically discussed in the next chapter.

The following chapter discusses the relationships among teachers' beliefs about the nature of science, teaching, and learning, their understanding of IBT, and their inquiry practices, in the light of the influences of their teaching context, to deeply understand Chinese physics teachers' perceptions and implementation of IBT.

7. Discussion

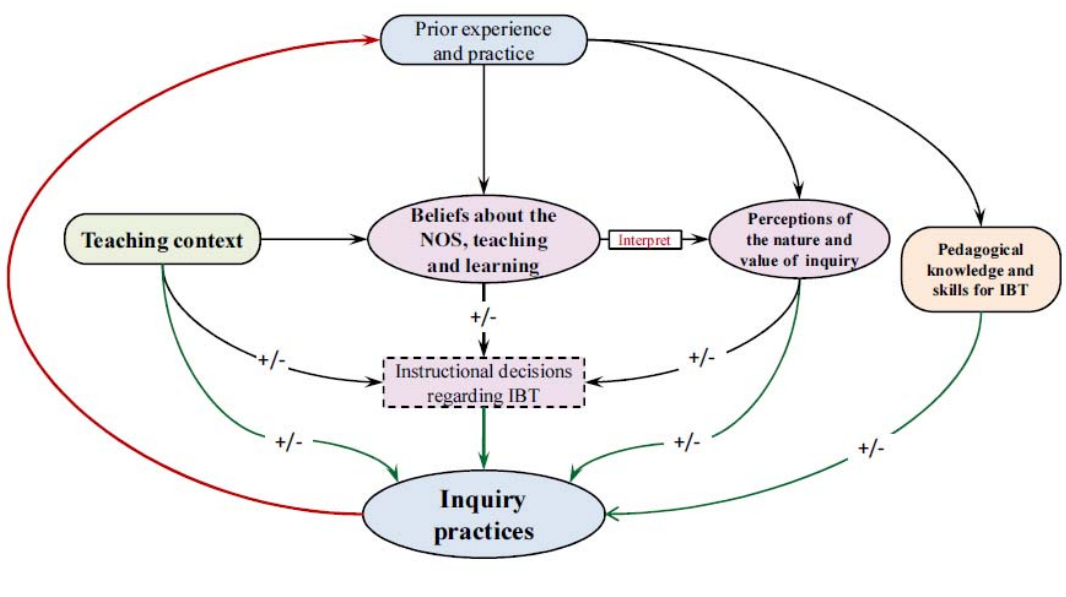
This chapter presents a discussion of the key findings from this study. This study is aimed at developing a better understanding of Chinese high school physics teachers' perceptions and implementation of inquiry-based teaching (IBT). In order to achieve this goal, the results from the surveys, interviews, and case studies were triangulated. Teachers' beliefs about the science teaching and learning, their perceptions of IBT, their inquiry practice, and the teaching context, were linked together to form an overall picture of the teachers' perceptions and implementation of IBT. The discussion is intended to answer the following research questions:

Q4: What are the relationships between teachers' beliefs, perceptions of IBT, and their implementation of IBT?

Q5: To what extent does the teaching context in China influence teachers' implementation of IBT?

The discussion leads to a proposed model (Fig. 7-1), which represents the relationships between teachers' beliefs, their perceptions of IBT, and their inquiry practice in their teaching contexts. With this model, the readers could form a clear overview of the discussion that is represented in this chapter. The model is specifically explained in the summary section.

Figure 7-1 Proposed model for understanding Chinese physics teachers' inquiry practice



These positive and negative influences are represented by symbols of "+" and "-" respectively.

More specifically, the following sections address the above two research questions from the following aspects:

1. What are the characteristics and issues of teachers' implementation of IBT?
2. How do teachers' perceptions of IBT influence their implementation of IBT?
3. How are teachers' perceptions of IBT related to their beliefs?
4. What is the relationship between teachers' beliefs and their implementation of IBT?
5. To what extent does the teaching context in China influence teachers' implementation of IBT?

The chapter concludes with an explanation of the proposed model for understanding Chinese physics teachers' inquiry practice in light of the discussions.

7.1 What are the Characteristics and Issues of Teachers' Implementation of IBT?

In Chapter 6, this study closely examined the nuances of inquiry practice in five teachers' classrooms in order to reveal how Chinese senior secondary physics teachers implemented IBT in their specific contexts. The findings suggest that these teachers' implementation of IBT could be characterised by the following features:

1. A general *RSPIC* instructional model of implementing IBT
2. Different processes of classroom inquiry
3. Preference for guided approaches to classroom inquiry
4. Employment of diverse strategies to manage and guide student inquiry

The following sections discuss these characteristics and relevant issues in relation to the literature.

7.1.1 The general *RSPIC* instructional model of implementing IBT

As summarised in Chapter 6, a general *RSPIC* instructional model (see Fig.6-6) was generated by the researcher to represent and understand teachers' implementation of IBT, based on the case study teachers' classroom practice (see Chapter 6 for details). The instructional model allowed the teachers to incorporate inquiry into their teaching practices

The *RSPIC* model included five pedagogical phases: *Reviewing knowledge* (*R*), *Building problem-solving scenario* (*S*), *Preparing knowledge* (*P*), *Constructing knowledge through inquiry* (*I*), and *Consolidating knowledge* (*C*). Individual teachers' models may lack the *R* or/and the *C* phases depending on their classroom situations. For example, Min's model was *RSPI*, Pan's models were *SPIC*. This section discusses this general model and its issues in relation to prior literature.

This model represented some important pedagogical characteristics of teachers' instructional models.

First, the *RSPIC* model is task-oriented. Teachers often managed student inquiry in one section of the lesson (the *I* phase), while employing their regular teaching styles and whole-class instruction for the rest of the lesson. Using this approach, teachers incorporated features of inquiry into their teaching practice that centred on accomplishing teaching tasks. The students were allowed to take some responsibility for their learning in the section of classroom inquiry. Teachers kept the pace of student learning under control, and adjusted the time and content for each section in order to accomplish the teaching task.

Second, in this model, the *P* phase was normally scheduled before the classroom inquiry (the *I* phase), it also occurred repeatedly during the process of classroom inquiry. This situation occurred in all teachers' lessons. Whenever the teachers felt that their students needed some specific knowledge to continue the inquiry, for example, procedural knowledge to manipulate equipment, they stopped the student inquiry and brought the students' attention to the necessary knowledge using whole-class lectures or individual reminders, and then let students continue their inquiry.

Third, the great diversity in individual teachers' instructional models was demonstrated in *I* phase. The built-in inquiry schema of the *RSPIC* model illustrated the complicated process (see Fig.7-2). All teachers' schemas included the same six basic elements (SHMEC, 2004), while how teachers managed these elements varied from teacher to teacher. Loops occurred between different elements; the process of inquiry took place in different forms; and teachers gave different types and amounts of guidance to student inquiry. These differences are further discussed in the next section.

The repeated occurrences of *P* phase, and the loops within different elements in classroom inquiry, were two important characteristics reflecting the dynamic nature of teaching and learning in classrooms. Critical to these processes was teachers' guidance, helping students construct knowledge and understanding, which involved continuous assessment for student learning and corresponding judgment and strategies to address student learning problems in inquiry.

The *RSPIC* instructional model demonstrated how the teachers make sense of their teaching contexts. It was practical because it gave attention both to developing students' inquiry abilities and to accomplishing the teaching tasks. On the one hand, the *RSPIC* model incorporated the dynamic of inquiry into their regular teaching practice, in response to the requirement of the new curriculum standards. It differed from the prior approaches teachers used to construct knowledge. On the other hand, this model was developed from their regular instructional models which were centred on accomplishing the teaching tasks. They have some same instructional phases that served as similar pedagogical functions, such as reviewing, preparing, constructing and consolidating knowledge.

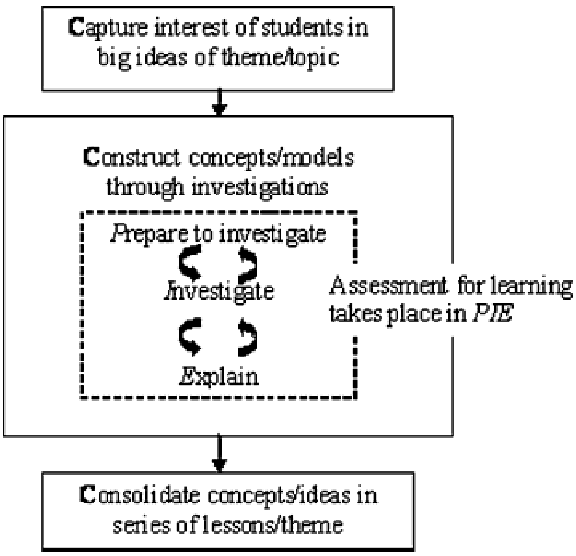
The *RSPIC* instructional model is unique and different from those theoretically-derived models. However, some components of this model are consistent with those of prior literature (Atkin & Karplus, 1962; Barman & Kotar, 1989; Bybee, 1997; Bybee, Buchwald et al., 1989; Bybee, Taylor et al., 2006; Karplus & Thier, 1967; Lawson, 1995; Lawson et al., 1989; Martin et al., 1999; Schwab, 1965; Suchman, 1962). For example, comparing the *RSPIC* instructional and the BSCS 5E instructional model (Bybee, Taylor et al., 2006), the two models bear resemblance in many aspects. The BSCS 5E instructional model consists of five phases*: Engagement*, *Exploration*, *Explanation*, *Elaboration*, and *Evaluation*. In the *Engagement* phase of the BSCS 5E model, teachers help students become engaged in a new concept through the use of short activities that promote curiosity and elicit prior knowledge (Bybee, Taylor et al., 2006). The *R* and *S* phases of the *RSPIC* model address the same pedagogical purposes. In the *Elaboration* phase of the BSCS 5E model, students extend conceptual understanding and skills through new experiences (Bybee, Taylor et al., 2006). Similarly, in the *C* phase of the *RSPIC* model, students are required to apply new knowledge to novel situations. In addition, the phases of *Exploration*, *Explanation*, and *Evaluation* in the BSCS 5E instructional model serve as the pedagogical functions of constructing and assessing student conceptual understanding, process and skills (Bybee, Taylor et al., 2006). In the *RSPIC* model, the *I* phase integrates the functions of these three phases. The described activities in this phase are similar to the BSCS 5E instructional model, and teacher's guidance and evaluation are considered as a critical part of these phases in this model.

On the other hand, there were several pedagogical functions of different phases in the *RSPIC* instructional model that were not evident in the theoretically-derived models. The pedagogical function of *R* phase was reviewing the knowledge learned in the last lesson, generally taking the form of questions and exercises. The purpose of *C* phase also included helping students to synthesise what they have learned in the lesson and link to prior knowledge. These pedagogical functions were related to the teachers' purpose of helping students synthesise and make connections across knowledge to meet curricular requirements and to be better prepared for examinations. Although one can argue that these functions might not be integrated ingredients of the theoretical inquiry-based instructional models, there were other arguments that prevailing instructional models of IBT gave too much emphasis to discrete concept learning at the expense of knowledge system learning (Duschl, 2008). Strategies that require students to synthesise and make connections across concepts help students engage in the meaning and purpose of inquiry (Flick, 2000; NRC, 1996).

In particular, in the *RSPIC* instructional model, the repeated occurrence of *P* phase before and during the process of inquiry, and the loops within different elements of inquiry, reflected the dynamic character of inquiry practice. These were not found in those prevailing models. As Flick (2000) argued, "the current models of inquiry-oriented instruction do not account for classroom variables that require teachers to adjust or redirect instruction in order to reenter inquiry at a different place (p. 111)".

In contrast, the *RSPIC* model supported those practice-oriented models developed based both on classroom observations and using theoretical frameworks, regarding the dynamic character of classroom teaching and learning. Recent research conducted in Singapore (Poon, Lee, Tan, & Lim, 2012) defined a three-phase pedagogical framework to represent the inquiry practices of four elementary school teachers. It had three pedagogical components: Capture interest of students in big ideas of theme/topic, Construct concepts/models through investigations, and Consolidate concepts/ideas in series of lessons/theme. The following diagram (Fig.7-2) represents this model.

Figure 7-2 The pedagogical framework of inquiry practice **(Poon, Lee, Tan, & Lim, 2012, p. 318)**



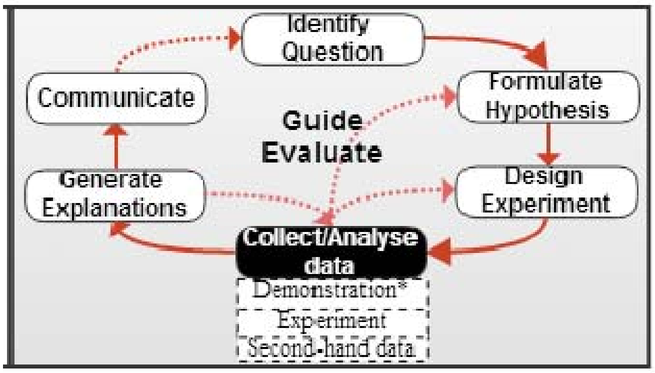
Poon et al.'s (2012) model also emphasised the dynamic nature of teaching and learning in enacting inquiry practice. Two important characteristics of this model were the pattern of PIE cycle (*P* for "prepare to investigate", *I* for "investigate", and *E* for "explain"), and the integrated ongoing assessment process. As the researchers argued, they "reflect more accurately the real dynamic practice of teaching as the teachers were constantly making and changing pedagogical decisions based on informal assessment of their students' learning as the lesson progressed " (p. 317).

The *RSPIC* model is significant, not only because it was consistent with the core components of inquiry teaching proposed by the prevailing inquiry-based instructional models such as the BSCS 5E instructional model, but also because it reflected how teachers make sense of their teaching context, and reflected the dynamic character of teaching and learning in inquiry-based classrooms. The model helps the reader form a clear picture of what was actually going on in the classroom, building a contextualised understanding of complex and dynamic teaching practices involved with inquiry.

7.1.2 Different processes of classroom inquiry

The built-in inquiry schema of teachers' instructional model (the *I* phase) illustrated how teachers managed student inquiry in their classrooms. All teachers' schemas included the same six basic elements (SHMEC, 2004), while how teachers managed these elements was different. Fig.7-3 shows the differences in the inquiry schema of the case study teachers.

Figure 7-3 Inquiry schema of instructional model



The arrows show the sequence of classroom activities that were observed in all teachers' lessons.
The dotted arrows indicate teaching sequences that were observed in some teachers' lessons.
The dashed frames represent classroom activities that were observed in some teachers' lessons.

* Demonstration: The student experiments are scheduled in a follow-up laboratory lesson.

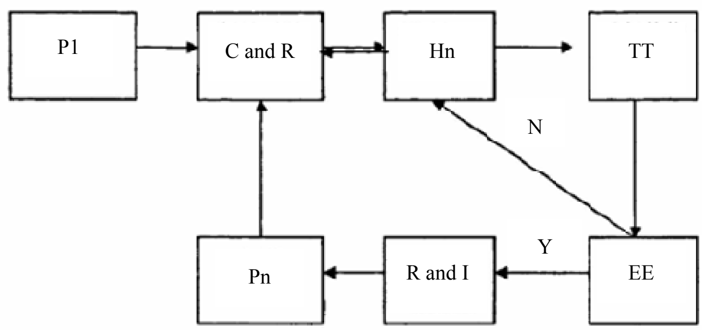
The differences were represented in two aspects. First, during the process of doing inquiry, loops between different elements took place. The loops took place whenever the teachers decided it to be necessary to do so. For example, in Ding's classroom, loops between *designing experiments* and *collecting data* repeatedly occurred. In Min's classroom, loops occurred between *formulating hypothesis*, *designing experiments*, and *collecting/analysing data*. Second, the process of classroom inquiry took different forms in different classrooms. For example, in Ding's and Min's classrooms, the process of classroom inquiry flowed in one direction, which started from a question and ended at a conclusion. While in Pan's and Wen's classrooms, the process of inquiry occurred in a big loop from a question to a new question (see Chapter 6 for details).

These two differences represented the dynamic nature of classroom inquiry. Critical to these processes was teachers' guidance as that helped students construct knowledge and understanding. It involved continuous evaluation for student learning and corresponding strategies to address student learning problems in inquiry.

The dynamic nature of inquiry is not evident in the process of scientific inquiry described by the Shanghai's physics curriculum standards (SHMEC, 2004). The curriculum standards have not specified how these elements should be structured. Furthermore, teacher roles in the process of student inquiry were not evident. Consequently, some teachers may picture the process of inquiry as a static, linear flow, rather than a complex and dynamic process, as indicated in the *RSPIC* model.

The dynamic schemas of inquiry are supported by prior studies. One Chinese study proposed a dynamic development model for scientific inquiry teaching (Dong, 2010). It was developed using the theoretical framework of Popper's four-step problem-solving schema, integrating the key elements of inquiry. This model was then examined by experts, researchers and teachers, and also tested by some teachers. The following diagram (Fig.7-4) shows this model. The author argued that inquiry teaching is a dynamic process involving dynamic loops, which "could better reflect the nature of science and the real procedures of scientific inquiry activities" (p.107).

Figure 7-4 The dynamic development model for scientific inquiry teaching (Dong, 2010, p.108)



P1-Problem1; C and R –Conjectures and Refutations; H- Hypothesis; TT- Tentative Theory; Pn- Problem n; Rand I- Result and Information; EE-Error Elimination

In comparison to the above described inquiry schemas, the built-in inquiry schema of *RSPIC* instructional model in this study extends our understanding of real practice of classroom inquiry, by suggesting the dynamic character of teachers' schemas of inquiry and the critical role of teachers' guidance and evaluation in the process of student inquiry.

7.1.3 Preference for guided approaches to classroom inquiry

It was found that the case study teachers preferred to use guided inquiry to implement IBT. This finding was consistent with the survey and interview results. Teachers attached a critical role to teacher guidance in student inquiry and preferred to use guided inquiry in their classrooms.

These findings supported the conclusions of prior studies. It was argued that secondary school science should use integrated instructional units that are characterized as guided inquiry (Bybee, 2010). Teacher-guided inquiry was considered as the preferred approach by some researchers as they recognised the impracticality of having students spending all their time in independent discovery activities (Smith & Hall, as cited in Deboer, 2004). In addition, guided inquiry is considered to be suitable for secondary students in many situations. According to the NRC (2000), guided inquiry lessons usually work for young children when they are not developmentally or academically ready to benefit from open inquiry lessons. Guided inquiry can also best focus learning on the development of particular science concepts. Furthermore, guided inquiry has benefits in developing higher cognitive abilities, requiring less effort than open inquiry and less reliance on students' prior knowledge, promoting better team working and communication, and being really contextualised (Chatterjee, Williamson, Mccann, & Peck, 2009; Deters, 2005).

Some of the teachers also used other types of classroom inquiry in addition to guided inquiry, but deployed them differently based on their student situation. For example, Min initiated a guided inquiry and adapted it to a structured inquiry. Pan persisted to complete a guided inquiry and adopted a structured approach in the follow-up inquiry activities. Wen started her lesson with a demonstrated inquiry, and then tried two modes of guided inquiry based on experiments and second-hand data respectively.

It is worth noting that these teachers were teaching different groups of students in different types of schools. Most students in Min's schools were publicly regarded as low achievers in learning, and having bad learning habits. Pan taught in a school enrolling students who had lower academic performance than those of other public schools. When Min and Pan found that guided inquiry did not work in their classrooms, both of them adapted their approaches. In contrast, Wen's students were publicly recognized to be the most capable students in this district. These students had relatively high inquiry abilities. Therefore, she tried multiple methods to conduct guided inquiry. The teachers' approaches to inquiry recognised and responded to the abilities of their students.

These findings suggest that teachers' beliefs about the nature of students affected their instructional decisions. This finding echoes prior studies in the western countries (Crawford, 2007; Cronin-Jones, 1991; Roehrig, & Luft, 2004; Wallace, & Kang, 2004) suggesting that teachers' beliefs about the nature of their students impacted their use of inquiry-based instruction.

7.1.4 Diverse strategies used in IBT

The case study teachers used diverse strategies in implementing IBT (see Chapter 6 for details). They demonstrated different expertise in using strategies to implement IBT. The experienced teachers tended to use more effective strategies to implement IBT than the inexperienced teachers. For example, Ding and Zhao were found to be more confident and effective in managing an inquiry classroom, guiding students, and using a variety of questioning techniques than Min and Wen.

However, it was not necessary the case that all teachers with long teaching experience used more effective strategies to implement IBT than inexperienced teachers. For example, although Pan had been teaching physics for more than 20 years, he did not use more effective strategies in guiding student inquiry and questioning students than Min and Wen. Indeed, as with the inexperienced teachers, Pan lacked the appropriate knowledge and effective questioning skills to guide student inquiry.

Therefore, it is argued that teachers' experience in teaching should be consistent with the spirit of inquiry to have positive effects on teachers' implementation of IBT. This argument is supported by findings of prior studies in different settings. Both Laplante (1997) and L. Smith (2005) described how teachers' experiences with science influence the way they present science in their classrooms. Lotter et al. (2007) found that high school teachers' current experience with science outside of schools exerted an influence on how they teach inquiry. Amerine and Bilmes (1990) established that teachers without research experience tended to be more comfortable with the traditional "cookbook lab" approach in which the unexpected results were viewed as failures rather than as interesting scientific findings that could lead to further investigations. In the current study, both Ding and Zhao used various questioning skills in their regular teaching to prompt students' thinking in their classes, regardless of the lesson types. Their expertise in questioning, which was developed over long years of teaching, could be transferred and adapted into effective strategies to guide student inquiry without radical change. However, Pan typically used lecture style of teaching and drills training in his regular teaching. Therefore, his teaching experience was of little help for his implementation of IBT.

7.1.5 Issues in teachers' inquiry practice

There were several common issues existing in teachers' strategies used in IBT. One issue is that these teachers seemed to provide a higher level of structure to students' inquiry than was needed on some aspects of inquiry. For example, all of the five teachers gave little time for students' own questions and discussion, and seldom asked their students to communicate and draw conclusions by themselves. Ding, Wen and Zhao even conducted the experiments for students. Students were not allowed enough initiative for their inquiry activities. These outcomes illustrated that these teachers cared considerably about students' thinking process, while downplaying the functions of student experiments, team work and communicating results. Although one can argue that the high level of structure was needed considering their students' lack of inquiry abilities (NRC, 2000; Llewellyn, 2011), these classroom practices were hardly linked to teachers' considerations for students' inquiry abilities.

On the contrary, this situation makes more sense when considering teachers' concerns about the time limits and completing teaching tasks. In order to accomplish certain teaching tasks in a relatively limited time, these teachers intended to employ whole-class instruction, reduce time on teamwork and group discussion, and demonstrate specific procedures or conduct experiments for students, making the classroom inquiry more structured. They took more responsibility for students' learning than was needed.

This situation raised a relevant major pedagogical issue as their approaches were apparently not highly effective in developing students' inquiry abilities. These approaches did not encourage initiating group dynamics, students' critical and deep thinking, and students' communication. Students might lose the fun of doing inquiry due lack of challenges, and they might lose interest in inquiry when they found that they could not actively participate in it.

This issue was related in part to these teachers' beliefs about what students would achieve in the activities of conducting an experiment, communicating and drawing conclusions, and how important they thought the procedural knowledge developed in these activities were to students' learning. From the observed lessons, it was found that these teachers tended to focus more on students' thinking processes than practical experiences and communication skills. They might not perceive the procedural knowledge as having the same importance as the declarative knowledge. Therefore, when time was limited, they possibly shorten the time spent on activities which was intended to develop students' procedural knowledge.

This issue was also associated with the pedagogical knowledge teachers held to manage to develop students' inquiry abilities and at the same time to cover the required content. Some teachers might estimate it too difficult or troublesome to do so, and thus intended to use a more structured approach. This necessitates accumulated experience and appropriate pedagogical skills to implement IBT, and to use time effectively.

Another common issue was that whole-class activities, such as lectures, videos/demonstrations, exercises/tasks, and teacher-whole class conversations, were the most frequently used strategies to engage all students in learning. Having all students do the same thing, these activities gave little attention to different student learning needs and learning styles. Although the students were given some opportunities to independently and collaboratively complete experiments, the prescribed objective did not allow them to undertake an inquiry in different directions based on their interests and expertise.

According to the SHMEC (2004), the physics curriculum must "meet the needs of diverse students" (p. 64). Therefore, science teachers should recognise and respond to student diversity and encourage all students to participate fully in learning. In the literature, inquiry is the best way to meet the needs of diverse learners (see Lawson, 2010). Science teachers were encouraged to employ differentiated inquiry to meet the different student needs (Llewellyn, 2007). However, how teachers design and implement differentiated inquiry-based instruction to match students' different learning needs and learning styles could be a very difficult task for teachers without appropriate experience and training (Llewellyn, 2011). Apparently, it was the case for these Chinese physics teachers.

Another common issue was that these teachers generally used questions and observation to check student progress and used homework and classroom exercises to assess students' understanding, but seldom employed other formative assessment strategies. They assessed the extent to which students acquired and understood the introduced concepts (declarative knowledge, see J. Anderson, 1990), but did not include effective strategies to assess the extent to which students could do science and think scientifically (procedural knowledge, see J. Anderson, 1990).

This issue was possibly caused partially due to teachers' lacking the pedagogical knowledge of developing alternative methods of evaluation to assess procedural knowledge. Another reason was associated with the importance teachers perceived of procedural knowledge and declarative knowledge in the current assessment system. Because the former is difficult to assess by the paper-based exams, it was not strange that teachers might lack motivation to develop multiple methods of assessment, even if they could do so.

This study also found that the case study teachers, regardless of age and experience, all had individual pedagogical issues in using strategies to implement IBT. For example, Ding did not give students enough wait-time to think deeply and respond to her questions. Wen, Min, and Pan did not allow time for students' explanations and did not respond well to unexpected answers. Zhao seldom asked questions in the process of collecting and interpreting data. These pedagogical issues arose in different classroom situations. They are further discussed in later sections.

7.1.6 Summary

As discussed above, these Chinese physics teachers' inquiry practices were diverse. However, their inquiry practice shared some common pedagogical characteristics, which were embodied in their instructional models of implementing IBT, approaches to inquiry, and the process of doing inquiry. Meanwhile, pedagogical issues were identified in their implementation of IBT. These issues indicated that there is a big gap between their implementation of IBT in the classroom and what is required by the curriculum standards. To bridge this gap, these issues should be appropriately addressed. The following sections of this chapter further discuss these issues.

7.2 How do Teachers' Perceptions of IBT Influence their Implementation of IBT?

This study reveals that teacher's perceptions of IBT were a significant factor influencing their instructional decisions regarding the use of IBT, which in turn affected their inquiry practice. Because teachers perceived IBT in different ways, the influences of their perceptions were varied and could be positive or negative. For example, Zhao and Lu's intentions of using IBT were discouraged when they perceived that IBT was a time-consuming activity. In contrast, Ding and Yao, who thought that IBT could be easily incorporated into their regular teaching, showed more interest in trying IBT in their classroom.

The influence of teachers' conceptions of IBT on their inquiry practice was observed in many aspects, such as the approaches and strategies they employed to structure student inquiry. For example, all case study teachers adopted the guided inquiry approach because they considered that teacher guidance was important to student inquiry and they were concerned about the efficiency of acquiring knowledge in a limited time.

Although teachers perceived inquiry differently, one similarity across the teachers was that they generally perceived that classroom inquiry was a process of thinking and doing science. This common understanding was mirrored in both teachers' instructional decisions and their inquiry practices. For example, they payed considerable attention to the thinking and practical activities, and attached importance to appropriate thinking abilities and practical skills involved in classroom inquiry.

The influence of teachers' perceptions of IBT on their inquiry practice was particularly evident due to teachers lacking understanding of inquiry and appropriate knowledge to implement IBT, and misconceptions of IBT. The following sections discuss these two issues specifically.

7.2.1 Lacking understanding of inquiry and pedagogical knowledge to implement IBT

This study found that, to different extents, the teachers in this study lacked an adequate understanding of inquiry and relevant knowledge to implement IBT. For this reason, their implementation of IBT often deviated from their intended plan. Pedagogical issues also emerged in this process.

Teachers' implementation of IBT was often distorted by their lack of appropriate understanding and pedagogical knowledge to guide student inquiry. In student inquiry, the type and amount of guidance given to students should be determined by teachers' intended learning outcomes and students' inquiry abilities (NRC, 2000). It is suggested that "The type and amount of structure can vary depending on what is needed to keep students productively engaged in pursuit of a learning outcome" (p. 136). A teacher should be able to identify what skills or information students lack and provide necessary support to assist student inquiry (Gabel, 2006). However, the teachers in the current study seldom considered their student inquiry abilities when deciding the type and amount of structure. For example, Ding provided a high level of structure to student inquiry and kept students' learning pace under her strong control. The inquiry activities were not challenging for her students who had relatively high inquiry abilities and a good understanding of inquiry. In other words, she gave more structure for student inquiry than was needed. Although she achieved her intended teaching objective, her implementation of IBT did not encourage group dynamics, critical and deep thinking, and student communication.

In contrast, Pan gave little guidance to student inquiry, regardless of students' lack of experience in conducting inquiry. He tended to think that student independence in inquiry meant giving minimal guidance to his students. However, his students had never been trained to conduct inquiry and their inquiry abilities were relatively low. Students need extensive experience and teachers' scaffolding to develop inquiry abilities and skills before moving to a higher level of inquiry (Bell et al., 2005; Banchi, & Bell, 2008; Llewellyn, 2011; NRC, 2000; Schwab, 1966). For Pan's students, as novice learners of inquiry, minimal guidance did not work. Consequently, most of his students failed to meet his expectations and he then switched to a highly structured approach in the follow-up inquiry activities.

Min provided another different example. On the one hand, Min suggested inquiry meant "students' autonomous learning" and defined the teacher's role as a guide. One the other hand, he felt it was difficult for him to determine how much guidance and clues should be given to student inquiry due to his students' very poor inquiry abilities. Min used guided inquiry in his class, but felt frustrated when he found that the students did not actively respond to his guidance. He then adapted it to a very structured approach to inquiry. Lacking appropriate knowledge of implementing IBT contributed to a discrepancy between his theoretical understanding of inquiry and the actual inquiry practice in his classroom.

Teachers' inquiry practice was also found to be distorted when they lacked appropriate understanding and pedagogical knowledge of IBT to deal with classroom uncertainty and unexpected situations. When implementing IBT, teachers need to anticipate and prepare for more classroom uncertainty and unexpected events. For example, students will give more unexpected answers because "problems arise when they attempt to apply this understanding [prior knowledge] to contexts that involve factors that they have not yet encountered or considered" (BSCS, 2005, p. 22). It could be a good opportunity to attack their misconceptions. However, when lacking this understanding and related pedagogical knowledge, the teachers could not use IBT effectively to develop students' thinking. In the current study, Min, Wen and Pan continued their teaching by avoiding, or giving little feedback to, students' unexpected answers. They did not accept all sincere student answers as valuable contributions to constructing understanding and improving learning. They did not appreciate that questions and answers from students truly reflected students' thinking. This kind of teacher behaviour discouraged students' active thinking and interest in participating in inquiry, and also violated the dynamics of IBT.

In addition, in many cases, teachers' inquiry practice was flawed due to their lack of appropriate understanding of teacher roles and student roles in student inquiry. IBT requires teachers to discard their traditional roles as "knowledge transmitters" to become "facilitators" of student learning (Fradd & Lee, 1999). Crawford (2000) further suggests a more expansive range of teacher roles necessitating more active and complex participation than that of a facilitator or guide. These roles included scientist, diagnostician, motivator, guide, innovator, monitor, mentor and collaborator. If teachers did not have an appropriate understanding of the teacher role and relevant skills, they could not effectively engage students in the kinds of cognitive processes used by scientists. In the current study, Pan gave little guidance to student inquiry, taking a role as an "observer" rather than a facilitator of student learning. Most of his students were unsuccessful in doing inquiry and the classroom fell into disorder. Zhao chose to be a "story-teller" and decided to use this approach to offer his students a vicarious, rather than authentic and direct, experience of inquiry. The consequence was that his students could not experience inquiry by themselves.

7.2.2 Misconceptions of IBT

The teachers in this study also demonstrated some misconceptions of IBT. With misconceptions, they interpreted, redefined, and distorted IBT in different ways. These misconceptions were found to cause significant obstacles to them using IBT successfully in classrooms.

A typical misconception was perceiving classroom inquiry to be a process of reproducing scientists' research work. This perception of classroom inquiry is much closer to a "scientist's inquiry" (inquiry in science) instead of a "classroom inquiry" (inquiry in the classroom). Li's statement is typical.

> I always want my students to go back to the time point when the scientist has not solved this question. I want them to do inquiry at the same level with the scientist. (Li-I)

Some of the teachers who did not differentiate the methods and thinking processes of practicing scientists ("scientists' inquiry", or inquiry in science) from the activities in an inquiry-based science classroom ("classroom inquiry", or inquiry in the classroom) often demonstrated this misconception. They, therefore, considered that conducting classroom inquiry was very difficult for students. For example, Lu stated that "it is impossible for them [students] to redo scientists' experiments and reconstruct laws". Consequently, he claimed that he did not have good ideas of how to use IBT. Zhao held that inquiry was so complicated for students that relying on students' thinking to do inquiry was not a scientific attitude. He, therefore, proposed a compromise that offered his students a vicarious experience of inquiry by telling them stories of scientists' inquiry, instead of designing classroom activities for students to experience inquiry.

A related misconception of IBT tended to perceive inquiry as students' independent (or autonomous) learning activities in which teachers gave minimal guidance or structure to student inquiry. This perception is much closer to open inquiry, or "discovery learning" (Bruner, 1961), rather than other approaches to inquiry.

There might be particular considerations that some of the teachers attached great importance to student independence or minimal guidance in inquiry. For example, Dong preferred to make inquiry more open. He explained,

> If the research method and equipment are prescribed… For students, this degree of openness is not enough. I don't think it is a real inquiry-based teaching. (Dong-I)

However, as discussed in the literature review, an open inquiry is not necessarily the most appropriate method of doing inquiry for students with different levels of inquiry abilities and inquiry understanding (Llewellyn, 2011). Depending on the student experience and abilities, all approaches to inquiry have their places in the classroom (NRC, 2000). A teacher should take into account his students' situation and decide an appropriate approach to inquiry.

Another misconception of IBT was about the understanding of how to use IBT. Jun perceived that the knowledge students learned in class was barely suitable for student inquiry because the knowledge was not "unknown". He said,

> He [student] has already constructed concepts before learning the knowledge. He is not absolutely ignorant of it. (Jun-I)

With this perception in mind, he generated more misunderstanding of inquiry. For example, he asserted that the question for inquiry "should not have been investigated before and must be generated by students themselves". Furthermore, he insisted that "it is difficult for teachers to generate such a question to let students inquire about in physics classrooms" and "an authentic inquiry is impossible to be conducted in the classroom". Finally, he decided that he only used IBT outside the classroom and let students inquire about questions that have never been investigated previously.

Lin was also confused about how to use IBT because she perceived that in inquiry, students had to "use new methods and new ideas which had not been previously considered and used". In this sense, she considered that "authentic inquiry-based teaching was quite rare". This perception was reinforced when some outsiders came to visit her class and offered similar comments. Therefore, she always doubted and felt wavering about her inquiry practices because of this understanding.

The above examples show that teachers' misconceptions often constituted barriers to their implementation of IBT. Similar misconceptions were identified in prior Chinese literature (Yuyong Wang & Chang, 2011; Zeng, 2004; C. Zhu, 2011). For example, Yuyong Wang and Chang (2011) reported that some physics teachers perceived that "all physics knowledge should be acquired through inquiry", ignoring the advantages of traditional teaching approaches. Some teachers "overemphasised the scientific processes, ignoring the importance of scientific knowledge and its application". Some teachers regarded "inquiry is a large number of questions", while ignoring the quality of questions. And some teachers tended to "downplay the important role of teacher in student inquiry" (p. 69). These studies and the current study show that many Chinese teachers usually emphasised one aspect of IBT in the classroom and considered that they were doing inquiry-based teaching, consequently their inquiry practice always turned out to be not effective.

Similar issues were also found in prior studies conducted in western countries. Reiff (2002) found that the pre-service teachers in her study had many misconceptions, such as misconceptions about who had control in the classroom, and the notion of a disparity between the scientific method and inquiry. These misconceptions were found to hinder their use of inquiry in science classrooms. R. Anderson (2002) claimed that "[inquiry teaching] is the one that means so many different things to different people, the one that is difficult for many people to visualize in actual practice, and the one that is so difficult for many teachers to put into successful practice" (p. 3).

7.2.3 Summary

Costenson and Lawson (1986) suggest that a precise understanding of scientific inquiry and being skilled in inquiry teaching strategies, along with sufficient understanding of the structure of knowledge, were crucial ingredients of implementing inquiry in the classroom. They argued, "Lacking this knowledge and skills, teachers are left with little choice but to teach facts in the less effective expository way" (p. 158). The current study supported this argument by suggesting that teachers' implementation of inquiry-based instruction was often distorted by teachers' lack of appropriate understanding and pedagogical knowledge to implement IBT, and their misconceptions of IBT.

These findings were consistent with previous Chinese studies (Hong, 2006; F. Li, 2010; G. Liu, 2004; Y. Zhao, 2011) showing a common issue among Chinese physics teachers that they were not adequately prepared, either in understanding and pedagogical knowledge of inquiry, or in practical experience, for implementing IBT effectively. In the current study, the findings from surveys, interviews, classroom observations provided evidence for this argument. The findings showed that these teachers acquired information and knowledge of inquiry and IBT mainly from the curriculum standards and the textbooks, sometimes from the internet. They accumulated experience mainly from observing other teachers' lessons (public classes) and limited times of delivering exemplary lessons, while seldom having chances to participate in workshops, research projects, or conferences. Although the teachers had some theoretical understanding of the process of inquiry, interviews and classroom observations found that most of them had not developed an adequate practical understanding and pedagogical knowledge to incorporate IBT into their classroom teaching. Furthermore, most teachers were left to their own devices to try this new teaching approach, and seldom provided with extra pedagogical support from experienced teachers and experts (in the area of IBT). In this situation, they might encounter great difficulties developing appropriate pedagogy to transform their subject knowledge into effective teaching using IBT.

This issue was not unique to the Chinese context. For example, it was reported that in the United States, "most teachers have not had opportunities to learn science through inquiry or to conduct scientific inquiries themselves. Nor do many teachers have the understanding and skills they need to use inquiry thoughtfully and appropriately in their classrooms" (NRC, 2000, p. 87). It suggested that the reason for teachers failing to use inquiry effectively has to do with the lack of adequate understanding and knowledge to implement IBT.

These findings and similar results from prior studies stressed the importance of appropriate understanding and pedagogical knowledge of inquiry to implement IBT effectively, and entailed appropriate professional development for teachers' success in implementing IBT. Its implication is further discussed in the next chapter.

7.3 How are Teachers' Perceptions of IBT Related to their Beliefs?

This study found that teachers interpreted inquiry and incorporated IBT into their regular teaching in ways that matched their beliefs about science, teaching and learning, and the teaching context. Teachers' beliefs strongly affected how they perceived inquiry and IBT. Ding, for example, believed that achieving a correct conclusion was essential. She insisted that student inquiry had to be performed on the premise of reaching correct conclusions. In contrast, Wen attached more emphasis to the methods and the process of learning than achieving results. Therefore, she gave much of her instructional attention to the students' process of doing inquiry.

Research indicates that teachers' beliefs help them to develop "practical theories of teaching" (Fox, 1983; Sanders & McCutcheon, 1986), which are mostly concerned about the fulfilment of their teaching goals. Teachers develop and change their teaching theories through a "process of practice-centred inquiry" (Sanders & McCutcheon, 1986, p. 60). This process consists of "a teacher deciding whether a new teaching is valuable and plausible", "testing the idea out in her classroom", "reflecting on the experience and its results", and if satisfied, "incorporating the idea into her conception of effective teaching" (pp. 60-61). They suggest that using these practical theories of teaching, a new teaching idea is assessed, examined, and tested. Only if it is determined as valuable and plausible, will it be accepted and tested out in their classrooms. Otherwise, it will be rejected or modified before being tested.

In the current study, the case study teachers continuously assessed the effectiveness of IBT by their theories of teaching during their implementation of IBT. The conclusions they achieved from their own assessment further affected their instructional decisions in the future. For example, Pan provided minimal guidance to his students at the beginning of his lesson and then switched to a structured approach to inquiry when he found minimal guidance did not work well. After class, he commented that his teaching was not effective because the classroom was in disorder and his students were not successful in doing inquiry. He explained that it was because he set too high a requirement for his students' inquiry ability and the latter were not capable of doing inquiry. Apparently, Pan used his beliefs about physics teaching and the nature of his students to explain his unproductive inquiry practice rather than his improper use of inquiry.

It is apparent that teachers' perceptions of IBT relied more on their beliefs about how physics should be taught to achieve their teaching objectives in their teaching contexts, rather than the theoretical understanding of inquiry. In other words, teachers interpreted inquiry in a way that accommodated their understanding of inquiry into their belief systems. This argument was supported by the assertion of Pajares (1992) that beliefs strongly influence perception and beliefs make teachers the filter through which new knowledge is interpreted and, subsequently, integrated in existing belief construct.

7.4 What is the Relationship between Teachers' Beliefs and their Inquiry Practice?

The findings of this study offer important insights related to the literature about the relationship between teachers' beliefs and their inquiry practice.

The major finding is that teacher beliefs about the nature of science, teaching, and learning, interacted together to influence teachers' instructional decisions regarding the use of IBT. These beliefs often acted as personal pedagogies to guide instructional decisions.

Teachers developed their beliefs about the nature of students, how they teach, and how students learn, to make sense of their teaching context. In the current study, teachers demonstrated strong beliefs about how senior secondary physics should be taught to their students in their schools, and indicated that their ways of teaching were effective. These contextualised beliefs, gained from their own earlier school experience and many years of teaching practice in their unique teaching contexts, had the most tangible influence on their implementation of IBT. This finding reinforced the statement proposed by Nespor (1987) to explain how beliefs become personal pedagogies or theories to guide teachers' practices:

> The answer suggested here is that the contexts and environments within which teachers work, and many of the problems they encounter, are ill-defined and deeply entangled, and that beliefs are peculiarly suited for making sense of such contexts. (p. 324)

The current study proposes a further explanation for the influence of beliefs by highlighting the significance of personal judgement and evaluation. It is argued that teachers' beliefs justified their pedagogical values, helping themselves legitimate their instructional choices. For example, Zhao argued that, "the teacher is the only one who understands his own teaching goals and intentions". Ding stated, "Every teacher makes individual judgements on the objectives and the value of his/her own teaching", and these judgements were "hard to change". Lu claimed,

> I do not think there is a unified standard [of teaching]. The main point is that we feel comfortable with the way we teach. As long as we feel comfortable, and students have mastered the knowledge, basically, I think, this approach is the best. There is no fixed way of teaching, but appropriate ways. (Lu-I)

These examples support the above argument that the teacher beliefs affirmed their pedagogical values, and legitimated their instructional decisions. This argument is also supported by prior literature. Pajares (1992) explains that beliefs "provide personal meaning and assist in defining relevancy" (p. 317). Mansour (2009) argued that "teachers are pragmatic, and may establish or validate their beliefs in context-specific environments where their instructional experience is successful" (p.33).

The above results of the current study support a considerable body of literature conducted in western countries that found the important influence of teachers' beliefs on their teaching practice (Brickhouse & Bodner, 1992; Brickhouse, 1990; Crawford, 2000, 2007; Cronin-Jones, 1991; Gallagher, 1991; Hashweh, 1996; Haney & McArthur, 2002; Lotter et al., 2007; Pope & Gilbert, 1983; Tobin & McRobbie, 1996; Wallace & Kang, 2004).

On the other hand, this study shows evidence for that the teachers' inquiry practice had mutual influences on their beliefs. Teachers' beliefs might be reinforced or modified by their actual practice of IBT. In addition, teachers' experience of implementing IBT would be accumulated to facilitate their understanding of IBT. For example, Jun changed his perceptions of IBT, when he found IBT was always unproductive when conducted in classrooms while effective when he brought students to do outdoor investigations. He then switched to a belief that an authentic inquiry has to be conducted outside the classroom and classroom teaching should be transmissive teaching. Pan felt frustrated when he found that the classroom was in chaos and his students were "lost" in inquiry. This inquiry practice reinforced two of his prior perceptions that "it was very difficult for his students to conduct inquiry", and that "inquiry should fit the students' situation".

These findings align with previous literature (Levitt, 2001; Fang, 1996; Mansour, 2009; Munby, Cunningham, & Lock, 2000; Tobin & McRobbie, 1996), finding that the relationship between teachers' beliefs and their instructional practices was not unidirectional. For example, Levitt (2001) revealed that beliefs and practices of the teachers in his study changed in a reciprocal way through implementation of the curriculum models. Carter and Doyle (1996) suggested that learning to teach is a very personal adventure in which beliefs about teaching are either negotiated or reinforced in field experiences.

In all, the above findings of the current study suggest that the relationship between teachers' beliefs and their instructional practices was complex. Teacher beliefs significantly influenced teachers' implementation of IBT, while teachers' inquiry practice might reinforce and modify their prior beliefs, and help construct their understanding of IBT.

The following sections specifically discuss the influence of teachers' beliefs about the nature of science, teaching and learning, and beliefs about effective teaching, on their implementation of IBT.

Beliefs about the nature of science, teaching, and learning

This study found that teachers' beliefs about the nature of science, teaching, and learning were closely aligned (or nested), and these nested beliefs influenced teachers' perceptions of inquiry and their instructional decisions regarding the use of IBT. This argument bolstered prior literature showing that teachers' beliefs are complex and nested (Bryan, 2003; Tsai, 2002). The current study also extends their findings, suggesting that these nested beliefs affect teachers' perceptions and practice of inquiry-based instruction. For example, Lu perceived senior secondary physics as a model-based subject that required students to "use idealization to construct scientific models". He suggested that "whichever strategy teachers employed was to help students construct physics models". He argued "this process was impossible to occur naturally in real life and thus it was very difficult for students to do experiments without teachers excluding the external disturbance in advance". Consequently, he perceived that inquiry activities "were limited by many conditions and difficult to complete [in the laboratory]", and insisted that he did not have good ideas to implement IBT. He decided not to use IBT in his classrooms. In contrast, Ding's beliefs about the nature of science, teaching, and learning were found to be in favour of inquiry, and she showed more passion for implementing IBT and used more effective strategies to guide and manage student inquiry in her lesson.

The current study also found that teachers' beliefs were sometimes conflicting. These conflicting beliefs had opposite effects on their implementation of IBT. In the study, all teachers held some beliefs that espouse the spirit of inquiry. For example, physics is an experiment-based school subject; and using experiment and practice can foster students' interest, understanding, manipulative skills, and collaborative skills, and more. Meanwhile, they believed that preparing students for examination and maintaining efficiency in covering the required content were overarching goals for teaching, which acted as the main constraints for their implementation of IBT. This finding is consistent with those of prior studies conducted in western countries (Bryan, 2003; Crawford, 2007; Tobin, McRobbie & R. Anderson, 1997; Wallace & Kang, 2004) showing that beginning and prospective teachers often hold competing sets of beliefs that influence their instructional decisions. For example, Wallace and Kang (2004) found the six prospective teachers in their study held two competing sets of beliefs that exerted different influences on their implementation of inquiry. They suggested that the first belief strand appears to stem from school culture and centres on constraining factors that limit inquiry, and another strand of teacher beliefs based on the individual teacher's notion of successful science learning that work to promote inquiry.

Furthermore, individual teachers' beliefs varied significantly. Their beliefs can be stimulations or obstacles to their intention to implement IBT. For example, science teachers who held that students learned from experience (Yao, for example) planned to use varied teaching strategies to develop students' conceptual understanding. Science teachers who thought that learning had to achieve right conclusions (Ding, for example) tended to pay less instructional attention to the process of doing inquiry. This finding echoed those of previous studies (Crawford, 2007; Lotter et al., 2007; Wallace & Kang, 2004) showing various influences resulted from different beliefs.

Beliefs about effective teaching

Although the influences of the teacher beliefs were complex and inextricable, this study found that teachers' beliefs about effective teaching played a vital role in their instructional decisions and inquiry practice. In this study, the researcher perceived teachers' beliefs about effective teaching as a compound belief structure, because it involves the interactions between teachers' beliefs about the nature of science, teaching, and learning, and their instructional knowledge developed over many years of teaching in their specific teaching contexts. These interactions affected teachers' beliefs about what constituted effective teaching and how to conduct effective teaching.

Teacher developed individual beliefs about how senior secondary physics should be taught to their students to effectively achieve their teaching objectives in their teaching contexts. These beliefs about effective teaching have significant influence on teachers' implementation of IBT. The influence might be positive or negative. For example, Ding stated that to conduct effective teaching teachers should "help students develop a good and open habit of mind". She suggested that to deliver effective teaching teachers should employ some important teaching skills such as interacting with students using questioning, observing students' discussions, designing appropriate questions, and adjusting instruction to individual differences to keep students on task. These beliefs were consistent with the essential elements of inquiry-based instruction, and supported her use of inquiry-based instructional strategies. In contrast, Pan maintained that specific instruction, along with drill training, were the most suitable approaches to teaching for his students. His beliefs about effective teaching were at odds with inquiry instruction and constrained his intention to implement IBT.

These findings aligned with prior literature (Cornett et al., 1990; Crawford, 2000; Lotter et al., 2007) showing that beliefs about effective teaching supported or constrained teachers' use of inquiry-based teaching strategies. For example, Dai, Gerbino, and Daley (2011) argued that if teachers are sceptical about the effectiveness of inquiry-based learning in achieving their teaching goals, they are likely to adhere to the traditional direct teaching approach.

To sum up, teachers' beliefs about the nature of science, teaching, and learning interacted together in their teaching contexts to influence their instructional decisions. This finding supported that of Lotter et al. (2007) showing how four core conceptions, including teachers' conceptions of science, their students, effective teaching practices, and the purpose of education, interacted together to influence the type and amount of inquiry instruction. The current study extends their finding by suggesting that teachers' beliefs are contextualised, so that the influences of beliefs on their implementation of inquiry varied in different teaching contexts. This finding is specifically discussed in later sections.

7.5 To what Extent does the Teaching Context in China Affect Teachers' Implementation of IBT?

The findings of this study draw attention to the influence of the teaching context in China on teachers' implementation of IBT. The teaching context can be envisioned as including the contextual factors within the school, and the wider sociocultural context in China. It was found that the teaching context in China had tangible influences on teachers' beliefs, their instructional decisions, and their inquiry practices in classrooms. The following sections discuss the influence of the school teaching context and the wider sociocultural context in China on teachers' enactment of IBT.

7.5.1 The influence of the teaching context within the school

The teaching context within the school affected teachers' beliefs about teaching and learning, and further their interpretation of IBT. The teachers in this study were very aware of the teaching context within their schools. They developed varied beliefs about how senior secondary physics should be taught to their students in their teaching contexts. These contextualised beliefs were found to be used as references by teachers for their interpretation of inquiry and IBT. For example, Ding argued that IBT "should be enacted on the premise that students are able to acquire a correct systematized body of knowledge". She explained that was because "Reaching the conclusion is more important in most cases because the [physic] law is the one that students have to master".

However, teachers formed two overarching beliefs which made sense of the "test-oriented education system" in China: preparing students well for examinations, and maintaining the efficiency of covering the prescribed teaching tasks in a limited teaching time. This finding was consistent with that of Tobin and McRobbie (1996), in which the authors defined four "cultural myths" as constraints to the enacted science curriculum, including teachers' beliefs about the transmission of knowledge, being efficient, maintaining the rigour of the curriculum, and preparing students to be successful in examinations. According to Tobin and McRobbie, "The meaning given to myth is not an idea that is wrong, but a belief that is a referent for intuitive actions in given social settings (p.225)". They also suggested that "some cultural myths take the form of restraints that are conceptualized as beliefs that given behaviors are appropriate to enable specific goals to be attained in the contexts that apply to action (p.226)". These similar findings indicate that these myths are shared by teachers and society alike, and hampering efforts at science education reform.

These contextual factors also influenced, positively or negatively, teachers' instructional decisions regarding the use of IBT. It is found that, the test-oriented student assessment system, limited teaching time, and the nature of students significantly constrained teachers' intentions to implement IBT. However, the influences of some of the contextual factors, for example, classroom culture school environment, and collegial influences, might be positive or negative to individual teachers.

The contextual factors further shaped teachers' inquiry practice. Similarly, the influences might positively or negatively contribute to effective inquiry practice. For example, the classroom culture was found to have positive or negative influences on the classroom discourse and learning environment. However, the nature of students was often found to negatively affect teachers' inquiry practice. These influences exacerbated the gap between teachers' intended inquiry practice and the real inquiry practice in the classroom.

These findings were consistent with prior studies (e.g., Mansour, 2009; Nespor, 1987; Pajares, 1992; Tobin & McRobbie, 1996) suggesting that teachers often developed contextualised beliefs about how schools operate, how teachers teach, and how students learn. Furthermore, the school context (the nature of students, classroom culture, school environment, and so forth) influenced teachers' instructional decisions (see, Crawford, 2007; McGinnis, Parker, & Graeber, 2004; Munby, Cunningham, & Lock, 2000; Rop, 2003; Roehrig & Luft, 2004; Tobin & McRobbie, 1996; Tobin, McRobbie, & Anderson, 1997; Wallace & Kang, 2004).

This study has identified a number of contextual factors within the school that influenced teachers' implementation of IBT. These included the curriculum and assessment system, the nature of students, classroom culture, school environment and collegial influences, and some practical factors such as the limited teaching time and resource constraints. These factors, individually or collectively, affected teachers' implementation of IBT. Among them, the test-oriented assessment system and limited teaching time were found to be particularly influential. However, these factors were associated with each other and their influences were inextricably intertwined. The following sections mainly discuss the influences of the test-oriented assessment system and limited teaching time, but also gave a considerable attention to other contextual factors which impacted teachers' implementation of IBT.

The influence of the test-oriented assessment system

The results from surveys, interviews and case studies show that teachers' concerns about the test-oriented assessment system were the main barrier to teachers' implementation of IBT.

Teachers suggested that the current assessment system focused on students' test scores rather than other outcomes that could be achieved by inquiry-based instruction. Although both acquiring knowledge and developing inquiry abilities and understanding were demanded by the curriculum standards, it was difficult to assess the latter using paper-based tests, and this was seldom attempted. Teachers, therefore, maintained that IBT was not in step with this test-oriented assessment system.

Furthermore, when “the existing school assessment criteria do not assess student understanding of processes and methods” (Zhao-I), students gaining high test scores seemed to be the only indicator of teachers’ teaching abilities. Teachers worried that “the teaching effects [of IBT] may be misunderstood” because “the students’ scores may not be high enough” (Zhao-I). Therefore, they committed to “coverage” because of a perceived need to prepare students for examinations. They cared about their students’ scores in examinations, particularly when their students’ scores were linked to administrators’ perceptions of their abilities to teach. Teachers tended to perceive risks associated with implementing IBT when it was not possible for them to resolve the conflicts between IBT and the test-oriented assessment system. As Ding argued, it was hard for teachers to strike a balance between teaching for test scores and teaching for developing inquiry abilities in the current assessment system.

This finding in the current study was not unique to the Chinese context. Prior research has identified similar issues in science teachers’ inquiry practice in western countries (e.g., Munby, Cunningham, & Lock, 2000; Savasci & Berlin, 2012; Tobin & McRobbie, 1996; Wallace & Kang, 2004). For example, Tobin and McRobbie (1996) described preparing students for exams as one “cultural myth” that acted as a constraint to the enacted curriculum in science teachers’ classrooms. These studies indicated that this issue has existed for the last two decades acting as a major barrier to teachers’ inquiry practice and has not been appropriately addressed.

However, the literature suggests that the status quo in Chinese teachers' classrooms is more severe than those of western countries. Student performance on matriculation examinations is treated as the most important criterion for assessing the quality of school education by parents and the society (Gao, 2007). Students’ scores on examinations [12] affected their teachers’ income – in almost all schools, the distribution of a bonus (a part of teachers’ incomes in China) among teachers was based on their students’ achievement in tests and examinations (Gao, 2007). “If the performance of students is not as good as expected, their teachers, principals and the head of the local government education department are all punished” (Gao & Watkins, 2002, p. 71). Furthermore, there is an enormous pressure, individually and collectively, to perform well in the high school and, later,

[12] These include mid-term tests and end-of-term tests that are organized externally. Among them, the two most important public examinations are the senior secondary school entrance exam and the college entrance exam.

college entrance examinations in order to get into better high schools and more prestigious colleges (Dai et al., 2011). This keen academic competition is not only due to the rigid assessment system, but also results from the large population in China, and the sociocultural values that the society attributes to higher test scores and higher education. For example, gaining more knowledge is regarded as a pathway for higher social status in society. Hard work and academic excellence are highly honoured. Students attend prestigious colleges in order to have high-status careers and make high incomes in the future (H. Chen, 2001). Students with high test scores are considered to be intelligent students, and teachers who can help students improve problem solving skills are considered to be good teachers (Qian, 2012). The influences of the sociocultural values of the society on teachers' implementation of IBT are further discussed later.

These results and the findings of the current study confirmed that test-oriented assessment system constituted the greatest barrier to Chinese teachers' implementation of IBT.

The influence of limited teaching time

As noted in the survey and the interviews, limited teaching time was another great concern that teachers reported to affect their implementation of IBT. This concern was closely associated with teacher's concern about the student assessment. Indeed, many teachers reported that IBT was time-consuming while the content of the syllabus had to be covered on schedule to meet the requirements of the unified examinations. They were generally not convinced of the efficiency of inquiry-based instruction in covering the required content in a limited time. Therefore, regardless of the evident benefits of inquiry for developing students' deep understanding, teachers did not intend to incorporate IBT into their regular teaching practice.

Teachers' concerns about teaching time, and other practical issues, such as resources and spaces, were often related to schools' resources management and administrators' attitudes towards physics as a school subject. The school incentives and resources often go with raising test scores (Dai, et al., 2011). However, it should be noted that the number of teaching hours provided was generally fixed because the teaching tasks were decided by the universal course curriculum rather than by the school. Therefore, all these teachers had similar numbers of teaching hours and similar teaching tasks, which could not be changed much by school administrators. The limited teaching time for prescribed teaching tasks, therefore, seriously restrained teachers' attempts to implement an unfamiliar teaching approach, say, IBT.

Similar issues were often found in previous Chinese studies (Dai et al., 2011; Qian, 2012; B. Zhang et al., 2003; Muju Zhu, 2007). Dai et al. (2011) argued that the traditional teaching approaches were apparently more efficient than IBT in producing immediate, tangible results (transmitting large amounts of information) that parents and schools would appreciate for “accountability” purposes, therefore many of the teachers may not feel compelled to try the new approach.

In this sense, curriculum reform is a prerequisite if teachers are required to switch from their familiar teaching modes to a new teaching approach. Taking feasible steps to reform curriculum and assessment system and enable schools to better manage resources and teaching hours would be effective to promote teachers’ implementation of IBT.

The influence of the nature of students

This study found that the nature of students affected teachers’ implementation of IBT, while the influence varied between key school and non-key school teachers.

The results from the surveys show that there was a significant difference in the influence of the nature of students with teachers’ intention to implement IBT between key school and non-key school teachers (see section 4.4.1, Table 4-1). The non-key school teachers were more than somewhat influenced by the nature of students, but the influence of the nature of students for key school teachers was weak.

The data from interviews and classroom observations extend understanding of this result. In interviews, non-key school teachers, for example, Pan and Min, showed more concern about the nature of their students (learning abilities, learning habits, interests, and so forth). They indicated that their intentions to implement IBT were often constrained by their students’ relatively low learning abilities and poor learning habits. Their inquiry practices were also found to be shaped by the nature of their students. Both Pan and Min switched to more structured approaches to inquiry in their lessons, when they found their designed guided inquiry did not work well due to their students’ low inquiry abilities.

On the other hand, for key school teachers, whose students’ abilities were relatively high, the nature of students was not a great concern for their teaching. However, they did not show a tendency to implement more IBT, or use more open methods to conduct inquiry, in their classrooms. For example, Wang felt that the ability of the students in his school “are at a relatively higher level” compared to students in other schools. Therefore, he stated that he “set higher requirements for students in the aspect of the process and methods”. Although these perceptions were in favour of inquiry-based instruction, he did not show great passion for using IBT. Similar situations occurred with other key school teachers. The classroom observations also supported these findings. For example, Ding's students were the most capable students in the district. While the nature of students appeared to favour inquiry-based instruction, Ding's did not use more open methods to conduct inquiry.

All of the above evidence from this study support two conclusions. First, teachers' concerns about the nature of students often constituted a great constraint to implementing IBT for teachers who taught students with relatively low learning abilities and poor learning habits (non-key school teachers). Second, for teachers whose students had relatively high abilities (key school teachers), the nature of students had a weak association with teachers' use of IBT.

The first finding is consistent with the observations made by some researchers in western countries (Crawford, 2007; Roehrig & Luft, 2004; Wallace & Kang, 2004) finding that teachers' beliefs about the nature of their students could constitute a great constraint for their use of inquiry-based instruction. It also supported the findings of prior Chinese studies (Dai et al., 2011; Y. Zhao, 2011) reporting that Chinese teachers' concerns about students' lack of knowledge and ability to handle the learning tasks were obstacles to the inquiry pedagogy.

The second finding has seldom been found in previous studies. The finding suggests that the nature of students in favour of inquiry-based instruction did not provide sufficient motivation for teachers to implement IBT. A plausible explanation for this phenomenon is that in the Chinese context, other factors, such as the pressure of a test-oriented assessment system, imposed greater negative effects on their tendency to use more IBT in classrooms.

The influence of classroom culture, school environment, and school community

This study found that classroom culture, school environment, and school community, could all positively or negatively influence teachers' perceptions and implementation of IBT.

Regarding classroom culture, teachers reflected that the communication styles of students and the learning climate of a class affected their perceptions of how IBT should be implemented in their classrooms and later, their instructional decision regarding the use of IBT. Furthermore, the classroom culture was found to affect the classroom discourse, and consequently affect the effect of teachers' implementation of IBT. For example, Wen found her three classes had different styles of communication, she modified instructional strategies after each lesson and generated impromptu instruction to better cater for her students in different classes. In addition, the positive relationship between Wen and her students encouraged teacher-students communication and engaged students in active learning. In contrast, Min reported that the negative learning environment in his classroom and the aloof relationships between teacher and students discouraged him to implement IBT with students. He felt it's very difficult to require his students to do inquiry. Furthermore, this negative classroom culture discouraged communication between Min and his students, negatively affected Min's mood and led to a change to his instructional practice.

School environment and school community might also exert positive or negative influence on teachers' perceptions and enactment of IBT. For example, Yao reported that the school environment in her school was beneficial to foster teachers' perceptions of inquiry-based instruction. The relationships among teachers were harmonious. The teachers in her school often sit together to communicate and discuss ideas about teaching. She found that this teaching context gave her positive impact on her teaching. In contrast, Min articulated that his intentions to implement IBT was greatly constrained by the school environment and his colleagues. He reported that in his school, the purpose of education was preparing students for examinations. Physics was not ascribed much value by the school administrators due to considerations of the tertiary enrolment rates. Teaching hours were cut down. Teachers' gave little attention to student experiments. Few public classes were organised. Students were not interested in learning physics and generally did not have appropriate learning objectives. Min felt helpless in this context. He reported that he sometimes had to change his ideas of teaching because teachers in his school were evaluated and compared by their students' test scores.

The influences of school environment and colleagues were found to be particularly significant with inexperienced teachers in this study. Wen and Xu, two student teachers, were both found to be easily affected by the school environment and the teaching styles of their mentors and colleagues. Wen stated that the practicum school attached considerable importance to student experiments. Her mentors and other teachers in this school gave her a lot of help, along with strict requirements, for planning her teaching. After working for a period of time in this school, she gradually made sense of the school environment and the nature of students. She developed teaching practices to be consistent with the requirements of her mentor (preferring IBT), the school culture (emphasising student experiments), and the nature of students (high-ability students). In this situation, she tried multiple methods to conduct guided inquiry and indicated that she would like to try more IBT in the future. Similarly, Xu reported that he changed instructional ideas and rewrote teaching plan after discussions with his mentor, when he came to the conclusion that his mentor did not like the way he originally planned to teach. He also changed his teaching strategies to suit for students in different classes.

These findings were consistent with those of prior research conducted in western countries (e, g., Fernandez et al., 2008; Nielsen, Barry, & Staab, 2008) showing that the positive classroom culture, school environment and collaboration between colleagues were important for teachers' success in implementing IBT. The current study extends their finding by suggesting that the classroom culture, together with some other contextual factors such as teaching time and the nature of students, further shaped teachers' inquiry practice, contributing to a distance between teachers' intended inquiry and the real instructional practice in the classroom. The inconsistency between teachers' beliefs and the practice was also noted by some prior researchers. Fang (1996) suggests that "the complexities of classroom life can constrain teachers' abilities to attend to their beliefs and provide instruction which aligns with their theoretical beliefs" (p. 53). Ajzen (2002) found that real-life factors, such as learner behaviours, time, resources, and course contents, could cause a mismatch between beliefs and practices. The distance between teachers' intended and real practice indicates the necessity to take feasible strategies to increase the positive, while decrease the negative, impacts of the contextual factors.

To sum up, all these findings and the similar results in prior studies suggest that teachers' beliefs and inquiry practice cannot be understood in isolation without considering the influence of contextual factors. The current study extends this understanding by paying attention to the positive or negative influences that the contextual factors may exert on teachers' enactment of IBT. In addition, the study suggests that contextual factors further shaped teachers' inquiry practice. As found in the study, some factors, such as the school environment, collegial influences, and classroom culture, had positive influences on some teachers' enactment of IBT. These findings contribute to the promising prospect of implementing IBT in Chinese physics teachers' regular teaching practice.

7.5.2 The influence of the wider sociocultural context in China

The study also highlighted the influence of the wider sociocultural context in China on teachers' beliefs and teachers' enactment of IBT, such as the influence of the cultural values of the parents, the public and the society. The tacit cultural values in Chinese secondary schools were affected by the wider sociocultural context because the societal forces inevitably situate the teachers' class in the larger context of an educational system.

In relation to teachers' perceptions of IBT, their teaching objectives and how they perceived IBT as an approach to achieving their teaching objectives were the central concerns. These perceptions reflected the value orientation of the current education system in the current social contexts of

China. By examining these teachers' intended teaching objectives and their inquiry practice, it was found they seemed not to see the procedural knowledge as being as important as the declarative knowledge because the former was difficult to assess by the current paper-based assessment system. In addition, teachers attached high value to problem-solving skills in order to achieve higher test scores. This value was reflected in their teaching objectives by helping students acquire conceptual knowledge and test skills to be prepared well for examinations. Meanwhile, these teachers seemed not to give IBT a high priority in their teaching because they did not see IBT as an effective approach to achieve their intended teaching objectives. Clearly, these perceptions of IBT were affected by the value orientation of the current evaluation system which did not provide incentives for promoting higher-order thinking skills and intellectual independence.

In addition, some of the teachers did not see inquiry-based learning as an approach to cultivating critical thinking and intellectual independence in the current social context in China. Zhao, for example, held a very pessimistic view of the social context in China. In his opinion, the current social context does not encourage independence and creativity, and IBT could not help resolve this issue. Pan saw IBT as an approach to proving teachers' abilities to teach, rather than a meaningful learning method for students. He might use it when outsiders come to observe his classroom. Jun perceived IBT as another educational fashion that comes and goes, and would not have a real effect on teachers' teaching. These teachers' perceptions were examples showing that they treated IBT as instruments rather than a meaningful approach both for teaching and learning. To some extent their perceptions reflected the pragmatic cultural values attached to education by the Chinese society – that teaching and learning are centred on the CEE. This situation was often reported by other Chinese researchers. Zhong, Cui, and Wu (2003) reported that "Teaching for exams, learning for exams" is very popular in primary and secondary schools. Qian (2012) found that 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.

The teachers' inquiry practices also drew attention to several influences of the cultural values of the Chinese society in the classroom. One issue was related to the amount of guidance and structure these teachers provided to their students' inquiries. As discussed earlier, teachers took more responsibility for students' learning in inquiry than was needed. Beyond the pragmatic reasons, such as time limits, and pedagogical issues, this situation implied that these teachers might not accept changes in their role to be less a source of information and more a facilitator of learning, and changes in the classroom atmosphere. This resistance to change partly reflected some of the current

Chinese classroom culture which was rooted in China's long history of Confucian ideology (Yang Chen, 1999; Salili, Zhou, & Hoosain, 2003). This ideology places the scholar in a place of prominence and prestige. In this cultural environment, intellectuals are highly respected (H. Chen, 2001). Teachers are perceived as the authority of knowledge and the moral models of students. Teachers are well respected by students and parents for these reasons. The classroom is expected to be hierarchical, orderly and quiet. Classroom activities focus on the maintenance of classroom order and the efficiency of transmission of knowledge, and little time is devoted to group and individual activities (C. Lee & Gerber, 1996).

In addition, Carson (2007) pointed out that the identities of Chinese teachers have been formed over many generations in a practice of "fixed knowledge, passive students, teacher-centred instruction, and centralized control through national examinations" (p. 5). Teachers' cultural positions impede them from completely adopting a student-centred teaching approach to let students experience scientific inquiry in which they create knowledge, rather than accept knowledge.

This situation also reflected a sense of anxiety among these teachers about entrusting the ownership of learning to their students in IBT. This kind of worry seemed to "mirror the attitude of Chinese parents towards their children as if they have to lead their children every step of the way" (Dai et al., 2011). Chinese educators have identified an effect of China's "One Child" policy, a unique situation not mirrored in other countries, on teachers' implementation of instructional change. Teachers generally felt that today's parents pay too much attention to their children (Hickey & Jin, 2007). In addition, the effect of China's "One Child" policy is also represented in parents' high expectations for their students' academic performance while caring too little for the latter's personal and social development (Hickey & Jin, 2007).

In the current study, some of the teachers reported the high expectations from the parents for teachers' teaching and students' learning outcomes. For example, Jun said that the parents of his students wanted him to assign more homework to his students. Lu reported that "all parents want their students to be intellectual elites in the future… They want to keep pace with the society and be afraid of falling behind ". Liu stated that it was impossible for them to ignore the parents' desire for students' high test scores, because it is "a social phenomenon that was decided by the current social context of China". Teachers stressed that they could not change this situation but accept that. Consequently, they decided to continue to use their regular lecture style of teaching, leaving few opportunities to try IBT.

Another cultural issue observed in this study was cultural conflicts arose in between teachers and students, which were found to constrain teachers' intention to implement IBT. In the current study, many teachers saw that learning physics is seeking for truth. They, however, found that most of their students took a utilitarian attitude towards learning, only interested in instant solutions and problem-solving skills, instead of the truth and the process of achieving truth. This cultural discrepancy between teachers and students dampened teachers' passion, more or less, for trying IBT.

These findings supported those of Chinese studies which gave attention to the cultural influences of the teaching context on teachers' instructional choices (e.g., Dai et al., 2011; Hickey & Jin, 2007; F. Liu, 2008). Hickey and Jin (2007) pointed out that, for many teachers, "the attitudes and behaviours of today's children were interpreted as violation of culture, rather than an evolution of culture" (p. 11). He suggested that differences in cultural beliefs between teachers and students broadened the generation gap. The generation gap has its most tangible impact on the teachers in their implementation of new pedagogy. Dai et al. (2011) pointed out the influence of performance pressure imposed by the high-stakes entrance exams and a sense of insecurity among the Chinese teachers in handling the uncertainties resulting from a more "open-ended" approach to teaching. They went further to discuss the issues of the value of the current assessment system and the values that were highlighted in inquiry including individuality, inquisitive minds, and intellectual independence. The current study extends their findings by providing a more comprehensive perspective through which to examine the influence of the teaching context in China on teachers' implementation of IBT.

7.5.3 Summary

It is found that the teaching context in China had tangible influences on teachers' beliefs about science teaching and learning, their instructional decisions regarding the use of IBT, and their inquiry practices in classrooms.

The teaching context can be envisioned as including the contextual factors within the school, and the wider sociocultural context in China. These contextual factors within school included the assessment system, the nature of students, school environment and collegial influences, classroom culture, practical factors such as time and resources. Among these contextual factors, the test-oriented student assessment system, limited teaching time, and the nature of students are found to significantly constrain teachers' intentions to implement IBT, whereas the influences of some contextual factors, for example, classroom culture, school environment and collegial influence, could be positive or negative to individual teachers.

Furthermore, it is found that the teaching context, such as the nature of students and the classroom culture, influenced the classroom discourse and learning environment, and further shaped teachers' inquiry practice. It exacerbated the gap between teachers' intended inquiry and the real inquiry practice in the classroom.

This study also draws attention to the powerful influences of the sociocultural context in China on teachers' perceptions and their implementation of IBT. It is found that the sociocultural values affected how parents, school administrators, teachers and students perceived the goals of education, the value of different learning objectives such as knowledge, skills, emotion and values, the value of inquiry, the ownership of learning, and so forth, and in turn constituted challenges for teachers' implementation of IBT.

These findings indicate that expectations for teachers' instructional changes should be based on how individuals make sense of and contribute to the situations in which they live and work.

7.6 Summary

In the light of the above discussion of the key findings of this study, a model is proposed for understanding Chinese physics teachers' inquiry practice in their unique teaching context (see Fig.7-1). The proposed model may help the readers to form an overall picture of how the Chinese physics teachers implemented IBT in the teaching context in China.

This model represents the complex relationships between teacher beliefs, perceptions of inquiry, and their inquiry practice in the classroom. It is suggested that teachers' beliefs act as personal pedagogies to guide their instructional decisions regarding the use of IBT, which in turn affect subsequent inquiry practices. The decision-making process includes a process of interpretation in which teachers matched their understanding of inquiry with their beliefs. The teaching context affects teachers' beliefs, as well as their instructional decisions. Teachers' prior experience plays vital roles in developing teachers' beliefs, their understanding of inquiry, and their pedagogical knowledge and skills for IBT.

There is a discrepancy, however, between teachers' intended inquiry practice (instructional decisions) and actual inquiry practice in their classrooms. The teaching context, teachers' perceptions of inquiry, and their pedagogical knowledge and skills for IBT affect the way in which their instructional decisions are put into effective inquiry practices. And finally, teachers' experience of implementing IBT is accumulated to facilitate their understanding of IBT.

As found in this study, these abovementioned factors might positively or negatively contribute to teachers' intention to implement IBT, as well as effective inquiry practices. These influences are represented by symbols of "+" and "-" respectively in this diagram. When the positive influences exceed the negative influences, teachers' instructional decisions tend to be in favour of an inquiry-based instruction, and teachers' inquiry practices tend to be more effective.

8. Conclusion and implication

8.1 Conclusions of this Study

The recent Chinese reform to the national secondary science curricula has made inquiry a compulsory component of teaching objectives. It encourages science teachers to provide their students with more inquiry experience, but has not provided ready-made models for implementing inquiry-based teaching (IBT). However, many Chinese science teachers are finding it very challenging to implement inquiry-based teaching (IBT) in their classrooms (B. Zhang, et al., 2003). These issues are mirrored in many other education systems in the world where IBT is mandated. Evidence suggests that teachers all over the world struggle to implement inquiry-based changes to their teaching practices (R. Anderson, 2002; Campbell, Oh, Shin & Zhang, 2010; Saad & BouJaoude, 2012).

Many Chinese scholars writing in the field of curriculum and instruction have attempted to find a solution to the problem of the limited uptake of IBT by science teachers by focusing on theory, for example, teacher roles in IBT, strategies, and instructional models for implementing IBT (e.g., Gao & Liang, 2002; He, 2002; Lu, 2005). On the other hand, the amount of research grounded in real classroom contexts is relatively small. Particularly, only a small number of these studies are related to senior secondary physics. Among the prior empirical studies, many of them are front-line teachers' self-reports of their experience in implementing IBT with regard to particular content (e.g., L. Zhang, 2004; S. Zhao, 2002； Meng Zhu, 2011). A small amount of studies pointed out that teachers' perceptions and knowledge about inquiry play an important role in their implementation of IBT (e.g., G. Liu, 2004; Y. Zhao, 2011). Little research attention, however, has been given to investigating teachers' beliefs, their motivations and reasons for implementing IBT. Furthermore, few of them investigated how teachers develop practice-oriented instructional models in their unique teaching contexts and incorporate IBT into their day-to-day teaching.

In response to the above identified issues, this study contributes to our understanding of the enactment of IBT in science classrooms by investigating Chinese secondary physics teachers' perceptions and implementation of IBT. A mixed-methods methodological approach has been employed to explore how teachers' beliefs about science teaching and learning, perceptions of IBT, and their inquiry practices interact in their unique teaching contexts. Using teacher surveys, in-depth semi-structured interviews and case studies, this study provides an insider's view to Chinese senior secondary physics teachers' perceptions and enactment of IBT.

The following sections present these findings in relation to the research questions of this study.

Question 1: How do Chinese physics teachers perceive IBT?

In this study, teachers demonstrated diverse understanding and knowledge of inquiry and how to conduct IBT. Regarding inquiry, teachers generally perceived that classroom inquiry was a process of thinking and doing science, while from different perspectives. They attached different values to the elements involved in inquiry. Meanwhile, they showed clear knowledge about the process of inquiry, which was consistent with the descriptions of the curriculum standards. These perceptions indicated that these teachers had developed a considerable degree of theoretical understanding of inquiry.

Teachers proposed various methods of conducting IBT in their classrooms. Their ideas reflected their thinking about how IBT would possibly work in their classrooms. Nevertheless, most of the teachers attached high value to teacher-guided, and experiments-based, instructional methods that incorporate IBT into their regular teaching practice. These findings indicated that teachers preferred, and/or felt more comfortable, to implement IBT using instructional models in which teachers control the classroom and student learning.

Teachers also reported a number of factors that influenced their instructional decisions regarding the use of IBT. These factors are pertaining to teachers' reflection on the subject matter, the curriculum, the nature of inquiry, their teaching, their students, and their teaching context. The most frequently reported factors were limited time for prescribed teaching tasks, the current assessment system, and the nature of students.

These findings and the results of prior studies in western countries (Crawford, 2000; Flick, 1995; Fradd & Lee, 1999; Keys & Kennedy, 1999) indicate that teachers formed individualised conceptions of inquiry and used these as a referent for science teaching in ways that may not match the conceptions of university researchers. However, these findings showed that teachers perceived and interpreted IBT in their specific teaching contexts.

Meanwhile, there were several issues in teachers' understanding of IBT. First, some of the teachers demonstrated misconceptions about inquiry. Second, teachers were generally not convinced of the efficiency of IBT in acquiring knowledge, particularly for the low-proficiency students. Third, some teachers did not see that the experiments in the textbook could not be used for IBT. Forth, some teachers articulated difficulties about how to conduct IBT. These issues indicate the importance of appropriated development for teachers' updating understanding and pedagogical knowledge of IBT.

Question 2: What are teachers' beliefs about the nature of science, teaching, and learning?

This study found that the case study teachers held complex, nested, and sometimes conflicting, beliefs about the nature of science, teaching, and learning.

On the one hand, teachers shared certain basic beliefs about the nature of the science and demonstrated common understandings about the means used to develop scientific ideas. Linking to physics as a secondary school subject, teachers perceived that physics was a school subject based on phenomena and experiments. Giving priority to phenomena and experiments and focusing on scientific methods to develop scientific understandings were their major perspectives of physics as a senior school subject. They also generally suggested that, for effective learning to take place, students need good habits of mind and interest. Students need observations and experiments to develop understanding of physics phenomena and scientific methods, as well as manipulative skills. Students also need to develop inquiry abilities and good habits of mind which will benefit their future lives.

On the other hand, most teachers indicated that science is a body of existing knowledge students need to acquire. To acquire knowledge, students need a lot of instruction and drill training. Teachers regarded teaching as transmitting knowledge and task-centred. Meanwhile, they believed that preparing students for examination and maintaining efficiency in covering the required content were overarching goals for their teaching.

Teachers differed in their beliefs about what constituted effective teaching. These beliefs, concerning how senior secondary physics should be taught to their students in their schools, were content-dependent and contextualised. These beliefs were affected by their prior experience and their teaching contexts. The significantly influential contextual factors seemed to be the student assessment system, limited teaching time, and the nature of their students. Teachers' beliefs about effective teaching reflected their ideas about what was the most appropriate way to teach physic in their specific contexts.

Question 3: How do Chinese physics teachers implement IBT in their specific teaching contexts?

The study finds that the case study teachers developed diverse inquiry practices, which shared some common pedagogical characteristics. A general *RSPIC* model of implementing IBT could be identified in teachers' teaching, with the most significant differences found in the process of classroom inquiry. Teachers preferred to use guided approaches to classroom inquiry, but they deployed their approaches differently, and some of them also tried other approaches to inquiry.

In addition, teachers managed different processes of classroom inquiry, and employed different strategies to guide and manage student inquiry, engaging students in all or some aspects of classroom inquiry. Teachers' expertise played an important role in their use of questioning strategies to guide student inquiry. Nevertheless, their strategies also demonstrated some common pedagogical features. Teachers seemed to provide a high level of structure to students' inquiry to keep students' learning under control. They generally used whole-class activities to engage all students in learning, and often employed questions and observation to check student progress.

The nuances of inquiry practice reveal that teachers interpreted and implemented IBT in their specific teaching contexts. The common pedagogical characteristics distinguish the instructional models of implementing IBT of these teachers, as a whole group, from those of science teachers in western countries.

The case studies indicate that teachers generally faced challenges and lacked adequate motivations for implementing more IBT in their regular teaching practices. However, they made great effort to make IBT work in their classrooms, by incorporating the features of inquiry into their regular teaching practices that centred on accomplishing teaching tasks. Issues were also identified in their inquiry-based instruction. It seemed that teachers created their own ways to conduct IBT to be consistent with their belief systems and the teaching contexts. These, however, may or may not be considered to be canonical and appropriate approaches to implementing IBT, and may not fit the curriculum planners' intentions in mandating IBT. However, they support the viewpoint of Keys and Bryan (2001) that "multiple modes of inquiry teaching and learning will invite teachers to engage in participating in inquiry in ways that match their own beliefs and teaching styles (p. 632)".

On the other hand, some critical issues, such as teacher-centred instruction, ineffective use of strategies of guiding student inquiry and questioning skills, were found in teachers' inquiry practice. These issues indicate that to different extent these teachers lacked an adequate understanding and experience of implementing IBT, and also lacked relevant pedagogical knowledge to manage and guide student inquiry. These issues also reveal the significant influences of the teaching context, such as limited teaching hours, needs to cover prescribed contents, and preparing for examinations, on their pedagogy to implement IBT. In order to boost teachers' chances of effective implementation of IBT, these issues need to be addressed appropriately.

Question 4: What are the relationships between teachers' beliefs, perceptions of IBT, and their implementation of IBT?

This study confirms that teachers' beliefs acted as "personal pedagogies or theories" to guide their instructional decisions regarding the use of IBT, which in turn affected their subsequent inquiry practices. Since teachers' beliefs about the nature of science, teaching, and learning were complex, nested, and sometimes conflicting, their influences on teachers' instructional decisions were often complex, inextricable, and sometimes opposite. Nevertheless, they interacted together to influence teachers' instructional decisions. Among them, the influence of teachers' beliefs about effective teaching was significant.

The decision-making process included a process of interpretation in which teachers matched their understanding of inquiry with their beliefs about science, teaching, and learning. This process of interpretations, or 'thick descriptions' (Geertz, 1973), of instructional innovation is generated in their unique teaching context, involving not only the complex classroom practice, but also teachers' personal positionality in a sociocultural and historical context. Teachers' prior experience played vital roles in developing teachers' beliefs, their understanding of inquiry, and their pedagogical knowledge and skills for IBT.

There is a discrepancy, however, found between teachers' intended inquiry practice (instructional decisions) and actual inquiry practice in their classrooms. The teaching context, teachers' perceptions of inquiry, and their pedagogical knowledge and skills for IBT affected the way in which their instructional decisions were put into effective inquiry practices.

This study also shows evidence that teachers' inquiry practice had mutual influences on their beliefs. Teachers' beliefs might be reinforced or modified by their actual practice of IBT. Their experience of implementing IBT would be accumulated to facilitate their understanding of IBT.

Question 5: To what extent does the teaching context in China influence teachers' implementation of IBT?

This study found that the teaching context in China had tangible influences on teachers' beliefs about science teaching and learning, their instructional decisions, and their inquiry practices in classrooms. The teaching context can be envisioned as including the contextual factors within the school, and the wider sociocultural context in China. The identified contextual factors within the school included the curriculum and assessment system, the nature of students, classroom culture, school environment and collegial influences, and some practical factors such as the limited teaching time and resource constraints.

The teaching context affected teachers' beliefs about teaching and learning, and further their interpretation of IBT. Teachers' developed vaired beliefs about how senior secondary physics should be taught to their students in their teaching contexts. Nevertheless, preparing students well for examinations, and maintaining the efficiency of covering the prescribed teaching tasks in a limited teaching time, were two common overarching beliefs. The contextualised beliefs were used as references by teachers for their interpretation of inquiry and IBT.

These contextual factors also influenced, positively or negatively, teachers' instructional decisions regarding the use of IBT. It is found that, the test-oriented assessment system, limited teaching time, and the nature of students significantly constrained teachers' intentions to implement IBT. However, the influences of some of the contextual factors, for example, classroom culture school environment, and collegial influences, might be positive or negative to individual teachers.

The teaching context further shaped teachers' inquiry practice. Similarly, these influences might positively or negatively contribute to effective inquiry practices. For example, the classroom culture was found to have positive or negative influences on the classroom discourse and learning environment. However, the nature of students were often found to negatively affect teachers' inquiry practice. These influences exacerbated the gap between teachers' intended inquiry practice and the real inquiry practice in the classroom.

The wider sociocultural context in China also had powerful influences on teachers' perceptions and implementation of IBT. In the current study, it was found that the sociocultural values affected how parents, school administrators, teachers and students perceived the goals of education, the value of different learning outcomes such as knowledge, skills, emotion and values, the value of inquiry, the ownership of learning, and so forth. These cultural values often constituted challenges to teachers' implementation of IBT. "Teaching for exams, and learning for exams" were typical responses of schools, parents, teachers, and students to the influences of the sociocultural context in China. Cultural conflicts were also observed in classrooms as results of differences in individuals' beliefs, values, and goals, which caused difficulties to teachers' implementation of IBT.

These findings suggest a comprehensive perspective through which Chinese senior secondary physics teachers' perceptions and implmention of IBT should be examined. Meanwhile, they highlight the importance of developing effective strategies to foster the positive influences and decrease the negative influences of the contextual factors on teachers' intentions to implement IBT.

Drawing together, these major findings of this study provide an overall picture of how Chinese physics teachers perceived and implemented IBT in the teaching context in China. It also highlights three compelling challenges that Chinese physics teachers encounter involving challenges due to changing belief, pedagogical challenges, and cultural challenges for their use of IBT.

8.2 Implications of this Study

This study, particularly the case studies with five secondary physics teachers, has provided a useful perspective of viewing Chinese secondary teachers' perceptions and implementation of inquiry-based teaching. It reveals that Chinese physics teachers interpreted IBT in a way to be compatible with their belief system. They developed instructional practices that best suited their purpose of teaching in their specific contexts. Noting the nuances of inquiry practice among teachers, and the differences between teacher-developed instructional models and theoretically-driven models, this study suggests the significance of devoting attention to teachers as "mediators of school reform" (Olsen & Kirtman, 2002) for transmitting the inquiry-based curriculum reform initiatives into classroom practice. This study points out that several compelling challenges teachers encounter need to be appropriately addressed in order to improve their success implementing IBT. A number of educational implications can be also drawn from the findings of this study for teacher professional development and curriculum development.

8.2.1 The challenges the Chinese physics teachers encounter in implementation of IBT

This study reveals that some of the teacher beliefs and perceptions, pedagogical knowledge and skills, and a number of contextual factors worked against teachers taking up opportunities to implement IBT. This study, therefore, highlights three compelling challenges that Chinese physics teachers encounter in their use of IBT: challenges due to changing belief, pedagogy challenges, and cultural challenges.

Challenges due to changing belief

Implementing IBT requires that science teachers understand, appreciate and embrace this teaching approach. In the current study, many teachers expressed a set of traditional beliefs about science, teaching and learning which was not in favour of IBT. This situation entails belief change. As Richardson and Placier (2001) suggested, in order to enhance instructional change, teachers need to reflect upon their own epistemologies and undergo fundamental transformation of their thinking about teaching and learning. However, changing teachers' beliefs is a complex and challenging process (Hall & Loucks, 1982; Lortie, 1975; Nespor, 1987; Pajares, 1992).

Pedagogical challenges

The complex, multifaceted nature of inquiry can make inquiry a challenging method to implement (Gabel, 2006; Vanosdall, R., Klentschy, Hedges, & Weisbaum, 2007). In the current study, the teachers generally did not show a deep understanding of inquiry, and some of them lacked the appropriate pedagogical knowledge essential for assisting students to conduct a successful classroom inquiry. As teachers move outside their "comfort zone" to develop new instructional practices, they will inevitably encounter a great pedagogical challenge to be able to confidently and properly applying IBT into their practice.

Cultural challenges

In the current study, the teaching context in China brought sociocultural influences to bear on teachers' beliefs and instructional practice. These identified cultural influences highlight the unique cultural challenges Chinese teachers encountered in their implementation of IBT. Teachers encounter cultural conflicts because implementing IBT challenges teachers' cultural positions that "have been formed within the confines of the previous curriculum" (Carson, 2007, p.5). In addition, teachers face challenges when they try to change the classroom culture in order to actively engage students in authentic science activities. These challenges are how to create instruction in which "a classroom culture is fostered, that allows students to experience 'science in the making', in combination with a curriculum that helps students develop conceptual understanding" (Kock, Taconis, Bolhuis, & Gravemeijer, 2013, p.581). In a sense, these cultural challenges entail a system reform including a change in classroom culture on the one hand, and curriculum and assessment reform on the other hand.

These three identified challenges provide significant implications for teacher professional development and the curricula reform in China. They reinforce the importance of appropriate professional development for teachers' success implementing IBT. In addition, these challenges call for a sociocultural perspective through which the curriculum system is evaluated, reformed, and developed.

8.2.2 Implications for teacher professional development

This study suggests that professional development should encourage teachers to seriously examine their own instructional practice in relation to their beliefs about teaching and learning science, and determine what they really need. Teachers need to see the value and benefit of implementing IBT, both to themselves and students, to embrace the inquiry-based curriculum reform initiatives. It is impractical to expect teachers to embrace IBT on faith alone or because of the top-down curricular mandation (Crawford, 2007). Richardson and Placier (2001) suggest that science teachers need to reflect upon their own epistemologies and undergo fundamental transformation of their thinking about teaching and learning in order to change. Therefore, teachers should be allowed to reflect upon their own teaching beliefs and instructional practice, know the difficulties, understand and evaluate the benefits of inquiry-based instruction, and then make a cautious choice. As Lotter et al., (2007) suggest, only when the teachers' conceptions aligned with the professional development goals or the teachers were dissatisfied with their current instruction, were changes made to their practice.

In addition, appropriate professional development should help teachers understand the essential features of inquiry and apply it to their unique teaching contexts. This includes opportunities to work collaboratively with colleagues, experts, university researchers, and curriculum developers, to develop their own effective instructional models to implement IBT (Keys & Bryan, 2001; van Driel et al., 2008), for example, developing, testing out, and modifying a whole unit of teaching plans based on their classroom situations. These suggestions were supported by prior research. It was suggested that it is important for teachers to understand inquiry, develop their skills of inquiry, learn science concepts through inquiry, and learn how to teach this way (Crawford, 2007; Gabel, 2006; NRC, 2000). Appropriate professional development that extends teachers' own inquires to the implications for their teaching, or is designed especially to help teachers teach through inquiry, will help teachers to achieve these ends (NRC, 2000). Teacher learning might be more likely to occur through practical experiences within teachers' own classrooms or through interactions with colleagues within a school's culture (Cochran-Smith & Lytle, 2001; Munby, Russell, & Martin, 2001). Community dialogue is important in allowing teachers to start collaboratively analysing the relationship between their teaching intentions and their practices. Such dialogue may lead to collective action among teachers (Gitlin, 1990). Collaborative reflection in the research relationship was portrayed as a means of empowering teachers to examine their beliefs and make changes to their practice to be more congruent with reform initiatives (Lynch, 1997; Parke & Coble, 1997; Tobin, Briscoe, & Holman, 1990; Tobin & LaMaster, 1995). Richardson and Placier (2001) endorse this view by stating that this process can be enhanced through dialogue, particularly dialogue with those who understand existing practices and the particular context in which one is working, which helps teachers to realise their own tacit beliefs and understandings, and then begin to question their beliefs and practices and consider change.

This study also suggests that science teachers need to be provided with sustained and systematic professional development to improve their use of inquiry. The pedagogical issues found in the participating teachers' inquiry practice reveal that the teachers were not adequately prepared, either in knowledge and understanding of inquiry, or in practical experience, for confidently and regularly implementing IBT in their practice. Teachers proposed different demands for professional development, including theory support, advice for practice, and information support, regarding how to use IBT in their own practice. In addition, it was found that the professional development provided to these teachers was often piecemeal and fragmented. Research has suggested that professional development must be sustained and sufficient amount of time spent on the professional development activities is one of the important characteristics of effective professional development (Blank, de las Alas, & Smith, 2008; Desimone, Porter, Garet, Yoon, & Birman, 2002; Garet, Porter, Desimone, Birman, & Yoon, 2001; Marshall & Smart, 2013; T. Smith et al., 2007; Supovitz & Turner, 2000).

In order to improve teachers' success in implementing IBT, the researcher of this study argues that the science teachers, prospective and inexperienced teachers in particular, need to be provided with appropriate, sustained, system, and contextualised professional development. It helps them to examine and reflect upon their beliefs of teaching and learning, update their knowledge and skills of using inquiry, change attitudes towards IBT, extend their understanding of inquiry to their teaching practices, and accumulate successful experience of using inquiry instruction in their teaching contexts.

8.2.3 Implications for curriculum reform

This study proposed that science curriculum reformers should appropriately address issues related to teachers' beliefs and knowledge, practical constraints and cultural factors when developing new curricula, and provide more tangible and systematic support for teachers to adopt and implement the new curriculum successfully.

First, the curriculum reformers should communicate, consult, and cooperate with science teachers when developing new curricula, and provide effective scaffolding to teachers when testing and implementing new curricula. This study found that teachers interpreted and adapted inquiry-based instruction in a way compatible to their belief system. There is a great discrepancy between the intent of the curriculum developers and teachers' understanding of the curriculum in their classroom context. Research has shown that disconnection between curriculum theory and teachers' understanding impeded science curriculum reform. Yerrick et al. (1997) argued that teachers do not develop their knowledge of teaching through abstract reflection upon teaching removed from the context of school. Fernandez et al. (2008) also point out that without planning for teachers' participation in the negotiation of curriculum meanings, curriculum developers themselves become marginalized, and the new curriculum they have developed will be adopted in unanticipated ways. In contrast, Ben-Chaim, Joffe, and Zoller (1994) reported positive efforts of collaborating with teachers in the decision-making and planning of science curriculum innovation and in determining the goals of their science instruction. Therefore, the current study highlights the importance of listening to science teachers' voice of understanding science teaching and learning, and argues that teachers' knowledge of classroom practice should not be overlooked.

Second, developing an effective assessment system to relate student performance to teachers' inquiry-based instruction is essential. Teachers' efforts to implement IBT needs to be evaluated and rewarded. Although the curriculum reform has already mandated "a new assessment system characterised by multiple assessment indicators and multiple ways of assessment, which takes both outcome and process into account" (Poisson, 2001, p. 17), the curriculum reform did not provide an effective mechanism to promote teachers' implementation of IBT. Since teachers' concerns that affected their implementation of IBT were tightly associated with the student assessment system, taking feasible steps to reform the student assessment system and help teachers develop effective assessment strategies would be an effective way to promote teachers' implementation of IBT.

Third, the curriculum reformers should take into account the practical constraints and cultural issues in the current Chinese social context when testing out new educational ideas, and take effective strategies to increase the successful implementation. Indeed, this study and prior Chinese studies (Dai et al., 2011; Qian, 2012; B. Zhang, et al., 2003; Y. Zhao, 2011) have addressed practical constraints and several cultural challenges encountered in teachers' implementation of IBT. Therefore, effective strategies should include increasing the impact of factors for success while reducing the impact of factors for failure. For example, allowing and encouraging teachers to collaborate with colleagues, school administrators, and curriculum developers to develop school-based curriculum and conduct research-based projects. This strategy could effectively foster the collaborative teacher culture which will improve teachers' implementation of the new curriculum (Cui, 2006; Ma & Xiong, 2007). Effective strategies should also include helping build a supportive school and community environment in which professional development is designed and enacted to help teachers improve their instruction. For instructional change to occur, professional development must be accompanied by a supportive school and community environment (Cohen & Ball, 2001; Powell & Anderson, 2002). Research has shown instructional interventions that were designed and launched as though they were independent of the environments often failed to achieve their goals (Cohen & Ball, 2001).

In all, this study suggests that to scaffold science teachers' implementation of IBT requires a systematic project. This project should include appropriate, sustained, and contextualised, professional development programs and multiple resources to scaffold teachers' efforts at updating beliefs and pedagogical knowledge to implement IBT, along with reforms to the student assessment system, and strategies to address practical constraints and cultural issues.

8.3 Limitations of this Study

Several limitations exist as a result of the study. First, the limited times of classroom observations constitute a limitation of this study. It is hard to determine whether the observed instruction is representative of the general inquiry practice implemented by the observed teachers when the researcher is absent from their classrooms. Furthermore, it is difficult to exclude the impact of the researcher from the observed classrooms on teachers' and students' behaviours. To make up for these shortcomings, the researcher spent time on communicating and building good relationships with the observed teachers and students, and endeavoured to describe and interpret observed instructional practice in a context that takes account of my presence. In addition, sufficient details of teaching and learning activities and examples of classroom vignettes are presented so that the readers are able to make sense of how these Chinese teachers used IBT in a manner of incorporating inquiry into their day-to-day teaching practices.

Second, this study did not assess the effectiveness of teachers' instructional models of implementing IBT. This research decision is based on a consideration that it is difficult to determine whether their models have immediate consequences on students' learning outcomes given a short-term study. Their impact on students' learning outcomes, in terms of test scores or understanding, might take effect gradually. While this omission of students' achievement might contribute to an incomplete understanding of this issue, it suggests the significance of further investigations on the effectiveness of teacher-developed instructional models of implementing IBT.

Third, the selected schools are in a major city of China, and therefore are not representative of all schools in China, particularly schools in more rural areas of the country. Furthermore, the data are context dependent, related to the subject matter, schools, students and teachers themselves. The findings could not be simply generalised to other situations, however sufficient detail and demographic information were included so that readers will be able to identify features of the study that are relevant to their own contexts.

8.4 Future Research Directions

This study provides five teachers' profiles, describing how teachers' beliefs, perceptions of inquiry, and inquiry practices interacted in their teaching contexts. These profiles may be used as references for future research studying on IBT and teacher professional development. Future research may reflect on what aspects of IBT the teachers need to be facilitated and further design appropriate professional development; future research may also compare these teachers' profiles in depth with teachers in other teaching contexts, western countries for example, and summarise the elements for successful implementation of IBT.

Also, as stated above, this study did not assess the effectiveness of teachers' instructional models of implementing IBT. It suggests the significance of further investigation on the effectiveness of teacher-developed instructional models of implementing IBT. It would be also valuable to compare the effectiveness of teacher-developed models with researcher-developed instructional models.

8.5 Final Summary

This study contributes to international knowledge in science education by offering deeper and more detailed insights into Chinese senior secondary physics teachers' perceptions and implementation of IBT. Particularly, it adds to the existing body of research on classroom enactment of inquiry-based teaching by providing five contrasting cases, describing how teachers' beliefs, perceptions of inquiry, and inquiry practices interacted in their teaching contexts, and how teachers develop and adapt inquiry-based instruction for their specific teaching contexts.

This study suggests that it is possible and practical to implement IBT in the teaching context in China. Teachers' instruction, however, was often constrained by their beliefs and their teaching contexts, and distorted by their misconceptions and lack of pedagogical knowledge about inquiry. Nevertheless, teachers in this study developed their own inquiry-based instructional models to incorporate inquiry into their teaching practice, giving both attention to developing student inquiry abilities and completing teaching tasks. The differences between these teacher-developed instructional models and those researcher-developed instructional models in the literature establish the value of researching how teachers design and adapt inquiry-based instruction to their unique contexts. It further suggests the importance of helping teachers develop their own effective instructional models to implement IBT for their unique teaching contexts.

This study reveals three compelling challenges encountered in Chinese science teachers' implementation of IBT, including challenges due to changing beliefs, pedagogy challenges, and cultural challenges. These provide valuable information that can help researchers, teacher educators, and curriculum designers support teachers' implementation of IBT. For the purpose of inquiry-based teaching becoming a more common and effective approach to teaching that leads to improved levels of scientific literacy for all students (MOE, 2006a, 2006b), these challenges need to be appropriately addressed in order to improve teachers' success in implementing IBT.

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Appendixes

Appendix A

The Status of Inquiry-Based Teaching in Secondary Senior Physics
(Chinese version was used in this study.)

Q1. During you implementation of inquiry-based teaching, which of the following approaches have you used most often? *(Please circle only one letter)*

A. Guided (The teacher provides the focus questions, then prompts and supervises approaches used by students to address these questions)
B. Open-ended (The teacher facilitates the process of students choosing their own questions and inquiry approaches)
C. Teacher-collaborative (the teacher and students are co-researchers, and together choose questions and strategies to find answers that initially are unknown to all)
D. Mixed (combining two or three of the above mentioned methods, please specify_________)
E. None.

Q2. Which of the following models of implementing IBT have you used most often? (*Please circle all the answers suit your situation*)

A. Implementing IBT using student experiments
B. Implementing IBT in a section of lesson, e.g. group discussion, formula deduction, and etc.
C. Guiding students to conduct a literature investigation
D. Using group research projects on designated topics that takes one week or longer
E. None.

Q3. Please read the following descriptions related to various level of implementation of inquiry-based teaching. Please circle the level that best fits where you are in.

A. I have little or no knowledge of inquiry-based teaching, no involvement with it, and I am doing nothing toward becoming involved.
B. I am seeking or acquiring information about inquiry-based teaching.
C. I am preparing for the first activity of inquiry-based teaching.
D. I have implemented some activities of inquiry-based teaching, with little time for reflection. My effort is primarily directed toward achieving the requirements set by the new curriculum standard.
E. I feel comfortable implementing inquiry-based teaching. However, I am putting forth little effort and thought to improve inquiry-based teaching or its consequences.
F. I vary approaches to inquiry-based teaching to increase the expected benefits within the classroom. I am working on maximizing the effects with my students.
G. I am combining my own efforts with related activities of other teachers and colleagues to achieve impact in the classroom.
H. I reevaluate the quality of approaches to inquiry-based teaching, seek major modifications of, or alternatives to, present approaches to achieve increased impact, examine new developments in the field, and explore new goals for myself and my school or district.

Q4. To what extent do the following factors impede your attempt to implement IBT?

1= not at all influential, 2=slightly influential, 3= somewhat influential, 4=very influential, 5=extremely influential

Factors	To what extent do they impede your attempt to implement IBT?
A. I am lacking appropriate approaches to IBT, and hard to connect theory of IBT and teaching practice	0 1 2 3 4
B. It is difficult of integrate IBT with present teaching methods	0 1 2 3 4
C. It is difficult to decide an inquiry topic sufficiently relevant, authentic and interesting to every student.	0 1 2 3 4
D. There is a incompatible conflict between the National College Entrance Examination and IBT.	0 1 2 3 4
E. Lacking a complete evaluation system to assess the procedure and product of student leaning in IBT	0 1 2 3 4
F. IBT is time-consuming and my teaching time is limited.	0 1 2 3 4
G. It is difficult of organise/manage IBT in a large-size class	0 1 2 3 4
H. Constraints of resource, equipment, space and etc.	0 1 2 3 4
I. Lacking a support school environment for IBT	0 1 2 3 4
J. The society and parents do not understand why we should use IBT.	0 1 2 3 4
K. I worry about the consequences of IBT on students' scores.	0 1 2 3 4
L. I worry about being unable to complete teaching objectives if implementing IBT.	0 1 2 3 4
M. I think that my students' nature/ learning abilities and habits are not very suitable for IBT.	0 1 2 3 4
N. My students show low enthusiasm in IBT.	0 1 2 3 4
O. I don't think that IBT suits all students. It suits more the students who want to be scientists and science and technology talents in the future.	0 1 2 3 4
P. I think that some content of physics are not very suitable for IBT.	0 1 2 3 4
Q. I think that IBT is not more effective, in many cases, than traditional teaching methods to teach physics.	0 1 2 3 4

Q5. Over recent years, how often have you attended the following research activities regarding IBT?

1 = never, 2 =once or twice, 3 =once a year, 4 = once a semester, 5 = many times

IBT activities	How often have you attended each of them?
A. Academic conferences (international or domestic ones)	0 1 2 3 4
B. "Keli" (Exemplary lesson) research activities	0 1 2 3 4
C. Observing other teachers' classes	0 1 2 3 4
D. Research projects on IBT	0 1 2 3 4
E. Workshops and expert s' lectures	0 1 2 3 4
F. Enrolling a short-term or long-term course of IBT in tertiary schools	0 1 2 3 4
G. Others (Please specify)	0 1 2 3 4

Q6. How important do you think the following strategies are to the successful implementation of IBT?

1= not at all important, 2=slightly important, 3= moderately important, 4=very important, 5=extremely important

Strategies	How important do you think?
A. Empowering schools to develop school-based curriculum	**0 1 2 3 4**
B. Promoting reform of the college entrance examination system	**0 1 2 3 4**
C. Providing teachers with relevant training programs	**0 1 2 3 4**
D. Providing support of modern educational technology	**0 1 2 3 4**
E. Promoting teachers' research activities (in & outside school)	**0 1 2 3 4**
F. Helping teachers to model effective IBT and promoting reflection	**0 1 2 3 4**
G. Providing students with necessary time, space, resources, and safety for inquiry	**0 1 2 3 4**
H. Enabling students to have a significant voice in decisions about the content and context of their work	**0 1 2 3 4**
I. Improving student assessment system	**0 1 2 3 4**

Q7. To what extent do the following factors contribute to your change in beliefs?

1= not at all helpful, 2=slightly helpful, 3=somewhat helpful, 4=very helpful, 5=extremely helpful

Factors	To what extent do they contribute to your change in beliefs?
A. Learning new textbook and teaching reference book	**0 1 2 3 4**
B. Communications and discussions among school colleagues	**0 1 2 3 4**
C. Discussing teaching methods with experts and excellent teachers	**0 1 2 3 4**
D. Instructions on teaching approaches from experienced teachers	**0 1 2 3 4**
E. Participating in workshops and expert s' lectures	**0 1 2 3 4**
F. Participating in research project on IBT	**0 1 2 3 4**
G. Enrolling a short-term or long-term course of IBT in tertiary schools	**0 1 2 3 4**

Appendix B

Interview Questions

Introduction:

Please describe your teaching experience and educational background

a. Number of years taught

b. School types taught in and Years level taught at

c. Education background (Degrees)

Questions:

1*. The nature of science

a. What do you think is the nature of science?

b. How do you view scientific theories?

c. What do you think is the nature of physics as a school subject?

2*. Science teaching and learning

a. How do you think people (students) learn science?

b. How do you define a good physics learner?

c. What are your teaching goals? (Are these goals different from the curriculum objectives?)

d. What do you regard as effective physics teaching?

3. Inquiry and IBT

a. How would you define inquiry?

b. Do you think that IBT is a good way to teach physics content? Why or why not.

c. How do you think IBT should be implemented in classrooms?

d. Do you often implement IBT in your classrooms? Why or why not?

e. If yes, please describe what a typical inquiry lesson looks like in your classroom.

f. If yes, how do you prepare your lessons?

g. If yes, what are the most important things in your mind when you plan your lessons?

h. If no, is there any particular reason why you do not use this method?

4. Professional development

a. Have you participated in any professional development program that supports your implementation of IBT?

b. If yes, in what way has the provided professional development changed the way you think about your teaching?

c. Did these programmes meet your expectations? Why/why not.
d. In your opinions, what kind of professional development programmes do you suggest are most helpful for implementing IBT?

5. The teaching context
   a. How do you perceive the abilities and learning habits of your current students?
   b. Are your students interested in physics?
   c. Whether your students' quality (abilities, interest, and etc.) affect your instructional decisions regarding the use of IBT?
   d. How do you perceive the school context in relation to your implementation of IBT?
   e. In what way has the support from professional community changed the way you think about your teaching?

Questions developed based on Lotter, Harwood, & Bonner (2007)

* Questions about the nature of science, and science teaching and learning, were used in interviews with case study teachers. However, semi-structured interviews allowed the conversation to diverge in order to pursue an interesting idea or response in more detail. Therefore, other interviewees may be also asked group 1 and group 2 questions.

Appendix C

Classroom Observation Form

Teachers' and students' behaviours in the process of classroom inquiry

Inquiry process	**Behaviours in the process of classroom inquiry (____________ Inquiry)**	
	Teacher	***Students***
1. Identify a question		
2. Formulate a guess/ hypothesis		
3. Design experiment		
4. Gather, analyse, and interpret data		
5. Develop explanations based on evidence		
6. Communicate procedures and results		

Developed based on NRC (2000) and SHMEC (2004)

Appendix D

Inquiry Science Questioning Quality Criteria (Brandon et al., 2008, p.248)

Inquiry Science Questioning Quality Criteria

The exchange of teacher questions and student responses is the sign of good, middle school inquiry-based science programs such as Foundational Approaches in Science Teaching (FAST), and teacher quality in inquiry-based science classrooms is shown by full and appropriate use of questioning strategies. Questioning is the heart of inquiry-based, science teacher instructional activities; the more that teachers ask the appropriate questions at the appropriate levels at the appropriate times, the better the inquiry.

Quality teacher-questioning behavior is marked by more than the use of questioning strategies, of course, but without the full and proper use of these strategies, inquiry-based science will not succeed. In FAST, the focus of the questions that teachers ask varies among the three primary phases of lessons (Introduction, Investigation, and Summary), but the questioning approach remains constant and is manifested by these primary characteristics:

1. The teacher listens to the students carefully, accepts what is heard, and ties students' responses to the teacher's initiating question.
2. Student–teacher interaction revolves primarily around questioning that supports student engagement and learning without excessive praise or criticism of student responses. Questioning strategies include the following:
   a. asking clear, unambiguous questions at the appropriate opportunities for the purposes of initiating discussions and encouraging student curiosity,
   b. using Socratic question-and-answer chains,
   c. asking the children to reflect on possible answers to their own questions (e.g., "What do you think?"),
   d. asking questions that gain insight into students' behavior (e.g., "What might happen if did you X?"),
   e. asking questions about how investigations might be conducted (e.g., "How might that be found?"),
   f. asking questions that seek comparisons or contrasts (e.g., "How do these results compare with our previous results?" and " How are they different?"),
   g. asking questions about the sufficiency of evidence (e.g., "What is the evidence for that, and what is the quality of the evidence?"), and
   h. asking questions about connecting the findings to everyday life.

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1. STATA output from ANOVA test for the influence of limited teaching time

```
            Number of obs =       62     R-squared     =  0.4675
            Root MSE      = .992944     Adj R-squared =  0.2939

    Source | Partial SS    df       MS           F     Prob > F
-----------+----------------------------------------------------
     Model | 39.8242448    15  2.65494965       2.69     0.0051
           |
        TE | 10.0560109     3  3.35200362       3.40     0.0254
        ST | .009004884     1  .009004884       0.01     0.9243
     TE#ST | 13.9008348     3   4.6336116       4.70     0.0061
        DA | .972064423     1  .972064423       0.99     0.3259
     TE#DA |  11.189808     3  3.72993601       3.78     0.0165
     ST#DA | 6.04768372     1  6.04768372       6.13     0.0170
  TE#ST#DA | 6.14518087     3  2.04839362       2.08     0.1162
           |
  Residual | 45.3531746    46  .985938578
-----------+----------------------------------------------------
     Total | 85.1774194    61  1.39635114
```

2. STATA output from tests of simple main effects for TE#ST on the influence of limited teaching time

```
. anovalator TE ST, simple fratio

anovalator test of simple main effects for TE at(ST=0)
chi2(3) = 13.607125   p-value = .00349176
scaled as F-ratio = 4.5357083

anovalator test of simple main effects for TE at(ST=1)
chi2(3) = 8.2267372   p-value = .04155094
scaled as F-ratio = 2.7422457


. smecriticalvalue, n(2) df1(3) df2(46) dfmodel(15)

  number of tests: 2
     numerator df: 3
   denominator df: 46
original model df: 15

Critical value of F for alpha = .05 using ...
------------------------------------------------
Dunn's procedure             = 4.2383064
Marascuilo & Levin           = 4.61029
per family error rate        = 3.4153894
simultaneous test procedure  = 7.4357552

. anovalator TE, pair at(ST=0) quiet fratio

anovalator pairwise comparisons for TE at(ST=0)

Comparison          Coef.   Std. Err.       z    P>|z|     [95% Conf. Interval]
1 vs 2            1.70833    .687335     2.49    0.013     .3611574    3.055509
1 vs 3            .333333    .758374      .44    0.660    -1.153079    1.819746
1 vs 4               2.25    .823306     2.73    0.006     .6363202     3.86368
2 vs 3             -1.375    .555073    -2.48    0.013    -2.462943   -.2870573
2 vs 4            .541667    .640943     .845    0.398    -.7145813    1.797915
3 vs 4            1.91667    .716596     2.67    0.007     .5121387    3.321195

.
```

ST=0: Key school; ST=1: Non-key school

TE=1: ≤5yrs; TE=2: 5-10yrs; TE=3: 11-15yrs; TE=4: >15yrs

3. STATA output from tests of simple main effects for TE#DA on the influence of limited teaching time

```
. anovalator TE DA, simple fratio

anovalator test of simple main effects for TE at(DA=2)
chi2(3) = 3.7105158   p-value = .29446762
scaled as F-ratio = 1.2368386

anovalator test of simple main effects for TE at(DA=3)
chi2(3) = 13.448631   p-value = .00376035
scaled as F-ratio = 4.4828769


. smecriticalvalue, n(2) df1(3) df2(46) dfmodel(15)

  number of tests: 2
     numerator df: 3
   denominator df: 46
original model df: 15

Critical value of F for alpha = .05 using ...
------------------------------------------------
Dunn's procedure              = 4.2383064
Marascuilo & Levin            = 4.61029
per family error rate         = 3.4153894
simultaneous test procedure   = 7.4357552

. anovalator TE, pair at(DA=3) quiet fratio

anovalator pairwise comparisons for TE at(DA=3)

Comparison          Coef.   Std. Err.       z    P>|z|     [95% Conf. Interval]
1 vs 2            .708333    .687335     1.03    0.303    -.6388426    2.055509
1 vs 3            .166667    .702118     .237    0.812    -1.209484    1.542817
1 vs 4            2.41667    .784991     3.08    0.002     .8780834     3.95525
2 vs 3           -.541667    .555073    -.976    0.329    -1.629609     .546276
2 vs 4            1.70833    .656771      2.6    0.009     .4210622    2.995604
3 vs 4               2.25    .672227     3.35    0.001      .932436    3.567564
```

DA=2: District A; DA=3: District B

TE=1: ≤5yrs; TE=2: 5-10yrs; TE=3: 11-15yrs; TE=4: >15yrs

1. STATA output from ANOVA test for the influence of resource constraints

```
               Number of obs =       62     R-squared     =  0.3703
               Root MSE      = 1.10648     Adj R-squared =  0.1650

      Source | Partial SS    df       MS           F     Prob > F
  -----------+----------------------------------------------------
       Model | 33.1180236    15  2.20786824       1.80     0.0637
             |
          TE | 8.38844663     3  2.79614888       2.28     0.0915
          ST | 1.58193125     1  1.58193125       1.29     0.2615
       TE#ST | 6.07238788     3  2.02412929       1.65     0.1902
          DA | 4.56215724     1  4.56215724       3.73     0.0597
       TE#DA | 4.53603255     3  1.51201085       1.24     0.3078
       ST#DA | 1.22447797     1  1.22447797       1.00     0.3225
    TE#ST#DA | 12.4140844     3  4.13802814       3.38     0.0260
             |
    Residual | 56.3174603    46  1.22429262
  -----------+----------------------------------------------------
       Total | 89.4354839    61  1.46615547
```

2. STATA output from a test of simple main effects for TE#ST#DA on the influence of resource constraints

```
. anovalator TE ST, 2way at(DA=2) fratio

anovalator two-way interaction for TE#ST at(DA=2)
chi2(3) = 3.0762189   p-value = .38002236
scaled as F-ratio = 1.0254063

. anovalator TE ST, 2way at(DA=3) fratio

anovalator two-way interaction for TE#ST at(DA=3)
chi2(3) = 12.269476   p-value = .00651482
scaled as F-ratio = 4.0898253

. anovalator TE, main at(DA=3 ST=0) fratio

anovalator main-effect for TE at(DA=3 ST=0)
chi2(3) = 13.182215   p-value = .00425868
scaled as F-ratio = 4.3940718

. anovalator TE, main at(DA=3 ST=1) fratio

anovalator main-effect for TE at(DA=3 ST=1)
chi2(3) = 1.4157835   p-value = .70183919
scaled as F-ratio = .47192785

. smecriticalvalue, n(4) df1(3) df2(46) dfmodel(15)

  number of tests: 4
     numerator df: 3
   denominator df: 46
original model df: 15

Critical value of F for alpha = .05 using ...
------------------------------------------------
Dunn's procedure              = 4.2383064
Marascuilo & Levin            = 4.61029
per family error rate         = 4.0357255
simultaneous test procedure   = 7.4357552

. anovalator TE, pair at(DA=3 ST=0) quiet fratio

anovalator pairwise comparisons for TE at(DA=3 ST=0)

Comparison          Coef.   Std. Err.       z    P>|z|     [95% Conf. Interval]
1 vs 2               2.25    1.23708     1.82    0.069    -.1746759    4.674676
1 vs 3          -.333333    1.27765    -.261    0.794    -2.837528    2.170861
1 vs 4                  3     1.5648     1.92    0.055  -.06699935    6.066999
2 vs 3          -2.58333    .845086    -3.06    0.002    -4.239702   -.9269644
2 vs 4                .75    1.23708     .606    0.544    -1.674676    3.174676
3 vs 4            3.33333    1.27765     2.61    0.009     .8291388    5.837528
```

DA=2: District A; DA=3: District B
ST=0: Key school; ST=1: Non-key school
TE=1: ≤5yrs; TE=2: 5-10yrs; TE=3: 11-15yrs; TE=4: >15yrs

1. STATA output from ANOVA test for the overall influence of the listed factors

```
                  Number of obs =       56     R-squared     =  0.4549
                  Root MSE      = .684708      Adj R-squared =  0.2505

         Source | Partial SS    df       MS           F     Prob > F
      ----------+----------------------------------------------------
          Model | 15.6512897    15  1.04341931       2.23     0.0222
                |
             TE | 3.92798416     3  1.30932805       2.79     0.0526
             ST | .440926883     1  .440926883       0.94     0.3380
          TE#ST | 4.93681674     3  1.64560558       3.51     0.0237
             DA | .793868113     1  .793868113       1.69     0.2006
          TE#DA | 3.64964923     3  1.21654974       2.59     0.0658
          ST#DA | 1.48280098     1  1.48280098       3.16     0.0829
       TE#ST#DA | 3.96393844     3  1.32131281       2.82     0.0512
                |
       Residual | 18.7529989    40  .468824972
      ----------+----------------------------------------------------
          Total | 34.4042886    55  .625532519
```

2. STATA output from a test of simple main effects for TE#ST on the overall influence

```
. anovalator TE ST, simple fratio

anovalator test of simple main effects for TE at(ST=0)
chi2(3) = 14.923953   p-value = .0018828
scaled as F-ratio = 4.9746509

anovalator test of simple main effects for TE at(ST=1)
chi2(3) = 4.4410283   p-value = .21761113
scaled as F-ratio = 1.4803428


. smecriticalvalue, n(2) df1(3) df2(40) dfmodel(15)

  number of tests: 2
     numerator df: 3
   denominator df: 40
original model df: 15

Critical value of F for alpha = .05 using ...
------------------------------------------------
Dunn's procedure             = 4.3125692
Marascuilo & Levin           = 4.6982454
per family error rate        = 3.4632597
simultaneous test procedure  = 7.5214526

. anovalator TE, pair at(ST=0) quiet fratio

anovalator pairwise comparisons for TE at(ST=0)

Comparison          Coef.   Std. Err.       z    P>|z|     [95% Conf. Interval]
1 vs 2            .612745    .473968     1.29    0.196    -.3162314    1.541722
1 vs 3           -.754902    .522954    -1.44    0.149    -1.779892    .2700886
1 vs 4            .727941     .56773     1.28    0.200    -.3848093    1.840692
2 vs 3           -1.36765    .382763    -3.57    0.000    -2.117863   -.6174308
2 vs 4            .115196    .441977     .261    0.794     -.751079    .9814711
3 vs 4            1.48284    .494145        3    0.003     .5143181    2.451368
```

ST=0: Key school; ST=1: Non-key school

TE=1: ≤5yrs; TE=2: 5-10yrs; TE=3: 11-15yrs; TE=4: >15yrs