UNIVERSITY OF SOUTHAMPTON

FACULTY OF SOCIAL, HUMAN AND MATHEMATICAL SCIENCES
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An Investigation and Comparison on Chinese and English Teachers' Use of Technology in Teaching Mathematics

by

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ABSTRACT

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AN INVESTIGATION AND COMPARISON ON CHINESE AND ENGLISH TEACHERS' USE OF TECHNOLOGY IN TEACHING MATHEMATICS

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This study investigates Chinese and English secondary teachers' use of technology in their teaching of mathematics from a comparative perspective. The purpose of the study is three-fold. Firstly, it identifies what technologies (hardware, software and online resources) are used by mathematics teachers; secondly, it examines how these technologies are used in teaching practices; and thirdly, it investigates what factors influence teachers' use of technologies in their teaching of mathematics.

The study applied mix-methods with three instruments for collecting data from Chinese and English secondary school mathematics teachers: questionnaire, classroom observation, and interview. 229 valid questionnaires from China and 119 from England are obtained and eleven teachers (6 in China and 5 in England) are observed the classroom teaching and interviewed.

The results reveal that for hardware, computer and data-projector are the most commonly used devices by Chinese teachers, followed by calculators and interactive whiteboards (IWBs), while the mobile phone is the least used facility. For English teachers, calculator, computer and IWB are the most commonly used devices, while the smart phone and other hardware (including the projector) are least used ones.

For software, Microsoft office packages (i.e. Word, Excel and PowerPoint) are most frequently used by teachers in both countries, followed by Geometer's Sketchpad (GSP) for Chinese teachers, and GeoGebra and Autograph for English teachers, and these dynamic geometry software are adopted in the teaching of geometry. However, data analysis software is used by only around 5% of Chinese teachers, and none English teachers used data analysis software.

As regards online resources, both Chinese and English teachers use different online resources in their teaching practices, including search engines (mainly Baidu for Chinese, and Google for English), subject-based websites, download pictures and videos, and content-specific interactive programs. Besides, Chinese teachers usually use local instant information exchange packages (such as QQ and Wechat) to share and collect teaching materials in their daily works.

For influential factors, the study constructed multilevel models and shows that school facility and resource; school support; teachers' knowledge and teachers' skill are four significant factors in both countries. Assessment requirement has been found by interviews as another important factor influencing teachers of both countries of their use of technology. In addition, training and professional activity are influential in China, while in England, teachers' pedagogical beliefs and attitudes, and students play important roles.

Based on the findings, comparisons of Chinese and English secondary mathematics educations are made, and then recommendations for practitioners and policy makers are provided.

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DECLARATION OF AUTHORSHIP

I, Kun Xiang declare that the thesis entitled ‘‘*An Investigation and Comparison on Chinese and English Teachers’ Use of Technology in Teaching Mathematics*’’ is my own work and has been generated by me as the result of my own original research.

I confirm that:

1. This work was done wholly while in candidature for a research degree at this University;
2. Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated;
3. Where I have consulted the published work of others, this is always clearly attributed;
4. Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work;
5. I have acknowledged all main sources of help;
6. Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself;
7. None of this work has been published before submission.

Signed: ………………………………………………………………..……………………

Date: ……………………………………………………………………………………......

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Abbreviations

Becta—British Educational Communication and Technology Agency

BERA—British Educational Research Association

CAI —Computer Assisted Instruction

CAL—Computer Assisted Learning

CAS—Computer Algebra System

CBR—Calculator-Based Ranger

CF—Contextual Factor

CSM—Computer Simulation Methods

DfE—Department for Education

DGE—Dynamic Geometry Environment

DGS—Dynamic Geometry Software

EDI—Education Development Index

FFT—The Fisher Family Trust

GCSEs—General Certificate of Secondary Educations

GSP—Geometer's Sketchpad

HLM—Hierarchical Linear Model

ICT—Information and Communication Technology

IEA—International Association for the Evaluation of Educational Achievement

IT—Information Technology

IWB—Interactive Whiteboard

LEA—Local Education Authority

MAS—Mathematics Analysis Software

MKS—Mathematics Knowledge and Skills

M-learning—Mobile-learning

MM—Multilevel Modelling

MTR—Mathematics Thinking and Reasoning

OECD—Organization for Economic Co-operation and Development

PC—Personal Computer

PD—Professional Development

PDA—Personal Digital Assistance

PDM—Positive Disposition towards Mathematics

PF—Personal Factor

PIGMI—Portable Information technologies for supporting Graphical Mathematics Investigation

PISA—Program for International Student Assessment

PME—The International Group for the Psychology of Mathematics Education

SHSEE—Senior High School Entrance Examination

SITES—Second Information Technology in Education Study

SMS—Short Message System

TI—Texas Instruments

TIMSS—Trends in International Mathematics and Science Study

TPACK—Technology Pedagogy And Content Knowledge

TPC—Tablet Personal Computer

UNESCO—United Nations Educational, Scientific and Cultural Organization

W/H—devices Wireless/Handheld devices

Chapter 1 Introduction

1.1 Background Information

The history of studying the potential of Information and Communication Technology (ICT) in educational field has been over half a century. According to Reiser (2001), as early as in the mid-1960s, studies on the ICTs as learning tools have been conducted. From the late 1980s, with the huge development of personal computer and laptop, increasing researchers believed that ICT would have the potential to offer new opportunities for improving teaching and learning in the ways that were impossible before (Bransford, Brown & Cocking, 1999; Cox, 2014), and more studies began to focus on educational ICTs, making it a hot spot in the field of educational research. Besides, the embracement of technologies in educational reforms launched in different countries and regions in the beginning of this century attracted even more attention from various aspects of the society from government and policy makers to school and individual teachers (Assude, Buteau & Forgasz, 2010; Sinclair *et al.*, 2010). It is hard to deny that integrating technology into mainstream educational settings and various educational activities has become a global trend which will continue for a long time (Pope, 2011; UNESCO, 2011). However, in practice, the integration of technology into school education ‘‘lags behind the high expectation that many researchers and educators had some decades ago’’ (Drijvers *et al.*, 2010a, p. 213), and the effectiveness of technology in assisting instruction has always been questioned (Cuban, 2001; Thomas, 2006; Drijvers, 2015).

Among all subjects, mathematics has always been one recognized by many researchers that would benefit the most from the integration of technology, by which the difficulty for pupils to understand abstract knowledge would be hugely decreased (Sead & Nihad, 2013), and therefore many explorations have been conducted in this field (e.g., Shang, 2008; Ruthven, Deaney & Hennessy, 2009; Pierce, Stacey & Wander, 2010). Nevertheless, the contradiction mentioned above still exists. One of the main reasons for such contradiction identified by many researchers is that teachers were greatly neglected for a long time in the discussion of educational technology in mathematics, as Trouche *et al.* (2013) pointed out that:

> *Policy measures may give priority to technological access and developments, over the intellectual growth of learners and the professional development of teachers – which should be more demanding goals of mathematics education.*
>
> *(p. 753)*

Hence, increasing researchers realised that considering technology from teachers’ perspectives is of great importance (e.g., Yeh *et al.*, 2014; Chow, 2015). This is because on the one hand, teachers play a key role in classroom teaching and exert significant influence in what and how children learn; on the other hand, technology itself doesn't mean positive changes in students' learning, and it is teachers who integrate technology into appropriate pedagogical practices that assure the effectiveness of technology in education (Clark, 1983; Watson, Cox & Johnson, 1993; Pierce & Stacey, 2009a; 2009b; Goos *et al.*, 2010; Geiger *et al.*, 2012). As Cheung and Slavin (2013) stated that

> *Educational technology would never influence learning under any circumstances and … the impact of technology on student learning was due to content and methods, but not technology per se*[1].
>
> *(p. 89-90)*

Consequently, in order to filling the ‘‘widely perceived gap’’ (Bretscher, 2014, p. 43) between the reality of the use of technology in school mathematics and ‘‘the potential of technology suggested by research and policy’’ (ibid), more studies and explorations on educational technology are needed from teachers' perspectives.

1.2 Rationale for the Study

A number of studies discussing educational issues related to teachers or from teachers' perspectives can be found in the research field of teacher education. However, by reviewing existing literature, Monaghan (2004) noticed that most studies on teacher education focused on knowledge and beliefs, while ‘‘research focused on teachers' practices … is a relatively recent phenomenon’’ (p. 328). He claimed that little attention had been paid to teachers' technology-related classroom instructional practice, which would provide useful information for educators to understand the use of ICTs in teaching mathematics. Similarly, Goos (2014) stated that a significant body of research focused on student's learning mathematics with technology, while ‘‘less attention has been given to teachers' technology-mediated classroom practices and the role of the teachers in technology integration’’ (p. 140). Moreover, she pointed out that a trend has been recently emerged towards discussing the influence of various technologies on ‘‘teachers' professional work’’ (p. 157), and therefore studying the mathematical potential of technology from teacher's perspectives will become of deeper interest.

Ertmer (2005) examined both teachers' beliefs and their instructional behaviors and found that

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[1] This is especially true in mathematics education. Hoyles and Noss (2003) stated that students needed to learn a set of schemes, such as ‘‘linking algebraic and analytic interpretation, transformation, and expression of a function’’ (p. 338), but these were not obvious from the adoption of technology, and only when identification, instruction and discussion had been made with the technology, can it be used to develop the schemes.

these two elements were not always matched. A similar finding was also revealed in Chen's (2008) study, in which she particularly focused her exploration on teachers' technology integration, and found that teachers didn't practice what they believed. Both researchers then suggested that more studies should be conducted to analyse teachers' classroom use of technology, and then linked it to their beliefs. By analysing data from an ICT professional training, Lau and Yuen (2013) found that teachers did not eventually adopt technology in practice as they were trained, which also confirmed Pierson's (2001) finding that some teachers reverted back from using technology to traditional approaches in classroom teaching after receiving technological training programs. These findings challenge the idea that professional training is always effective in altering teachers' instructional behavior, especially in the use of technology, which implies that scholars should put more efforts on teachers' practice.

Law (2008) discussed the potential of technology to not only enhance existing pedagogical processes but also alter the goals, processes and even the relationship among students and teacher in classroom teaching—which he called the pedagogical innovations supported by ICT. According to him, although Mishra and Koehler's (2006) TPACK framework provided a link between the field of teacher education and of educational ICT, the framework was just an abstract level of conceptualizing teacher knowledge. He believed that ‘‘a conceptualization of what it takes for teachers to effectively integrate the use of ICT … need to go *beyond* a focus on knowledge’’ (p. 426) His suggestion also echoed what had been proposed by Stenhouse (1975) that ‘‘[Teaching] strategies can only be developed in the classroom’’ (p. 25). Thus regarding ICT in education research, in addition to teachers' knowledge, their pedagogical practices should also be valued.

Even though some studies had been conducted to explore teachers' instructional practices related to the use of technology, both the quantity and the quality of the studies are not satisfactory.

Highfield and Goodwin (2008) conducted a meta-analysis on the studies of using technology in mathematics education, and reported that research in this field ‘‘is scant and so judgments about potential affordances in mathematics instruction are, to a large extent, purely speculative’’. Besides, Geiger *et al.* (2012) pointed out that although researchers had interests in studying educational technologies for over three decades, much of the research upon ‘‘how digital technology influences teaching and learning has been based in intensive small-scale studies’’ (p. 134).

In the same vein, in her comprehensive review, Cox (2014) found that it has been the case in many national and international study about ICT in education that questions being asked were only ‘‘about uses of ICT without specifying what types of ICT’’ (p. 24), which resulted in ‘‘very misleading’’ (p. 24) and even ‘‘erroneous’’ (p. 23) conclusions. She also pointed that most surveys on the ICT issues just considered either IT teachers or general teachers without specifying a certain discipline, which impeded our deep understanding of ICT-supported teaching. She then suggested that more detailed study should be conducted and evidence which specified what type of technology and what kinds of uses actually occurred in the classroom should be sought.

By reflecting existing studies and sharing the scholars' thoughts, I am going to explore mathematics teachers' use of technology in instruction and it is hoped that the study can provide empirical evidence on teachers' tech-related behaviours, which potentially serves as a foundation for the solid knowledge of this field, as well as for future discussions. In addition, it is also hoped that the study can shed light on how to improve teachers' use of technology in teaching mathematics.

It should also be mentioned here that this study is an international comparative study, which has been regarded by many researchers as an effective way to learn from each other (e.g., Bray, Adamson & Mason, 2007; Mugo & Wolhuter, 2013; Phillips & Schweisfurth, 2014). The importance of mathematics in equipping children with significant abilities for the 21st century has been recognized by a great number of researchers and educational communities (e.g., Niss & Jablonka, 2014; Van den Heuvel-Panhuizen & Drijvers, 2014; Jablonka, 2015; OECD, 2015), and therefore, identifying good pedagogies for mathematics education is of great importance for all countries. Through studying mathematics education comparatively, researchers are more likely to discover both cultural-bounded as well as international approaches in teaching mathematics, and to provide practical suggestions to improve the quality of mathematics education. My study compares China and the UK because researchers and policy-makers in China and the UK are interested in knowing and learning from each other. On the one hand, Chinese researchers think that Chinese mathematics education neglects students' individual differences and leaves little space for students' innovation. This could be amended by learning from the education in Western countries including the UK. (e.g., Leung, 1992; Li, 2006; Zheng, 2006) On the other hand, various international assessments on students' academic performances in recent years show that Chinese students always gained higher scores in mathematics than most participant countries, which seems to indicate the efficiency of Chinese mathematics pedagogy in equipping students with stable mathematics knowledge and skills. As a result, English researchers and policy-makers are interested in knowing more about Chinese mathematics education. (e.g., Guskey, 2010; NCSL, 2014; Miao & Reynolds, 2015; DfE, 2016a) Actually, in 2013, under the requirement of the Department for Education, the National College for School Leadership (NCSL) has developed the *China Maths and Science International Programme*, and in 2014, the mathematics teacher exchange activity took place in which selected mathematics teachers in England were provided chances to visit Shanghai schools to observe

Chinese mathematics classroom teaching, and to discuss Chinese pedagogy with Shanghai teachers. (DfE 2016a) Under such circumstances, I am doing the comparative study of China and England, in the hope that my study could provide research-based evidence in describing how Chinese and English teachers use technology in teaching mathematics, and provide useful information for researchers and teachers in both countries to reflect and understand these two mathematics education system, so that they can benefit from my study and improve their teaching practices.

1.3 Statement of Research Questions

In the study, I will investigate and compare Chinese and English secondary mathematics teachers' use of technology, with the following questions:

(1) How do Chinese and English teachers use technologies in teaching mathematics?

Although similar investigations have been conducted related to the question, most of them are either subjects-mixed or technology-oriented, in other words, teaching with technology rather than teaching *mathematics* with technology (Tsai & Chai, 2012; Bretscher, 2014), so little in-depth knowledge has been obtained related to the question. Specifically, Question (1) will be answered by two sub-questions:

(i) What technologies are used in classroom teaching practices?

(ii) How are these technologies used?

Question (i) aims to obtain information on what hardware, software and online resources are used by Chinese and English mathematics teachers; question (ii) aims to explore in which way and for what purposes are the technologies used? I hope that by answering the two sub-questions above, I can provide empirical evidences for practitioners and researchers to think about the usefulness of technology in mathematics education and that this study can illuminate on how teachers' use of technology can be improved.

(2) What factors influence Chinese and English mathematics teachers' use of technology?

Previous studies have shown that not only teachers' pedagogical practices, but also the reasons behind the practices varied across different subjects (Howard & Maton, 2011). By clarifying the behind reasons, we can understand mathematics teachers' behaviours deeper, especially why they use (or not use) technologies for instruction, and based on such understanding, more effective guidance and suggestions on technological integration can be offered to teachers. Hence an exploration of factors influencing mathematics teachers' technology-related instructional practices would be necessary and valuable.

1.4 Structure of the Thesis

The thesis consists of eight chapters. The first chapter provides the background of the study, the rationale for the study, and states research questions. In chapter 2, relevant literature is reviewed and discussed, based on which the conceptual frameworks on mathematics teachers' use of technology in instruction and the influencing factors are established and explained in chapter 3. The fourth chapter deals with the methodological issue of the study, in which the methodological foundations of this study and the research process are introduced. Chapters 5 and 6 present results of data analysis for China and England respectively, and in these chapters research questions are answered. In chapter 7 a comparison of the Chinese and English mathematics teachers' use of technology is made based on findings presented in the previous two chapters. Chapter 8 summaries the study, discusses implications for practitioners and policy-makers, and finally, reflections on the current study as well as recommendations for further explorations are offered.

Chapter 2 Literature Review

This chapter traces and discusses relevant literature in the field of technology in mathematics education, which serves for theoretical background and assists in understanding existing work done in the field. The chapter consists of four main parts: the first part reviews what educators and researchers mean by adopting 'technology' in general education and in mathematics education (section 2.1 and 2.2); the second part deals with function-based affordances of technologies which serves as one of the foundations for tech-integration instruction (section 2.3); the third part discusses existing studies which are more directly related to the research questions (section 2.4 and 2.5); and finally, studies and discussions on international comparisons in teachers' use of technology as well as in mathematics education are reviewed (section 2.6).

2.1 Technology and Educational Technology

Although the word 'Technology' is commonly used in education settings, researchers proposed different definitions when they discuss about it, and there is no single definition accepted universally. Many scholars believed that we were living in a fast-changing world, and the meaning of 'technology', or technology per se was exactly a reflection of such change.[2]

A great number of educational researchers describe technology as, in its concrete meaning, the tools or devices that are used for teaching and/or learning. This kind of usage can be traced back to the Greek concept ''Tekhnē'', which refers to mechanical or industrial art, and tekhnē is always understood as craft-based approach to produce or achieve something. (Oliver, 2013)

Knezevich and Eye (1970), for example, explained technology as something that ''deals with tools, techniques, procedures: the artefacts and processes fashioned by modern industrial man to increase his powers of mind and body'' (p. 17). They analysed the instructional function of blackboard and compared it with television to show the view that blackboard could be regarded as a technology for its provision of educational information. They even renamed book as ''a series of paper-based levers of varying sizes which can be bound together, within a hard or soft cover, and organized for the purpose of presenting information in a sequential manner'' (p. 19) to present the homogeneity of books and other tools in the mechanical aspects for providing information and messages.

Bruce and Hogan (1998) held a similar idea, and considered technology as ''a set of tools to perform a specific function'' (p. 270). However, they further asserted that for most of the scholars, blackboard, chalks, pencils, etc., although still widely used in many schools, were not considered

[2] For example, Mesthene (1968) stated that ''technological world is a world of change''.

as technologies anymore, because these tools became commonplace and embedded themselves in everyday activity and discourse in schools, and therefore, they became part of the work instead of novelties. ‘‘[T]he greater its integration into daily practices, the less it is seen as a technology at all.’’ (ibid.) Reiser (2001) defined ‘technology’ as ‘‘physical means, other than the teacher, chalkboard, and textbook, via which instruction is presented to learners.’’ (p. 55) Simon (1969) used three words to describe tools adopted by educators for hundreds of years: specificity, stability and transparency of function. Which means one certain tool, like pencil, is usually only for one function, i.e. writing, which has not changed for a long time, since its inner nature is simple and directly related to its function. It was these reasons, according to Simon, that made people exclude those tools when thought about technology.

Theoretically speaking, any tool or device, be it electronic (computer, overhead projector, etc.) or non-electronic (ordinary textbooks, abacus, etc.), can be accounted as technology in its broad meaning as long as it is for educational purposes. However, when researchers talk about technology, they actually mean electronic devices. Mishra and Koehler (2006), used ‘traditional technology’ to present the former tools in classrooms, in contrast with ‘‘computers software, artefacts and mechanisms that are new and not yet a part of the mainstream’’ (p. 1023), which they called ‘digital technologies’ or ‘emergent technologies’. Koehler and Mishra (2009) utilized three words, as Simon did, to briefly show the characteristics of digital technologies:

> *[Digital technologies] are protean (usable in many different ways), unstable (rapidly changing) and opaque (the inner workings are hidden from users).*
>
> *(Koehler & Mishra, 2009, p. 61)*

By saying so, Koehler and Mishra actually referred new technologies to those that were not originally design for educational purposes (although some software are designed for teaching and learning, such as Geometer’s Sketchpad or GeoGebra, the devices where they run, i.e. computers are not specially for education) and/or that with multifunction so that some adaptations are needed for their entry to the classroom.

In order to give a clear explanation of technology for my research, I will firstly conduct a briefly historical exploration upon the electronic devices used for instruction to gain a detailed information about what technologies were used as well as their progress in educational settings.

2.1.1 Visual media period

The history of using media for educational purposes can be traced back to the end of nineteenth century and the beginning of the twentieth century, when the standard sized ($3\frac{1}{4} \times 4$ inches) lantern slides were used for educational purpose. (Petroski, 2006) Within just a few years, the size of slides changed into tow-by-two inch, which served later for 35mm filmstrip and silent films emerged. Since these films were made without sound, they were also called ‘motion pictures’ in early time. (e.g. Emery, 1925; Dorris, 1928) Silent films were originally used to exhibit beautiful sights such as amazing seascapes and flying insects to interest paying audiences to earn money (Betrus, 2008), and until an American, Thomas Edison, who noticed the potential use of silent films in education, ‘‘released a series of films depicting historical events, natural phenomena and principles of physics’’ (Saettler, 1990, p. 96), so that the silent films entered the classroom (ibid. p. 98-99). In 1910, New York was the first city that used silent films in regular instructions in some public schools. (Reiser, 1987)

Within the next decade, many companies, government agencies and organizations as well as some individuals produced many silent films with various types, and early studies on the use of such films were conducted. The researchers concluded that accuracy of the information presented on the pictures should be a concern and that the educational value of such materials determined not only on the films per se, but also on how they were used by teachers, which rings as true today as then, if not more so. (e.g., Lashley & Watson, 1922; Knowlton & Tilton, 1929)

All the materials used by teachers by 1920s were without sound, so researchers adopted the term ‘visual’ to express their educational function of enriching learners’ ‘seeing experience’. However, researchers pointed out that teachers used these films at that time for reasons ‘‘other than their curricular relevance’’ (Betrus, 2008, p.219), so the visual materials had limited influence on educational purposes.

2.1.2 Audio devices period

Unlike visual media, audio devices were less used in early twenty century, and only some universities adopted radios for educational purposes[3]. (Forsythe, 1970; Wolcott & Napper, 1994) It is until late 1930s when some studies were launched in elementary and secondary schools that increasing schools began to use radios for instruction. For example, Saettler (1990) analysed two evaluation reports upon the early studies of effectiveness of radio broadcasts in education which both began in 1939. The first one was Ohio Evaluation of School Broadcasts Project, which aimed at studying the value of radio in children’s learning from social and psychological aspects. Saettler believed that this project had provided ‘‘factual evidence’’ which was helpful in understanding effective planning and using radios in education. (ibid, p. 242) The second one was a contrast

[3] For example, the University of Wisconsin utilized radio in 1919, and the Ohio State School of the Air was established in 1929. According to Forsythe (1970), in the U.S., there were 202 radio stations by 1936 licensed to educational institutions.

experiment conducted by Wisconsin research group, where conventional and radio-based instruction was compared in six school disciplines within grades 5-12. The results showed that there was no statistical difference resulting from two different instructional in any discipline. (ibid.) Some alternative comparative research conducted later by other scholars (e.g., Harrison, 1932; Heron & Ziebarth, 1946) indicated that radio instruction was at least as effective as, if not better than, conventional face-to-face instruction, and that radio-learning was more suitable for grasping foreign languages (Mathur & Neurath, 1959; Chu & Schramm, 1967). By referring to British Open University's experiences, Bates (1983) stated that radio as a supplement to text materials helped the unsuccessful students more than their successful counterparts.

Forsythe in 1970 completed a report in which he pointed out twelve instructional dimensions provided by radio (Forsythe, 1970), which indicated the influences of radios in changing school learning. However, due to development of more advanced devices, like television, general interest in radio-instruction declined[4] (Barron, 2004). But for those poor areas, radio was still widely adopted (Forsythe, 1970), because of its cheap price and easily accessible, so radios played an important role in instructing poor people around the world for a long period of time.

2.1.3 Audio-visual media period

During the late 1920s and the 1930s, big technological advances emerged in sound devices including broadcasting, sound-films and sound recorder (Finn, 1972), and this could have brought a chance of adopting new technology into educational field and of turning *visual media* into *audio-visual media*. However, due to the onset of the World War II in 1939, ''the audiovisual instruction movement in the school slowed'' (Reiser, 1987, p. 15), but audio-visual devices and materials found their ways into military services. As the war progressed, more and more individuals with various and complex backgrounds were conscripted into armies. In order to equip these soldiers with basic operational capability in a short period of time, audio-visual materials like sound films were widely utilised by various countries. For example, according to historical studies from Saettler (1968) and Olsen and Bass (1982), the U.S. government had spent over one billion dollars for purchasing film projectors and had produced 457 films for training purpose during the war time. Other equipment employed included slide projectors, for teaching the structure of aircraft and ship; audio devices, for teaching foreign language; and simulators, for flight training. (Reiser, 1987)

All these devices and materials were proved to be useful, and made a great contribution to the end of the war. Later, these technologies were all introduced to schools for regular education in the

[4] Wolcott (1994) stated that except for interactive radio which was still used for long distance instruction, ordinary radio was gradually replaced by other equipment in education in the wealthier countries.

following decades.

Television combines visual and aural experiences together to present both image and sound to students, and thus scholars believed that television could be a powerful technology in enhancing students' learning, which resulted in huge investment in instructional televisions in many countries. (Moss, Jones & Gunter, 1991; Reiser, 2001) The widely use of televisions in schools in 1950s indicated the entry of audio-visual media to education settings. (Reiser, 1987)

Various studies conducted prior to 1990s showed that television had been used in schools for a relative long time and for almost every discipline. For example, Almstead and Graf (1960) examined forth, sixth and tenth grade students in learning geometry and reading via television; Wade, by cooperating with a school, had conducted a longitudinal research and concluded that students in television instruction performed better in all the above subjects than students with conventional approach. (Wilkinson, 1980, p. 14) Chu and Schramm (1967) analysed results of previous studies and made the following assertion which supported Wade's findings:

> *The effectiveness of television has now been demonstrated in well over 100 experiments, and several hundred separate comparisons, performed in many parts of the world, in developing as well as industrialized countries, at every level from pre-school through adult education, and with a great variety of subject matter and method.*
>
> *(Chu & Schramm, 1967, p. 1)*

However, there are still some reports claimed the defects of the instructional television. Reiser (2001), for example, believed the mediocre quality of some instructional television program could be an important reason that many teachers refused to use television to teach. Gordon (1970) and Tyler (1975) added that the inability of television alone to construct a good learning environment for students and that the expense of installing and maintaining televisions also drove people to search for better tools for instruction.

2.1.4 Computer period

After the adoption of instructional television in education, computers caught the attention of plenty of educators. (Reiser, 2001) Although early studies on computers' instructional functions were conducted in 1950s and 1960s (Lewis & Pask, 1965; Atkinson & Hansen, 1966; Suppes & Macken, 1978), most of them focused on university level with mainframe computers, and ''had very little impact on education'' (Pagliaro, 1983). A broad interest in the computer as an instructional tool happened in 1980s when microcomputers entered primary and secondary schools (Hammond *et al.*, 2009). Microcomputers were relatively inexpensive but were capable of performing many functions. (Papert, 1984) For example, some research summarized common ways in which computers could be used in schools: as a demonstration tool to present subject-related content, and computers were trying to replace chalkboard; to provide drill and practice programs for students to obtain necessary skills for key knowledge; to teach students programming for ‘‘problem-solving’’ (Kelman *et al.*, 1983, p. 59-60); and finally to design simulations and educational games which presented a particular learning environment with man-made or real-world situation. (Ochsner, Ramirez & Steinkuehler, 2015)

Although the use of computers in education settings was widely discussed by researchers around 1990s, the rate of practical utilization of computers in schools was low (Reiser, 2001). Hammond *et al.* (2009) claimed that the inadequacy of technology supports and knowledge might be a main reason for the low utilization rate[5]. A rapid increase in the use of computers for instructional purposes occurred around the year of 2000, when various hardware and software are mass-produced commercially, and especially the internet was widely accepted. Some scholars use the term ‘Computer Assisted Learning’ (CAL) or ‘Computer Assisted Instruction’ (CAI) to present all the personal computer (PC)-linked hardware and software, which provide technological bases for learning (Moore, McGrath & Thorpe, 2000).

Researchers analysed the advantages of CAI and emphasised the advantage of ‘‘learning interaction’’ enhanced by computers. Lee (2000) stated that computers were excellent learning tools in 21st century because they emphasised individual needs and offered students more motivations. Taylor and Gitsaki (2003) suggested that with the help of the internet, students could get various learning resources in or out of schools, which encouraged their independent studies. Lai and Kritsonis (2006) made it clearer that when combining with the internet, computers could provide students with huge amount of ‘‘human experiences’’ and let students entered ‘‘global communities’’ (p. 3).

2.1.5 Recent development: mobile learning

Recent decade has witnessed a huge technology advance in Personal Digital Assistance (PDA) which ‘‘hybrid mobile and handheld devices into one device’’ (Motiwalla, 2007, p. 582), such as touch-screen tablets, and with the universal spread of smart phone, increasing researchers begin to explore the educational functions of mobile technologies, especially in distance learning. These devices are normally portable and have easy access to the internet, and thus learners with the help of these wireless and handheld devices (W/H devices) can get learning resources and study without

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[5] According to Hammond *et al.*, Windows interface (or graphical user interface) has not been launched until the end of the pre-internet days. Before that time, computer operators had to input codes into the less-friendly command line interface, which impede teachers’ use of computers.

the restriction of time and space. Due to the time/space-flexibility, this form of learning has been termed as ‘mobile-learning’ (m-learning). (Attewell & Savill-Smith, 2004; Motiwalla, 2007)

The use of mobile technologies has been analysed and reported by some studies. Mifsud, Morch and Lieberg (2013) reviewed studies of mobile learning, and found that the mobile technologies are now mainly used in making animations for different disciplines and topics, writing and revising sentences for language learning, downloading online data for inquiry-study or collaboration activities, etc. Ng and Nicholas (2009) found that handheld technologies, were mainly embraced by science, mathematics and language, and both primary and secondary teachers in these three areas had positive attitudes in integrating ‘‘pocket PCs (PPCs)’’ (p. 474). Researchers also noticed that mobile technologies were used as potential tools for classroom assessment of students’ progress (Roschelle *et al.*, 2005; Penuel, Lynn & Berger, 2007), because these devices could provide immediate feedback to both teachers and students. However, according to Penuel, Lynn and Berger (2007) and Vahey and Crawford (2002), the small screen size of handheld devices also limited their use in conducting assessment. Tatar *et al.* (2003) also raised other negative issues in using mobile devices for educational purposes, such as inappropriate use of game playing which led to off-task activities.

2.2 Technology in Mathematics Education

2.2.1 Technology as an umbrella term

In mathematics education, technology is not a well-defined term either and is always interchanged with other words including information and communication technology (ICT), information technology (IT), and digital technology, etc. Very little literature is found that has provided a clear definition of technology, and most of them just used the term as an umbrella term to cover a range of tools, or without any specific explanation as its meaning has already been understood and accepted by all scholars, as Monaghan (2001) pointed that

> *ICT use in mathematics classes is a collective term for a diffuse range of software and hardware. In an attempt to focus on something common and manageable project work focus on using technology tools: spreadsheets, graphic packages and calculators and algebra and geometry system. In an attempt to keep the project work as realistic as possible individual team members chose the tools they thought most appropriate for use with their classes.*
>
> *(Monaghan, 2001, p. 2)*

According to Monaghan, ICT is not a word that can be precisely defined. Although most people regard ICT as various devices and facilities (software and hardware), its meaning in specific situations is always decided by users.

Fuchs, with over 20 years' experiences in training mathematics teachers at various educational levels, highlighted the progress of computer sciences and its influence on mathematics education. In one of his article, Fuchs (2003) discussed about Computer Algebra System (CAS), which according to him, stood for

> *a wide range of computer systems which can be characterized by functions such as symbolic differentiation or integration of rational functions.*

(Fuchs, 2003, p. 20)

Fuchs suggested that CAS as a tool for learning mathematics had been claiming more and more space in various courses nationally and in myriads of curriculums internationally, and he believed that CAS had the potential to be a main technological tool for future mathematics education.

Heid, Thomas and Zbiek (2013) made it clearer that

> *Computer Algebra System (CAS) are software systems with the capability of symbolic manipulation kinked with graphical, numerical, and tabular utilities, and increasingly include interactive symbolic links to spreadsheets and dynamical geometry programs.*

(Heid, Thomas & Zbiek, 2013, p. 597)

They stated that school classrooms that incorporated with CAS could provide brand new ways to explore mathematics, because CAS changed the classroom dynamics, and provided students with multiple angles when viewing algebra.

Actually, Computer Algebra System (CAS) was originally designed and developed for professional people such as mathematicians, scientists, and engineers. CAS contains a series of products which are powerful in symbolic manipulation of real and complex variables, graphing, and statistical data analysing. Nowadays, CAS is found not only in computer systems, but also in symbolic calculators.

Similar to Fuchs, Pierce and Stacey (2010) discussed what is 'Mathematics Analysis Software' (MAS), and how would MAS be used in mathematics education. They described the MAS as a ''umbrella term'' that referred to software which enabled users to perform ''algorithmic process required when working in one or more branches of mathematics'' (Pierce & Stacey, 2010, p. 2). Like Monaghan (2001), Pierce and Stacey (2010) also thought that technology depended on who used it, and they made it explicitly that ''MAS is typically 'adaptable' software, where the user specifies what it will do'' (p. 3). They then provided an example list in detail which had discussed by other scholars in previous studies and could be counted as MAS:

> *Examples are software for computers or calculators that user can instruct to carry out arithmetic calculations, symbolic algebra manipulations, statistics calculation, data display (e.g. making a pie chart), function graph plotting, and construction of geometric figures. In education settings, these tools may be available as computer software … or hand held calculators.*
>
> *(Pierce & Stacey, 2010, p. 2-3)*

Zhang and Peng (2009), rather than providing a definition of information technology (IT), propose a taxonomy on the technologies adopted in mathematics educational activities. According to them, There are three different kinds of information technology (IT) used by mathematics teachers: one is *universal IT*, which is not specially developed for educational purposes, such as Micro-office package (Word, Excel, PowerPoint), message-communication tools (like QQ in China, or email worldwide), and the Internet; One is *commonly used IT in mathematics teaching*, including various kinds of calculators, Geometer's Sketchpad, Cabri, etc. and finally *specific IT in some topics of teaching activities*, such as some apps or software packages exclusively for exploring data fitting and fractal geometry. According to Zhang and Peng (2009), mathematics teachers should be careful in selecting universal IT, be familiar with most of the commonly used math-teaching IT, and know some specific math-topic IT.

Researchers used 'technology' as a collective term to cover a wide range of devices, facilities, software and application etc. Besides, in different studies, different technologies are discussed under the term. More commonly can be found in relevant literature is that technology is discussed as some specific hardware or software which support concrete pedagogical use in mathematics education. The most frequent discussions are about calculators and computers. Interactive Whiteboard (IWB) and Mobile devices are less-frequent discussed in mathematics education but relevant literatures can be also found.

2.2.2 Technology used in specific ways

Calculator

Among all technologies, calculator has been considered as the most significant catalyst to change the way in which school mathematics was taught and learned (Ellington, 2003). In many countries, students are even allowed to use calculator in high-stake tests, indicating that calculators are already part of mathematics education. Today, there are various types of calculators in the market, so I will briefly introduce the history of calculators to show the differences of tasks that different types of calculators can deal with, and then turn to review relevant studies.

The first hand-held electronic calculator was invented in November, 1966 by a team working for

Texas Instruments (TI), with the size being about 4″×6″×1.5″, and could only do four fundamental arithmetic operations, i.e. addition, subtraction, multiplication and division. In 1970, TI joined with Canon, a Japanese company, and eventually they produced the first Pocketronic to the market on 14th April. (Hamrick, 1996) Just two years later, Hewlett-Packard introduced the first scientific calculator, HP-35 (Waits & Demana, 2001). This scientific calculator could evaluate values of transcendental functions like 'log 2' and 'cos 25°', which makes it appropriate for scientific calculation and inquiry. In 1985, the first graphing calculator appeared (Jones, 2005), with its standard functions encompassing performing numerical calculations, displaying and manipulating statistical data, and graphing functions. Later, more sophisticated models came to the world with powerful graphing software, including dynamic geometry toolkits, which was previously found only on computers (Jones, 2005). After that, the technology in calculator developed quickly, and just within 5 years, computer algebra system (CAS) was built into some graphing calculators, like HP-50g, making these calculators capable of producing symbolic results. The computer algebra system has similar capabilities to those ''found in powerful computer-based systems such as *Mathematica* (Wolfram Research, 1997) or *DERIVE* (SoftWarehouse, 1995)'' (Heid & Edwards, 2001, p. 129). Therefore, the build-in CAS toolkit enabled calculators to manipulate algebra expressions and to present answers in exact form without numerical approximations (Artigue, 2002), and these calculators are also called CAS- (graphing) calculators or symbolic calculators. Here are a few examples of what a CAS graphing calculator can do that non-CAS calculators cannot:

1) Evaluate 100! and return the exact 158-digit long solution;
2) Simplify $\sqrt{3+2\sqrt{2}}$ to $\sqrt{2}+1$;
3) Factor $(y-z)x^2-(y^2-z^2)x+zy^2-z^2$;
4) Integrate $\int \arcsin x \, \mathrm{d}x$;
5) Find all roots of cos x=sin x.

Various studies and experiments on the use of calculators in mathematics education has been conducted by scholars from many countries.

During the beginning period of the introduction of calculators into schools, both successes and pitfalls of the implication of calculators have been discussed and reported (Suydam, 1980; Sigg, 1982; Suydam, 1982). Sigg (1982) found that students' achievements were not negatively affected by using calculators in the classroom, whilst no positive influence on students' attitudes toward mathematics learning was found due to the use of calculators. By reviewing 79 previous studies, Hembree and Dessart (1986) published a meta-analysis report stating that at all Grades but Grade 4, the use of calculators exerted positive influence on students' basic skills, and sustained use of calculator in Grade 4 ‘‘appears to hinder their development of basic skills in average’’ (Hembree & Dessart, 1986, p. 83). This report has drawn critical and cautious conclusions on the effect of calculators in mathematics education and appealed to more sophisticated research.

In the late 1980s when graphing calculators were introduced into schools, most educators believed that the focus of the research should be shifted from whether or not calculators should be adopted in mathematics classroom to how to most effectively incorporate calculators (Ellington, 2003), and the focus of mathematics education should be shifted ‘‘away from learning about procedures to learning about conceptual ideas useful for problem-solving, or in other words, expecting all students to learn to think’’. (Bright, 1994, p. 29), and thus more studies from both students’ and teachers’ perspectives were conducted.

Bitter and Hatfield (1993), for example, conducted a two-year longitudinal study on 580 seventh- and eighth-grade students, and they found that the use of calculator could increase test scores in both basic skill and problem-solving tasks. In their book *Impact of calculators on mathematics instruction*, Bright, Waxman and Williams (1994) claimed that students and teachers could view mathematics differently with the help of calculators. Calculators could liberate students and teachers from ‘messy’ computations tasks, and therefore created a chance to welcome real-world problems to the classroom. Besides, calculators could be used to generate a great amount of data that would be so time-consuming to generate by hand, and encourage students to involve in relationship and pattern-discovery activities in mathematics. In the same vein, Bright (1994) found that Graphing calculator change the way that teachers teach pictures of functions. In paper-and-pencil classroom, complete graph of functions normally were not be discussed, however, in graphing calculator, changing the scale can ‘‘dramatically influence the picture of the function that is visible’’ (Bright, 1994, p. 30), and thus both global and local properties of the graphs can be understood.

After 2000, more studies focused on graphing or symbolic calculators because these devices are more computer-like and are able to provide more professional support for deep mathematical exploration. Graham and Thomas (2000) conducted a classroom-based quasi-experiment to compare students’ learning of variables in algebra with and without help from graphic calculators. Pre- and Post-tests were designed to measure students’ ‘‘understanding of the use of letters as specific unknown, generalised numbers and variables’’ (p. 272). The results showed that the mean score of students in experimental group (with calculators) in the post-test was significant higher than those in the controlled group (without calculators), while no such differences was found at pre-test stage. The following interviews with both teachers and students confirmed the use of graphic calculators in enhancing students’ conceptual understanding of variables in elementary algebra.

Ellington (2006) reviewed forty-two studies focusing on using non-CAS graphic calculators in mathematics. He examined the ''effect of graphing calculators on student development of procedural skills, conceptual skills, and overall mathematics achievement'' (Ellington, 2006, p. 18). Conclusions showed that students could receive the most benefit when using calculators in both learning process and assessment process. A stronger finding stated as ''there were no circumstances under which the students taught without calculators performed better than the students with access to calculators'' (Ellington, 2006, p. 24). These findings were also confirmed by results of some experimental or quasi-experimental studies (e.g., Hasan, Azizan & Kassim, 2005; DeLoach, 2013; Tajudin & Idris, 2014), and a US large national assessment report (Klecker & Klecker, 2014).

Kissane and Kemp (2008) examined the use of graphic calculators in learning calculus at secondary school level. They highlighted the graphic calculator's affordances of providing multiple representations for students to understand abstract concepts. In the article, the authors provided eleven examples which had been considered hard to learn by traditional pen-and-paper methods, and showed that graphic calculator was supportive in helping students' conceptual understanding by linking multiple and dynamic representations together, so that students could easily obtain geometric intuition of the concepts. Besides, the fast speed of numerical generation and calculation was also discussed in helping students understand convergence of a series without introducing the definition and notion of infinite.

Similarly, in Tarmizi, Konting and Ali's (2009) study, quasi-experimental design was adopted with only post-test at the topic of straight line. The aim of the experiment was to examine whether there were differences in students' performances in understanding conceptual knowledge, procedural knowledge, as well as in solving both similar and transfer problems between the user and non-user of graphic calculators. The results suggested that students with calculators performed significantly better in the overall test, conceptual knowledge, and solving transfer problems of straight line topic than those taught with conventional instruction methods. However, no significant differences between the two group of students were discovered in understanding procedural and in solving similar problems of straight line topic. In addition, Tarmizi, Konting and Ali (2009) found that using graphic calculators could improve students' level of meta-cognitive awareness in problem-solving.

Regarding research in CAS- or symbolic calculators, Heid *et al.* (2002) found that students with CAS calculators were provided more time in concepts construction and understanding than those without calculators. In addition, CAS-calculators enabled students directly to explore and model real world around them in a mathematical way, and to access to a problem in multiple approaches and facets (Heid *et al.*, 2002). This finding is consistent with Fuchs's (2003) finding that CAS could be powerful in stepwise modelling which brought real-life problems into classroom and with King's (2003) result that CAS-calculators were effective tools in learning equations because CASs eliminated mistakes in numerical computation and thus helped students focus on the process of choosing appropriate strategies to solve equations (King, 2003).

Weigand (2008) directed a one-year study examining the influences of calculators on tenth grade students' learning of algebra in three Germany schools. Both pre-tests and post-tests were used in the study, and the test results showed that students' competencies had developed during the learning process. Besides, Weigand (2008) also found that symbolic calculators could be a good catalyst for students' inter-exchange and group work in mathematics classrooms.

Computer

Computer was introduced to secondary and primary schools in the 1980s in various nations including the UK and China, and since then it has attracted considerable attention from researchers worldwide. (Hammond *et al.*, 2009) Early studies found that teachers influenced by television instruction and used CD/VCD video materials in teaching mathematics but a huge problem with video-based instruction was that teachers could only use well-produced videos, and it was hard for themselves to produce videos which served for their own teaching requirement. Few interactions were found in computer-video mathematics instruction at that time until various educational software were created.

The very first kind of software used for mathematics education that attracted teachers' interests was drill-and-practice package. According to Myhre (1998), who studied an experienced secondary school teacher as a case of her typical use of computer in instruction, the primary way that teacher adopted computer was using drill-and-practice package to support students in a step-by-step way in solving routine problems, and the teacher viewed such package as a useful tool to guide students to go through the whole process of problem-solving correctly without seeking for her help. Becker, Ravitz and Wong (1999) compared how US teachers of different disciplines incorporated computers into their instructional practices, and they found that ''more math teachers use skills-practice games than any other type of computer software'' (p. 13). In the same vein, Niederhauser and Stoddart (2001) conducted a deeper investigation on U.S. elementary school mathematics teachers' perspectives of educational software, in which most teachers highlighted the effectiveness of computers in providing drill and practices, and in supporting creative and independent thinking. Interestingly, by comparing different teacher groups, the authors suggested that with the grade increasing, the number of users of open-ended software increased, and that at nearly all levels, ''more females teachers used only skill-based software than did their male counterparts and male teachers tended to use open-ended software slightly more frequently than did female teachers'' (p. 23).

It can be seen that early research suggested that teachers were fond of using skill-practice package, which based on the feature of quick-calculation and of providing immediate feedback to users, to increase students' ability in solving routine problems or to guide students' self-learning. With increasing software appearing in the market and available to teachers, studies suggested diverse ways of using computers by mathematics teachers with various pedagogical purposes (e.g., Li & Ma, 2010), and the cultivation of mathematics thinking and reasoning was highlighted. Visualization, for example, was highlighted as one of the most significant change that computer brought. Borba and Villarreal (2006a), for example, in their book discussed the difference between mental activities using traditional teaching methods (paper-and-pencil-based) and alternative methods (computer-based) and stated that traditional lecture always valued symbolic and logical activities and hugely ignored visualised activities which could be assisted by using computers. Villarreal (2000) identified two different ways of thinking towards mathematics questions: one is algebraic approaches, which preferred for algebraic solutions, and seeking formulate conjectures or generating explanations based on equations and formulas; the other one is visual approaches, which preferred to using graphical information to solve and express solutions, and seeking conjectures or generating explanations based on graphical representations. According to the author, computer-based mathematics software was powerful in linking these two approaches together and encouraging pupils in thinking diversely. In this way, visualisation and symbolic manipulations can ''complemented each other in order to contribute to a deeper mathematics understanding'' (Borba & Villarreal, 2006a, p. 91). Here, computers are not just used as feedback generators which help students practice by trail-and-error, they can be used to create contexts and classroom discussions to involve students to reflect the theorems and operational principles behind the results, as well as analysing various mistakes and the possible reasons.

Another example was enhancing students' learning of algebra via computers. Nobre, Amado and Carreira (2012) did a small-scale empirical study with four 8-grade students on the resolution of a contextual problem with help of Excel. The authors discovered that due to the interface of the spreadsheet, variable-columns were generated, which enabled students to express and observe variables in a form of numerical sequences and therefore their understanding of relations among variables was developed and enhanced. The study also pointed out that the use of spreadsheet as a computational tool served to filling the gap between 'algebraic thinking' and 'algebraic notation' (p. 7), and such spreadsheet activities should be promoted for bridging the gap for algebra learning. Their study confirmed opinions from many other researchers (e.g., Ainley, Bills & Wilson, 2004;

Haspekian, 2005; Rojano, 2008) that spreadsheet column-based interface allowed students to decompose complex algorithm to a ‘chained simpler ones’ (Nobre, Amado & Carreira, 2012, p. 2) and organize arithmetic solutions in an algebraic way which combined arithmetic and algebra together, resulting in assisting students’ development of algebra thinking.

In addition to bridge arithmetic and algebra, different kinds of changing phenomenon and chances for modelling with multi-representation including numerical, graphical, and symbolic can also be enhanced by computers (Arzarello & Robutti, 2010; Clark-Wilson, 2014), resulting in brand new mathematical environments for learners to engage with content, and the use of computer change mathematics from ‘‘static nature with paper and pencil to dynamic in computerized environments’’ (Tabach, Hershkowitz & Arcavi, 2008, p. 49). Multi-representations visualise mathematics, and are powerful tools in modelling, contrasting, and operating mathematical objects, which turns mathematics knowledge into mathematical activity, and turns display notation systems into action notation systems (Kaput, 1992), which can be especially helpful in the learning of geometry. Borba and Villarreal (2006a) described visualisation on two different levels: one is associated with mathematical proof; the other one is associated with other mathematical activities including ‘‘making conjectures, solving a problem or trying to explain some mathematical results to peers and teachers’’ (p. 86). Although, visual representations are not widely accepted as a way of formal proof, it worked as ‘‘heuristic accompaniments to proof’’ (p. 86), and provided hints for learners to think of and understand the formal proof, and therefore the second level of visualisation is more meaningful as a pedagogy.

Studies on the use of Dynamic Geometry Software (DGS) echoed discussions from Borba and Villarreal (2006b), and suggested that although doing geometric experiment was considered by teachers and researchers different to formal deductive reasoning, these software was adopted to prepare students in grasping proof (Hadas, Hershkowitz & Schwarz, 2000; Jones, 2000; Mariotti, 2000; Jones, 2002). DGS can provide learners with various functions such as dynamic observing, constructing figures, measuring and so on, and all these functions are important in assisting pupils of interpreting and applying their understanding of certain knowledge. By observing the change of numbers and shapes on the screen, students can have many chances to make, confirm, modify, and re-check conjectures, and the process helps pupils to obtain and view mathematics knowledge in different ways.

Jones (2000), for example, conducted an experiment with students aged twelve, who were asked to construct a figure which could be transformed into a specified figure by dragging, and then the students were asked to explain how they thought and what made their figure the expected ones. The results revealed that students, with the help of computers in creating and operating with figures, gained some progression in understanding ‘‘hierarchy of functional dependency within a figure’’ (p. 80), and changeable and unchangeable features of a mathematical object, which was good for them to make sense of proofs. Later, Jones (2002) reviewed and summarised studies on the adoption of Dynamic Geometry Software (DGS), and further suggested that interacting with DGS enabled students to ‘‘explore, conjecture, construct and explain geometrical relationships’’ (p. 20) by which students could obtain basis to build deductive proofs in future learning.

Similar to Jones, Mariotti’s (2000) did a long term study on proof in which 15-16-year-old students were grouped into pairs to be asked to construct figures, to explain constructing procedure, and to reflect the hidden reason which made the figure satisfying the set requirements. This activity, according to Mariotti (2000) was successful in changing students’ justification from ‘‘intuition geometry’’ (p. 30) to ‘‘theoretical thinking’’ (p. 48). Hadas, Hershkowitz and Schwarz (2000) developed two instructional activities which required students to make assertions on the observed geometric patterns and then checking the conjectures they made by using Dynamic Geometry Environment (DGE). For example, students were asked to measure (with the help of software) the sum of interior and exterior angles of a polygon with its shape changed (the number of sides increased), and then to generalise what they had observed to a general situation (or to form a conclusion). Later on, the students were encouraged to adopt DGE to check their conclusions. Students in the study made false hypotheses, and the checking of their conclusions did raise their need in looking for the reasons of the falsity of their conjectures. The use of DGE, according to Laborde (2000) did help students realise the necessary for proof in mathematics, and the exploration power in geometry learning offered by DGE was ‘‘the interplay of conjecture and checks, of certainty and uncertainty’’ (p. 154).

In addition to changing the way teachers and students engaging with traditional subject matters, computers also provide opportunities for new contents to find their ways to school mathematics. For example, Goos, Stillman and Vale (2007) believed that various technologies freed students from simple data sets which were man-made, and enabled students to face real world data which is living. The powerful functions of technologies can assist learners to do lots of exploratory work and make new contents available for younger students (such as regression in statistics). Besides, the use of software and certain programs in simulating and modelling random phenomena can be considered as scaffolds in promoting students’ statistical knowledge and thinking.

Garfield and Ben-Zvi (2008) noticed the strong connection between school statistic knowledge and statistical practices, and pointed out that with the help of technology, researchers and practitioners changed their ways in handling statistical problems, so the knowledge taught in the school should also be changed correspondingly. For example, many assumptions made for a simple and useful model due to the lack of advanced computing tools several decades ago are unnecessary now, and therefore students are possible to be exposed to and operate with the 'authentic' model rather than the 'simplified and approximate' one, which is more useful in promoting their statistic thinking. Similarly, due to the embracement of technologies, statistical tables such as *z*- and *t*- tables were unimportant, so was the so called 'short-cut methods' for calculating standard deviation. More efforts should be put, said the authors, on cultivating students' statistical literacy and understanding of the underlying principles rather than the manipulative rules, which was the focus of the past curriculum.

An experiment conducted by Gürbüz and Birgin (2012) reflected similar ideas. The experiment with 37 seventh-graders aimed to examine whether the use of animations and simulations through computers would decrease students' likelihood of having misconception on probability. The animation and simulation could generate infinite examples which helped students understand and verify the theoretical basis of the concept. In addition, as students could make conjectures every time before the implementation of the experiment, immediate feedback was provided enabling students to justify what they observed and enhance their inner-understanding of the concepts. The findings showed that the use of real world materials motivated students in exploring and learning processes, and students' understanding of the concepts of 'Probability Comparison', 'Equi-probability', and 'Representativeness' were all enhanced.

Real data can be downloaded online, but they can be also generated by learners themselves. According to Goos, Stillman and Vale (2007), data-logging equipment enable students to collect various kind of quantitative data from environmental features such as temperature, light intensity, dissolved oxygen, to body-related features such as heart rate, speed of pacing, etc. and these data can be adopted to promote students' learning of mathematical relationships and the graphical representations. By collecting and investigating the data, students are more likely to be motivated and to understand usefulness of mathematics in daily life.

Early in 2000, Kwon (2002) did an study with 590 students from six schools located in Seoul, Korea, of which five were middle schools and one was high school. The study, lasting for six class periods (45 minutes for each class period), aimed at exploring whether the use of Calculator-Based Ranger (CBR)[6] improved students' graphing ability. Pre- and post-test were adopted in the study to see students' change of understanding and interpreting graphs mathematically. The findings

[6] CBR – Calculator-based ranger, which is a sonic device detecting user's movement, and can measure distances, velocity, acceleration and present their relationship in various ways. Another similar term is CBL – computer-based laboratory, which detects the real-world situation such as light intensity, temperature, and also detects people's movement, with the data presented in the form of graph or table, etc.

showed that with the help of CBR, students' graphing ability developed significantly in three components: interpreting, transforming, and modelling. The author found that compared to the students learning graphs in the traditional approach, their counterparts with CBR presented a better understanding at both global feature of graphs as well as explaining the meaning of relationships between two variables. This study indicated a promising function of CBR in enhancing students' graphing ability as well as their ability of connecting mathematics with other disciplines. Another example was provided by Geiger *et al.,* (2014) who conducted a study in which students were asked to wear pedometers during all walking hours for one week, and the number of paces was recorded to Excel spreadsheet daily. Students then were asked to analyse their own data and compare the results with those of others. The authors discovered that digital technologies were useful in collecting, displaying and analysing data from real world, and students were motivated by using Excel to graph and visualise the data so that they could do more explorations. Besides, technologies also allowed students to ''choose the type of graphs they used to present data …[which] open up the prospects of students making their own decisions and then reflecting on the appropriateness and effectiveness of the resulting representatives in forming and justifying their opinions about different aspects of their classmates' level of activity'' (p. 19). What's more, Geiger *et al.,* (2014) also found that such activity helped students obtain a sense of how far they walked in a course of a week or a day in term of kilometres.

Other technologies

In addition to calculator and computer which are the most common two devices adopted in the mathematics classroom for decades, other technologies, including Interactive Whiteboard (IWB) and mobile devices, also find their ways to school education.

Within the recent decade, Interactive Whiteboard (IWB) became more and more popular in educational settings and has been embraced as a regular part of classroom equipment in many schools. Research evidences show that IWBs are widely accepted in many nations and regions including the UK, America, Australia, and China etc. (Cui, Huimin & Lina, 2012; Sead & Nihad, 2013; De Vita, Verschaffel & Elen, 2014), and enable teachers and students to interact with and integrate multi-forms of digital resources into classroom instruction.

The discussions of IWB in instruction have paid much attention to its touch-sensitive screen, which has been regarded as the most obvious difference provided by IWB compared to its predecessors. Educators believed that the touchable nature of IWBs enhanced material presentations in classes and enables multimedia resources to be utilised in an interactive way. (Boyle, 2002) According to Glover and Miller (2001), with the help of IWBs, teachers were more likely to go through a smooth transition among different instructional activities, and to combine and manipulate materials of different nature (static or dynamic pictures, animations or simulations, and audio resources etc.) in one lesson. These ideas were also supported by Latham's (2002) findings that less time was spent in preparing and managing instructional resources and the pace of mathematics lessons were quickened due to the use of IWBs, which facilitated a 'seamless flow' from one specific knowledge to the next.

'Interaction' has also been widely mentioned by researchers when talking about IWBs. Austin (2003) reported examples in IWB-based classroom where children were eager to stand up and come up to the board to write and draw with e-pens, indicating that physically interaction between learners and the board motivate pupils. In order to explore the interaction-enhancing function of IWBs deeply, Levy (2002) did a study with two Sheffield schools in which he found that the big scale of the IWB screen enabled visual information to be shared by the whole class, resulting in encouraging students to ask questions or make conjectures which could be directly and immediately demonstrated.

In addition, the use of IWBs for multimedia presentation was also widely studied in educational field across all levels. Edwards, Hartnell and Martin (2002) reported concrete examples where IWBs were used to help students grasp challenging mathematical concepts. They noticed that when teachers used real-time movement and animation effects provided by IWBs such as translation, rotation and highlighting, pupils were given visual clues to the related concepts and therefore were supported in grasping knowledge like operation of fractions, measuring an angle, and tessellation, etc. (Edwards, Hartnell & Martin, 2002) Carson (2003) found that IWBs-based interactive games could motivated pupils' motivation and thinking, and when they tried to manipulate mathematical objects on the screen, teachers could observe and monitor learners' progress and diagnose weakness of their learning or whether misconceptions were formed for an early rectification.

Early studies and discussions on the use of IWBs in educational settings focused on specific functions that IWBs have which can potentially benefit classroom instruction, and the number of schools adopting IWBs in regular teaching activities were found to be small. Therefore less large-scale and comprehensive studies were reported. With increasing programs pushing schools to use IWBs have been launched, in-depth investigations and longitudinal observations are possible, and more detailed analysis is also available.

Moss *et al.* (2007), for example, evaluated the expansion of the use of IWBs in all London secondary schools, aiming at assessing the impact of IWB use on teaching and learning; teacher/pupil motivation, and pupil attendance and behaviour; as well as students' outcomes of the core subjects. The authors revealed that IWB as a technology attracted increasing secondary schools of their core subject departments, and it adapted well to ''whole class teaching environment'' (p. 4). Among all subjects covered in the study, mathematics and science were regarded as the main beneficiaries of using IWBs, with plenty of external subject specific software available for teachers. Researchers also found that teachers in the classes always used IWB solely rather than combining IWBs with other peripherals, which had the potential to free teachers from the front of the class as mentioned in Walker (2002b). By analysing recorded mathematics lessons, Moss *et al.* (2007) found that when teachers lacked clear pedagogical purposes, they focused more on technological issues of the IWBs, and thus less interactions between teacher and pupils were discovered.

Similarly, Glover *et al.* (2007) video-recorded and compared 50 lessons which were given by 'successful' teachers from mathematics (34 lessons) and modern foreign language in secondary schools in the UK. The lesson videos were analysed with respects to lesson structure, classroom management, and IWB impact on effective teaching. According to the authors, there were three approaches to teach with IWBs environment: supported didactic, interactive, and enhanced interactivity (Miller *et al.*, 2005), with IWBs adopted as a visual support for assisting teacher-centred pedagogies, as novel tools to challenge pupils' thinking with the technological potential not being fully developed, and as a non-novel tool to assist interactivity in the class respectively.

Bruce *et al.* (2011) conducted a qualitative study and observed two classroom instruction over 8 months, aiming at investigating what effects IWBs have on students' learning, and how the effects achieved. The findings revealed that the 778 lesson observations overall showed a positive influence of IWBs on instructions, with 89% of the observations identified as productive use, where teachers or students used dynamic features of technology; 2% as reproductive use, where IWBs were just used for non-dynamic presentation ''which could easily have been substituted by a slide presentation or writing on the board'' (p. 440); and 9% as problematic instances, where technological errors occurred or trying to establish a visual learning environment without success.

These deep investigation suggested some common feature of using IWBs in school mathematics instruction: first, IWBs are useful in enhancing instructors' presentation in front of the (especially large-size) class, including navigate to multiple screens as a data projector, and displaying dynamic resources rather than statistic ones; second, when teachers obtained confidence in technology itself, they tended to become more aware of students' different learning styles; third, good practices with IWBs indicated teachers' move away from IWBs technical features such as drag and drop to utilize dynamic demonstration to create in-depth conceptual discussion and interactive work with learners, and therefore pupils' progression was enhanced by the quality of teaching rather than the IWB itself, and only when teachers get enough skills in using the technology, can it be fully developed as an effective pedagogical tool.

Another technology which attracts increasing researchers and practitioners' attention is various mobile devices. Even though the use of mobile devices in education is quite new, there are some studies discussing how mathematics education could benefit from joining in the mobile-learning (m-learning) groups.

An early study on the educational use of tablet Personal Computers (tablet PCs or TPCs) was done by Wise, Toto and Lim (2006). The study adopted both questionnaire and interview to collect data with 163 students participated in and they were asked about their preferences of using tablet PCs in learning as well as their opinions upon the effectiveness of tablet PCs in enhancing their learning. Overall speaking, students expressed a very positive attitudes towards the uptake of tablet PCs in lectures, and they were likely to pay more attention to teachers and learning materials when tablet PCs were used than when just pencil and paper were used. As regards to the effectiveness of tablet PCs in learning, 65% of the participants stated that tablet PCs made lectures easier to be followed and understood, and over 90% participants thought that non-textual information such as diagrams, pictures, and charts, could be better presented and key points could be highlighted by utilizing tablet PCs in classes. Though the findings were encouraging, authors were critical in interpreting them, and claimed that ''novelty effect'' (p. 20) could be the reason to the positivity, that is to say, new things were effective in grasping students' interests. Therefore more well-designed and comprehensive studies are needed.

According to Shin, Norris and Soloway (2007), mobile devices are widely adopted for inquiry-oriented instruction and learning activities in mathematics education, such as learning geometry and drawing graphs, exploring patterns in algebra, doing simulation games, scientific fieldwork and collecting data outside the school or classroom, etc. Hagos (2008) did an empirical study through which he examined how mobile phones could assist and enhance students' learning of mathematics when the teachers were absent from the classrooms. 90 students with their own mobile phones joined in the study, and short message system (SMS) was the main approach to send content-related texts (which was termed as 'lecture-texts'). Findings suggested that most students held a satisfactory attitudes towards the lecture-texts in terms of the content, illustration, ease of use, as well as flexible self-pacing and self-learning. However, the participants also reflected that due to the nature of texts, it was a little bit hard for them to understand difficult concepts in mathematics. In addition, students whose learning style was more of auditory-type might gain little through SMS.

Similarly, Amiratashani (2010) conducted an 10-week study to investigate how short message system (SMS)-based co-curricular activities could enhance students' learning of mathematics. 50 students were sent mathematics quizzes through SMS and they also received teachers' feedback via SMS over this period, with contrast to their counterparts consisting of another 50 students who didn't involve in m-learning. The findings revealed that students' motivations were increased through the use of SMS co-curricular activities. Besides, students with SMS were found to be more likely to interact and co-work with peers in solving mathematics problems.

A more comprehensive collection and analysis of empirical data has been done by Galligan *et al.* (2010), in which the authors surveyed students and teachers in the University of Southern Queensland in terms of adopting TPCs in mathematics education. Three different types of situation where TPCs exert impact were discussed: the lecture (one to many), the tutorial (one to few), and the consultations (one to one). According to authors, the main advantages for using TPCs in all situations was that the whole instructional process could be recorded for instructors to analyse as well as for learners to do after-class revision work. Besides, typical advantages for each type of situation were also identified: during whole-class lectures, teachers were able to write the problem-solving process in details with vocal explaining simultaneously under the use of TPCs; for tutorials, teachers were easily to capturing and analysing students' learning activities of different groups without disturbing them, and thus more specific guidance could be provided for further group work; for one to one consultation, instructional file could be established and the learning sessions could be reused and shared by other learners.

Roberts and Vänskä (2011) introduced a mobile learning program in South Africa, in which mobile phones were used for teaching and learning mathematics at secondary school level. Thirty public schools were involved in the program, and the following three aspects were discussed: learners' accesses to the services; learners' and teachers' use of the services; and the impact of the service on learners' mathematics outcomes. The findings showed that most of the students had own personal mobile phones, with a small proportion stating that they were unable to have access to mobile devices whether personal or shared ones; the overall pattern of teachers' use of mobile phone in accessing to the services mirrored that of their students' use, according to the authors, and during the time when learners needed to prepare to tests or competitions, they used the services more frequently; Teachers in the study expressed their opinions that mobile learning did make mathematics enjoyable to some extent, but they also worried about that students' mathematics learning would possibly be influenced by their inappropriate adoption of the devices. The findings also revealed that teachers' uptake of mobile phones in accessing the learning services greatly encouraged students' use, however learners' academic outcomes didn't reflect a significant contribution caused by using the mobile phones and services.

As can be seen, comprehensive and well-designed studies on mobile learning are still lacking and thus controversial findings were reported in different situations. However, through reviewing the existing studies, it can be found that although there may be exceptions, in a great sense, mobile learning is still an informal way of learning which acts as a complement to formal, classroom instruction. Besides, due to the lack of stability of network or the internet connection in some areas, the information-exchange between students and teachers through the mobile devices can be asynchronised, which influence its power in delivering mathematics instruction negatively.

2.3 Affordances of Technology for Mathematics Instruction

When discussing how technology can be used to enhance mathematics instruction, many researchers adopted the concept of ‘affordance’ to describe the usefulness of the tool for the users (e.g., Conole & Dyke, 2004; Pierce & Stacey, 2008; Hammond, 2010; De Vita, Verschaffel & Elen, 2014). Therefore it seems helpful to give a brief introduction on what does ‘affordance’ mean by researchers first, before discussing what mathematics educational practitioners can benefit from various technologies.

‘Affordance’ was firstly used and interpreted in the book *The Ecological Approach to Visual Perception* by the perceptual psychologist James J. Gibson. In his work (Gibson, 1977; 1986), Gibson highlighted the interactive characteristic between an individual and the environment, and explained an affordance as an action possibility based on the environment to an actor. According to him, ‘‘the affordances of the environment are what it offers the animal, what it provides or furnishes, either for good or ill’’(Gibson, 1977, p. 127), and the affordance has dual features: objective and subjective. It is objective because its existence doesn’t rely on any value or meaning interpretation; while it is subjective because it is associated with actors which refer to people, or at least organisms. McGrenere and Ho (2000) described Gibson’s affordance as an actor-environment mutuality where ‘‘the actor and the environment make an inseparable pair’’ (p. 2)

Hutchby (2001) adopted Gibson’s ‘affordance’ and moved it from environment to the field of technology where he discussed a lot about information technology (IT) artefacts. He regarded the affordance of IT artefacts as their functions to facilitate possible actions taken by actors (users). Hutchby (2001) also acknowledged the pre-conditional nature of affordance for an activity, and claimed that affordances of various technologies were object, for they were bounded within the artefacts themselves rather than anything out of them; and subjective, for their actualisation depended on the users. However, he highlighted that unlike environment whose affordance in Gibson’s (1986) work as can be ‘directly perceived’, IT artefacts were not that obvious in their use for potential actions when users had little idea about it. Similar explanation was also proposed by Hammond (2010) where he distinguished physical properties (such as size, materials, etc.) from symbolic properties (such as interface and texts) of technologies. According to Hammond (2010), although both physical and symbolic properties are ‘existence and real’ (p. 214), they are different in nature and need to be perceived differently by users. So affordance of a technology also indicated that the information of its potential was acquired by the user.

Consequently, affordance reflects the action-related relationship between a user and a technology. The affordance of one technology describes the features of the technology, how the technology could be used, as well as the user's perception of the potential of the technology.

Now let me turn to review studies conducted by different researchers on exploring and discussing what affordances technologies offer to education in general and to mathematics instruction in specific.

2.3.1 Affordances of technology in general

Higgins (2003) submitted a report to the British Educational Research Association (BERA) stating that according to the existing literature, technology did make a difference to pupil's learning, and there were large scale studies showing that positive link could be found between the use of ICT and children's attainment. In the report, Higgins proposed four advantages provided by technologies: (1) Increasing practice is a key feature of how ICT can help to improve learning; (2) Feedback from a computer can help pupils to learn in a range of different ways; (3) Multimedia helps presenting information in various forms, and pupils then can see connections between forms; (4) ICT can be used to promote discussion in small groups and in whole class settings, which can help develop pupils' thinking and understanding across the curriculum in a variety of subjects. The author emphasized that effective use of ICT depended on the choices that a teacher made about how to use ICT as part of the teaching, and no single or simple solution could be found to the effective use of ICT.

Conole and Dyke (2004), by adopting the notion of affordance, listed ten features that ICT brought in, and they believed the features can help practitioners to rethink their behaviours with technologies. Among the 10 features, *Accessibility* and *Speed of change* described the fact that ICTs made the obtaining of vast amount of various information easily and rapidly; *Diversity* and *Communication and collaboration* focused on the potential offered by ICTs that learning with and sharing experiences with 'others'; *Reflection* and *Multimodal and non-linear* indicated that the use of technologies provided a chance to individualized the way of learning, and asynchronous technologies enabled learners to come back to and to engage in the discussion over ''a longer time frame'' (p. 118) which promoted the reflection and criticality. The other four features of ICTs — *Risk, fragility and uncertainty*; *Immediacy*; *Monopolization* and *Surveillance*— were more like suggestions for teachers to think critically when teach with technologies.

In their review of literature on the use of Interactive Whiteboard (IWB) in classroom, Smith *et al.*

(2005) summarised six potential benefits provided by IWB for teachers: (1) *Flexibility and versatility*, which extended the content and activities of the lessons[7]; (2) *Multimedia/multimodal presentation*, which enabled teachers to use a wide range of resources including images, sound, and videos to ‘‘bring knowledge to life’’ (p. 93); (3) *Efficiency*, with specific reference to the fact that ‘‘touch-sensitive nature of IWBs facilitates a more efficient presentation and more professional delivery of multimedia resources’’ (p. 93). Besides, IWBs could help for smooth transition between activities within one lesson; (4) *Supporting planning and development of resources*, which referred to IWBs’ ability to save, share, and re-use teaching materials so that the planning time of a lesson would be reduced eventually; (5) *Modelling ICT skills*, which indicated that the frequent use of technologies in the classroom helped students learn and understand ICTs skills effectively and quickly, and (6) *Interactivity and participation*, meaning that the use of IWBs promoted purple’s verbal and physical participation as well as promoted students’ interaction with teachers and other peers[8].

According to Bruce (2012), the benefits of IWB were identified by many scholars as: (a) ease of use for whole-class demonstration; (b) increased level of student engagement; (c) integrated use of multimedia resources (p. 1). By conducting an empirical research, she found that teachers used IWB in various ways which reflected their views of IWB as different tools for mathematics education: Non-Dynamic Presentation tool and Dynamic Thinking Tool. She insisted that in addition to the benefits recognised by early studies, the IWB also provided (a) visually dynamic support for the illustration of complex mathematics; (b) opportunities for shared student reasoning, including use of IWB tools to justify and consolidate ideas and to debate multiple student solutions; and (c) opportunities to increase student agency and risk-taking (p. 4).

Similarly, De Vita, Verschaffel and Elen (2014) summarised plenty researchers’ opinions and stated that IWBs were powerful in teaching, with various functions being identified: (i) drag and drop; (ii) hide and reveal; (iii) colour, shading and highlighting; (iv) multiple visualisation; (v) multimedia presentation; (vi) manipulation of objects from other technologies and software; (vii) movement or animation; (viii) indefinite storage and quick retrieval of materials.

2.3.2 Affordances of technology for mathematics instruction

Auricchio *et al.* (1997) discussed some issues about computer laboratory activities in mathematics education. They noticed that many teachers in school didn’t form a comprehensive and critical

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[7] Walker (2002) reported a teacher stating that the ability of IWB to ‘‘flip back and review material’’ (p. 2) was quite beneficial for students with lower abilities or special needs.

[8] Levy’s (2002) study suggested that with the help of IWB, students were more inclined to share their work with and articulate and explain their ideas to others. Besides, students were also enjoy seeing, listening, and discussing other pupil’s work.

view of computer in teaching and learning mathematics. Some of them considered computer as a tool, like a textbook or a compass, and some others consider it as ‘‘a subject of interaction’’ (p. 246). The formers failed to recognise the full potential of computer in mathematics education and hence would not make full use of it; the latters however ignored the limits of computers in education and hence confused what can be expected to perform by computers and what must be done by users. The authors believed that in order to be a good user of computers in mathematics education, more attention should be paid on the balance of computers, users and mathematics tasks in hand. They stated 3 functions offered by using computers, which contained ‘‘fast computation, visualisation of two- and three-dimensional objects, and simulation of casual events’’ (p. 247), and some examples were provided as follows:

- *discuss the same mathematical concept from different points of view, which usually leads to a deeper understanding and a better master of concepts; for instance, geometrical transformations can be completely described by means of equations, but using also a graphical representation clarifies better the concept;*
- *changing the presentation order of some concepts, based on their relative degree of difficulty; for instance, the resolution of equations can be introduced graphically before completing the study of algebraic manipulation rules;*
- *focusing on resolution strategies rather than on performing calculations, which can improve problem-solving activities;*
- *emphasising the meaning of math concepts before being able to formally handle them; for instance, derivatives computed by some software can be used to find minima and maxima of a function, based on their meaning, before learning to compute them;*
- *exploring conjectures can lead to distinguishing conjectures from demonstrations;*
- *solving problems by trial and error can emphasise the power of formal methods;*
- *discovering rules by analysing the output of some software can make easier to remember them and to understand their meaning.*

Ruthven and Hennessy (2002) interviewed teachers from seven schools located around Cambridge, and these schools covered the secondary age range from 11 to 18. Questions upon what teachers saw as ‘‘successful practice’’ (p. 54) with ICT were asked and analysed. Finally, ten operational themes were summarised as teachers’ views about the affordances of ICT in supporting the achievement of classroom goals: *Ambience enhanced*, which meant that using ICT increased student’ interest in learning mathematics; *Restraints alleviated*, which indicated that ICTs liberated students from paper-and-pen work, so that all students, including those with lower abilities or physical disabilities who considered doing mathematics with paper-and-pen as ‘‘drudgery’’ (p. 66), could engaged in mathematics learning; *Tinkering assisted*, which supported self-correction and ‘‘trail and improvement’’ (p. 68) strategies for students; *Motivation improved*, which associated the use of ICT with students’ positive attitudes and self-confidence improvement; *Engagement intensified*, which highlighted that using ICTs could improve the students’ engagement in classroom work both quantitatively and qualitatively[9]; *Routine facilitated*, which focused on the fact that using ICTs allowed routine learning activities ‘‘to be carried out more quickly and reliably, with greater ease, and higher quality’’ (p. 70); *Activity effected*, which associated the use of ICTs with ‘‘securing and enhancing the pace and productivity of classroom activity as a whole’’ (p. 71); *Attention raised*, which meant that with the help of ICTs, students’ attention could be more easily focused on main tasks, rather than on subsidiary works (like complicated calculation or graphing); *Features accentuated*, which associated the use of ICTs with ‘‘the provision of vivid images and striking effects through which features of mathematical constructs — or relations between them— are accentuated’’(p. 72), and *Ideals established*, which highlighted the help of ICTs in formation and consolidation of mathematics ideas.

Goos, Stillman and Vale (2007), in their book *Teaching Secondary School Mathematics: Research and Practice for the 21st Century*, reviewed previous studies on the potentials of technology for mathematics learning and summarised seven ways in which various technologies are able to afford learning opportunities in mathematics: Learning from feedback; Observing patterns; Making connections between multiple representations; Working with dynamic images; Exploring simulated or authentic data; Visualisation; and finally Finding and sharing mathematics. In the book, the authors highlighted that knowing how to use technologies ‘‘was not as same as knowing how to teach effectively with technology’’ and hence knowing affordances of technologies for mathematics education is vital for a successful tech-rich classroom.

In 2009, the British Educational Communication and Technology Agency published two entitlement documents for primary and secondary students (Becta, 2009a; 2009b) in which six major opportunities that students could benefit from engaging learning with ICT in mathematics were proposed: Learning from feedback; Observing patterns; Seeing connections; Developing visual imagery; Exploring data; and ‘Teaching’ the computer. Several examples were attached in the document to clearly explain each opportunity, and the table below briefly summaries the information.

[9] Which means that using ICTs could encourage more students in mathematics learning, as well as increase the degree of independence and persistence in solving learning tasks.

Table 2-1. Opportunities provided by technology (Sourced from Becta 2009b)

Opportunities	Examples
Learning from feedback	Students use trial and improvement strategy to solve equations with calculator or spreadsheet; Students explore graphs of a function (e.g. $y=mx+c$) via varying coefficients and observing.
Observing patterns	Students drag a point on the screen and watch the movement of another point, and make a conjecture of the relationship between these two points; Students use number grid to learn calculation.
Seeing connections	Students use handheld devices to see formulae, tables of numbers and graphs and try to linked them together;
Developing visual imagery	Students manipulate diagrams dynamically by computer software to generate their own mental image; Exploring 3-D shapes dynamically.
Exploring data	Working with real data and observe them in different ways; or explore relationships between different variables to gain a deep understanding of statistics.
'Teaching' the computer	Using Logo to certain pictures and get familiar with the ideas behind; Using formulae and display in spreadsheet to understand and solve a problem.

By investigating mathematics teachers and students from 45 schools in the Tuzla Canton area in Bosnia and Herzegovina, Rešic and Bešic (2013) found that only 18% of the teachers participating the research said that they often use computers in the class, with 46% occasionally. However, 56% of the teachers showed their willingness to use computers more in teaching mathematics. Regarding how computers were used, they summarised the manners of adopting computers in teaching mathematics as *presentation*, which enabled students to be exposed to very real, 'original or interesting' (p. 114) situations; *video footage*, which made it possible to motivate students by interpreting parts of subject that were hardly to be performed in a utmost quality in a traditional class; *programs*, which divided the subject matter into small, easy and logically connected units; *games*, which contained many tasks to drive students to achieve; and *ready-made software*, which were specific designed for learning certain subject matters. Besides, the authors also discussed some potentials that computers could provide for student to learn mathematics in a better way. Firstly, pupils could focus more on understanding tasks, problems and the solving strategies with the help of computers, without being afraid of making mistakes in calculation. Secondly, teachers could be free via computers from choosing examples and tasks with 'nice solution', and therefore students could obtain better image and idea about how significant and useful mathematics was in real life. Finally, computers were also considered as an effective tool for evaluating and grading students' work since they provided more objective and reliable assessment of students' classwork and enabled comparison of results among different students as well as results of one student in various period of studying.

Sead and Nihad (2013) studied how IWB could serve for a better learning of mathematics. On the one hand, IWB was helpful in 'better motivating students and retaining their attention', as well as in encouraging 'multimedia presentations' (p. 133); On the other hand, various types of educational software and programs could be adopted via IWB, such as *Graphic tools*, including Winplot, Dplot, Graph; *Dynamic (interactive) Geometry Software*, including GeoGbra, Cabra, GSP, Cinderella; *Computer Algebra System (CAS)*, which was actually computer-based symbolic calculation application, including Mathematica, Maple, DERIVE, Sage, Maxima, etc.; and *Program for spreadsheet* (for data presentation and analysis), including Microsoft Excel, OpenOffice.org Calc, Lotus 1-2-3, Gnumeric, etc.

In terms of calculators, Hennessy (2000) explored and discussed a lot in how graphic calculators helped students do graphing investigations. In one of her paper under the PIGMI (Portable Information Technologies for supporting Graphical Mathematics Investigations) Project[10], She asserted, by surveying and interviewing both students and teachers, that the graphic calculators' main advantages for assisting students' graph learning contained that (1) visualisation of functions; (2) automatic translations between representations and providing immediate feedbacks, and (3) rapid and easy graph plotting (Hennessy, 2000). In a later exploration (Hennessy, Fung & Scanlon, 2001), a comprehensive perspective was formed about the benefit of the use of graphic calculators: (1) increased motivation through student 'ownership' of both the data and the technology in the context of an activity offering opportunities for active, independent learning; (2) speeding up the process of graphing and free students to analyse and reflect on mathematical activities; (3) encouraging translation back and forth between numeric and graphical representations; (4)

[10] A three-year half-time project began in 1996 and finished in November 1999, aiming at investigating the role of portable technologies in facilitating development of students' graphing skills and concepts.

immediate visual feedback from the user's actions; (5) providing opportunities for exploring properties/relationships between graphs; (6) the flexibility of portables — especially in terms of time and place of use, both inside and outside the classroom — is an advantage over desktop machines (p. 256). Besides, the authors also identified the support of graphic calculators for students' peer collaboration and communication on certain learning topics (Hennessy, Fung & Scanlon, 2001). The affordances listed above were also viewed by Hennessy as principles for activity design in mathematics learning.

In a qualitative study, Doerr and Zangor (2000) observed totally 270 minutes classroom teaching of one teacher in a suburban school. According to them, the graphing calculators mainly played five roles in learning mathematics: Computational Tool (used for evaluating numerical expressions, estimating and rounding); Transformational Tool (used for changing the nature of task); Data Collection and Analysis Tool (used for gathering data, controlling phenomena, finding patterns); Visualizing Tool (used for finding symbolic functions, displaying data, interpreting data and solving equations); and Checking Tool (used for confirming conjectures, understanding multiple symbolic forms). Besides, Doerr and Zangor (2000) also found that 'the use of the calculator as a personal device can inhibit communication in a small group setting, while its use as a shared device supported mathematical learning in the whole class setting'. (p. 143)

Heid and Edwards (2001) discussed deeply about the affordances provided by CAS-calculators. In their article, four possible roles of CAS-calculators in mathematics curriculum were considered: first, CAS-calculator could produce symbolic results, which ''enabled students to focus on other aspects of mathematics'' (p. 130); Second, symbolic procedures could be generated and presented, which made it a pedagogical tool for learning symbolic manipulation; Third, CAS could assist students to construct symbolic pattern through generalising from plenty examples, and finally, CAS could deal with problems in abstract form. Overall, the authors believed that CAS-calculators could enhance students' symbolic understanding, and enabled students:

- *to see that different symbolic expressions provide different information;*
- *to outsource routine work to the CAS so that they can focus on more conceptual ideas, on the "bigger picture," or on more general ideas;*
- *to reason about symbolic results with confidence (possibly reducing students' anxiety over "making mistakes");*
- *to develop their own symbolic procedures;*
- *to bridge the gap between concrete examples and abstract generalization;*
- *to interpret information gained through one representation in an equivalent one (to see the symbolic in the graphic, to see the graphic in the symbolic, to visualize a*

contextual situation symbolically);

• to develop generalized rules for problem-solving; and

• to examine symbolic patterns (more concretely).

(Heid & Edwards, 2001, p. 129)

Similarly, Chance *et al.* (2007) divided the types of technology used in school teaching and learning around the area of statistics and probability into seven categories, which indicated different affordances that the technologies provided: *Statistical software package*, which was designed especially for statistical analysis; *Educational software*, which aimed to provide students with help in learning statistics; *Spreadsheets*, as a widely used and easily available program in almost every personal computer; *Applet/stand-alone applications*, which were on-line tools helping students explore concepts in visual, interactive and dynamic environment; *Graphing calculators*, portable devices for students to learn and explore mathematics; *Multimedia materials*, tools which could be used to combine different types of technology; and finally *Data repositories*, which was a rich data set for students to do statistically explorative activities.

In an early report on the use of technology in statistic study, Garfield (1990) and his colleagues proposed four major feature which were considered to be able to facilitate the teaching and learning of statistic knowledge: *Direct access*, so that students could observe and explore data and its subset in various forms and visual representations; *Flexibility*: which allowed students to draw different graphs based on certain data and experiment with it, so that students could find different models and thought about the fitness of the models. *Connectedness*, which allowed children to download data and related software direct from the Internet and to explore real life statistic problems; and finally *Representations*, from which students could gain some senses about the pros and cons of different presentation in displaying one set of data, and thus learned to read and draw presentative graphs.

Similarly, after presenting instances about how technology could benefit school statistics learning, Ben-Zvi (2000) suggested that most of the tools which promoted the learning of statistics were developed to provide help in the following areas: (1) Students' active knowledge construction, by ‘‘doing’’ and ‘‘seeing’’ statistics; (2) Opportunities for students to reflect on observed phenomena; (3) The development of students' metacognitive capabilities, that is knowledge about their own thought processes, self-regulation, and control; (4) The renewal of statistics instruction and curriculum on the basis of strong synergies among content, pedagogy, and technology. (p. 128)

In a review of literatures, Mills (2002) revealed that concepts of probability and statistics became more and more important knowledge for students to grasp and increasing studies had been done due to the introduction of Computer Simulation Methods (CSM) to mathematics classrooms.

Mills found that there were four main definitions of CSM: (1) Random number generator, which enabled teachers and learners to generate random numbers or to perform an experiment (like flip a coin) via window-based generators in related software, like Excel or MINITAB; (2) Using program-based software, like SAS PROC to set up a model to test certain assumptions; (3) A combination of the previews definition, which provide learners a model with a changeable parameter, so that students could perform experiment in different situations; and finally (4) Using commercial software which were exclusively designed for simulation. It should be noticed that commercial software are usually professional and have the potential to include more functions such as multi-presentation of the data and conducting statistic test. The generation of random numbers, according to Mills (2002), benefited youngers learners of their better understanding of inferential concepts.

Overall, there are considerable reviews and studies centered on affordances of technologies for studying mathematics in general or for specific topics (such as geometry and statistics). However to me, the majority confused affordances, strategies, with instructional goals. *Affordances* refer to the function-based features of the technologies regardless of how users use them. For example, technologies can generate data easily and quickly; technologies can present multimedia resources. *Strategy* demonstrated how a teacher intertwine a certain function into his/her teaching and usually strategies depends on the aims of the instruction set by the teacher. For example, CAS-calculator can be used to generate immediate feedbacks for symbolic inputs, which is one of its main function. If the aim of one lesson is to enable students to master the skill of solving equations, the teacher may ask students to manipulate with the calculator by trial and error, in other words, students can input different algebraic operations to see whether it leads to the exact value of the unknown, and change to another operation if unexpected outcomes are shown on the screen.[11] In another lesson, if the teacher want to let students know an algebraic formula, he/she may use the calculator to generate many concrete examples through which students are asked to observe and to find the pattern, and finally acquire the formula. [12]

Based on the discussion above, I shall focus on the function-based understanding of affordances

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[11] Heid and Edwards (2001) recorded a classroom example where students were using CAS-calculator to solve the equation of $2 \cdot x + 7 = 3$. Most of students found no problem in subtracting 7 from both side of the equation simultaneously, and obtain the expression of $2 \cdot x = -4$ on the screen. However, for the next step, some students chose to keep inputting the order of subtracting 2 from each side to the calculator, and obtained the outcome as $2 \cdot x - 2 = -6$, which forced them to reflect their order and the operation between 2 and *x* in the equation. In this way, students changed their commands to transform the equation gradually until it was solved. The author commented that "[i]n this manner, they [students] can practice recognizing an appropriate sequence of symbolic manipulation without being distracted by paper and pencil errors." (p. 131)

[12] Monaghan (2005) recorded a classroom example where students were asking to inquiry the factorization of $x^n - 1$. CAS-calculators here were used for generating a series of factorizations from $x^2 - 1$, $x^3 - 1$, to $x^8 - 1$. By observing the examples on the screen, students were encouraged to make a conjecture and then conducted some work for further confirmation.

in the discussion of technology in mathematics instruction, and hold the idea that affordances refers to those functional properties that determine how the things could possibly be used (Pea, 1993). Besides, the previous literature review also pointed out that for mathematics education, researchers discussed the affordances of technologies more upon three aspects: Data generation; Multi-resources presentation; and Dynamic demonstration. In order to analyse the accomplishment the affordance, a goal or aim is necessary since it provide necessary reason for the choice of strategy of technological integration. More detail explanation is demonstrated in Chapter 3.

2.4 Mathematics Teachers' Use of Technology in Instruction

According to Monaghan (2004), compared with knowledge and perceptions, only a small number of studies focused on teachers' actual use of technology in instruction (p. 328), and comprehensive investigations on such issue haven't appeared until recently, although these studies are still more or less problematic in quality. However, it is necessary to briefly review existing studies on which future explorations can be based.

Thomas (1996) investigated how computers were used by mathematics teachers in New Zealand secondary schools. Information on how often and what topic that involved teaching with computers were sought through questionnaires. Ten years later, a similar study was conducted (Thomas, 2006), and the findings were compared to see whether the perceptions and the ways on which teachers' use of computers had changed. Thomas concluded that there was ''a significant increase in the use of computers for the learning of statistics'' (ibid., p. 268), and that more generic rather than content-oriented software were used. Information on how teachers used computers was also collected in both studies, and the findings indicated that there was a significant increase in the use of computers in demonstrations, while the use of computers for skill-development significantly declined.

In the UK, a non-profit organisation—The Fischer Family Trust [13] (FFT)—conducted an educational project called 'High Impact ICT Resources' in primary and secondary schools (Becta, 2009a; 2009b). Data for secondary school was collected in 2000 and 2001 with 314 schools joining in. The mathematics departments were asked to rate different ICT resources, from hardware, peripherals, to computer-software and specialist devices, about how frequently these resources were used and about their impact on students' learning. Researchers went through and counted all the responses, which gave an indicator of how common the resources were used in schools now, and mean score for impact was also calculated. The table below listed top ten resources in order of

[13] The Fischer Family Trust (FFT, www.fft.org.uk) established in 2001, and aimed at providing data and analysis to all schools and local authorities in England and Wales to enable students to achieve their full potential and schools to improve.

both number of responses and impact rating.

Table 2-2. Results of ‘High impact ICT resources’ project (Sourced from Becta 2009b)

Item	No. of responses
Microsoft Excel	185
Logo	124
Omnigraph	91
SMILE Mathematics (small software)	91
Microsoft Word	56
Successmaker	54
Graphical calculators	40
NRICH website	36
Test for Success Maths	32
Cabri Geometre II	21
The Geometer’s Sketchpad	21

Item	Impact rating
Interactive whiteboard	3.6
Autograph (graphing and statistics)	2.9
Successmaker (ILS)	2.9
Graphical calculators	2.8
Omnigraph (graph plotting)	2.7
BBC Bytesize website	2.7
Microsoft Excel	2.3
Coypu (graph plotting)	2.3
The Geometer’s Sketchpad	2.3
Cabri Geometre II	2.3

In the same vein, Hyde (2004) investigated 38 schools across South Central England based on an adapted Fischer Trust’s instrument (Becta, 2009b) and found that the most commonly used technology was Data Projector, followed by Interactive Whiteboard (IWB) and Word Processor. Mathematics-related technologies like Spreadsheet, Graphical calculator and Graphing Package ranked as 4th, 5th, and 6th respectively in term of frequency of use, and LOGO was the least commonly used technology according to the study.

Comparing the figures in the ‘High Impact ICT Resources’ project, we can easily find that resources which were ‘frequently’ used do not match those which had ‘big impact’. For example, Logo ranked second in term of number of responses, however it didn’t appear in the list of ‘high impact resources’; while Interactive Whiteboard was considered as having high impact on students’ learning but it was not frequently used. Similar phenomenon can be also discovered in Hyde’s (2004) findings. These differences were of particular interest and indicated me to do further study to reveal exactly how, not just whether or not, the resources are used in the process of teaching and learning.

A report provided by Kitchen, Finch and Sinclair (2007) on behalf of the British Educational Communications and Technology Agency (Becta) studied the availability and uses of technologies in English primary and secondary schools. Data about secondary schools was collected through questionnaires from heads of departments of mathematics, English, modern language, science, music, and geography. They found that the most commonly used technologies reported by the teachers were desktop computers, laptops, interactive whiteboard (IWB), handheld calculators, data loggers and tablet PCs. As regards mathematics teachers, the report revealed that over half of them (53%) were more likely to adopt subject-specific software in lesson delivery although less proportion of mathematics teachers were found than teachers of other subjects to use technologies in lesson planning. Nevertheless, the study just revealed some general facts about the use of ICT in schools, and more detailed information, like how each technology was adopted, was still lacking.

Similarly, Goos and Bennison (2008) implemented a survey to describe Queensland's secondary mathematics teachers of their use of computers, graphic calculators and the Internet in teaching mathematics. The collected data revealed that computers were the more commonly used technology in teaching junior secondary year students, while calculators and the Internet were more likely used by teachers in teaching senior secondary courses. The authors also found that graphic calculators were ‘‘most useful for algebra/calculus/statistics topics’’ (p. 121), and that the other two technologies were more useful ‘‘for geometry/statistics/financial topics’’ (p. 121).

Focusing on studying the use of computers in instructing beginning algebra, Tabach, Hershkowitz and Arcavi (2008) observed two different seventh-grade classes with computer intensive environment for a year. The authors found that with the help of computer, students regularly contrasted results against expectations for an inherent and close understanding of the problem, which indicated the meta-cognition-supporting function of the technology, and students were found to be more likely to come up with diverse solutions to the problem situations. A detailed example of students' use of Spreadsheet (i.e., Excel) in the paper further indicated that the data structure displayed in the Excel promote the need for use of symbols to generalise relations between different quantities for depicting both ‘‘local connections’’ and ‘‘global nature’’ (p. 50).

Howard and Maton (2011) investigated and compared mathematics and English teachers of their use of technologies. They found that teachers' use of technologies was strongly associated with their view of the nature of knowledge they taught, and ‘‘ICTs were thus used [by mathematics teachers] for knowledge-code practices, emphasising epistemic relations (knowledge, skills, principles, etc.) rather than social relations (learners' dispositions as shown for example by free expression)’’ (p. 202). Examples were provided as that teachers often highlighted the value of computer software (like spreadsheet) in teaching mathematical principles, as well as that online ‘‘drill and practices’’ (p. 202) and visualisation packages (like Geometers’ Sketchpad and GeoGebra) as useful tool for mathematical skills.

In 2011, Hu *et al.* (2011) conducted a survey on Chinese high school mathematics teachers from seven provinces of their use of information technology (IT). The survey aimed at obtaining information on the following seven aspects: (1) teachers’ cognition on the development of IT; (2) the situation of teachers’ network-based learning; (3) teachers’ use of IT in teaching; (4) teachers’ requirement on students’ use of IT; (5) teachers’ cognition on the function of IT in instruction; (6) teachers’ need on IT; and (7) teachers’ attitude on the teaching and learning in network environment. 8152 teachers joined in this survey and 8063 valid questionnaires were collected. According to the data, computer and the software which were commonly used (including PowerPoint and Geometer’s Sketchpad) were familiar to the teachers, while telephone-based conference, network-based learning, iPhone and iPad, and e-library were rarely known by teachers. The main purpose for teachers to use the Internet was searching and downloading instructional materials through web search engine; followed by browsing educational news and related information. Regarding teachers’ use of IT in teaching, the researchers set 11 topic based on which teachers were asked to reflect their instructional practices. In summary, the majority of the teachers used IT just for presenting purposes, with very few of them adopting professional software to deepen students’ understanding on specific contents, and fewer using network interaction to promote exchange between students and teachers and to share learning materials and resources. Researchers also found a positive relationship between teachers’ use of IT and their requirement on students’ use. In other words, those who frequently used IT for teaching were more likely to ask students to learn with IT, however, in general teachers’ requirement on students’ use of IT in learning was very low. As to the fifth aspect of the survey, teachers believed that using IT could help: (i) motivate students to learn; (ii) improve students’ creativity; (iii) present instructional content; (iv) promote classroom interaction; (v) construct a harmonious classroom atmosphere; (vi) evaluate students’ learning process; (vii) evaluate learning outcomes; (viii) improve teachers’ teaching ability; (ix) enhance exchange between students and teachers. Teachers’ need on IT showed that the most commonly used software in high schools were non-professional (except for Geometer’s sketchpad), and professional software like *Maple* and *Mathematica* were rarely used and even rarely heard by the teachers. Finally, most of the teachers indicated their view on web-learning that the network would exert great impact on mathematics teaching and learning in the future.

Zhang and Chen (2013) investigated teachers’ use of IT in preparing, implementing and reflecting instruction. 163 teachers from several subjects including Chinese and mathematics participated in the survey, and these teachers mainly came from the west of China. According to the results, most teachers prepared teaching materials and planned instruction based on their own experiences rather than searching information and resources from the Internet. Regarding the use of IT in implementing teaching, authors found that there were only 17.3% of the teachers rarely using IT devices, and fewer used IT devices in an interactive way (like linking to the Internet and presenting students' work). Finally, the survey also revealed that about 60% of the teachers rarely searching information via the Internet for writing papers, and that teachers who sometimes and often participating in web-based teaching and researching activities were only 26%. Besides, only 12.7% teachers themselves had experienced web-based learning.

Perrotta (2013), by analysing data collected from 24 England secondary schools in 2010/2011 academic year, studied teachers' perception and use of digital technology. He found that the majority of teachers used technology in an unambitious way—technology was adopted for preparing instructional materials, presenting teaching content, collecting and managing students' data, and no significant difference was found in teachers' responses across various subjects.

Clark-Wilson (2014) collected data on teachers' use of computers, and found that computers enabled students to observe different registers simultaneously, as well as switch among them. One example provided by the author was that a teacher asked the students to explore the transformations of functions by using electronic worksheet. In the worksheet, various transformations were set, including $y=f(x)\pm a$, $y=f(x\pm a)$, $y=-f(x)$, etc. A table was also provided so that students could compare the value of functions for certain values of independent. Students were asked to input functions which they were familiar to and then to observe both the number table and graphs showed on the screen, before making generalisations.

Based on previous works, Bretscher (2014) conducted a survey to explore what hardware and software were adopted by English mathematics teachers. Teachers from 87 secondary schools were asked to fill in a questionnaire, with 188 completed questionnaires returned. Bretscher (2014) discovered that Interactive Whiteboard (IWB) and Data Projectors were used in almost every lesson. She also noticed that although Computer suite were relatively less commonly used by teachers in teaching mathematics, the computer suite dedicated to the mathematics department was to be used slightly more often than the one shared with other department. Laptop was found to be less frequently used by teachers in classroom, as well as the graphic calculators. As regards the software, Bretscher (2014) compared those used in a whole-class context with an IWB or data projector to those in computer suite where students themselves had access to software. She found that IBW software, PowerPoint, MyMaths.co.uk and other websites were most frequently adopted software in the whole-class context, and only MyMaths.co.uk was frequently used in the other context.

Zhang *et al.* (2015) did a survey to obtain teachers in central China areas of their competence in using technologies in instruction. The selected samples consisted of 414 participants from four provinces (Hubei, Henan, Anhui, and Guangxi), with 38.7% of them being mathematics teachers (the highest proportion). The investigation revealed that teachers' familiarity varied across different educational technological environment: 29.1% of the teachers stated that they were familiar with simple multimedia environment; 27.1% familiar with IWB environment; 17.9% familiar with the network environment; and the proportion of teachers who were familiar with digital resources environment and mobile learning environment were 10.9% and 4.3% respectively. By examining teachers' use of technologies to optimise the classroom instructional capacity, the survey data suggested that teachers owned positive attitudes and beliefs in educational technology; their capacity in planning and preparing teaching with technologies, and their capacity in pursuing professional development using technologies were excellent; teachers' technology literacy, their capacity in using technologies in classroom assessment and students' problem diagnosis, and in using technologies to re-organize and manage classroom environment were good.

Besides national studies conducted by many researchers on teachers of different disciplines, there are some international comparative studies discussing about teachers' use of technologies in instructions.

In late 1998, the International Association for the Evaluation of Educational Achievement (IEA) conducted a project called 'Second Information Technology in Education Study (SITES)' (Pelgrum & Anderson, 2001) which contains two modules: Module 1 surveyed 26 countries and regions, including Chinese Hong Kong and Chinese Taipei, of their computer-using primary and secondary schools in the supportive climate, infrastructures, as well as staff development and school policies towards ICT instructional integration. Module 2 used case studies to identify and describe key features of ICT-based pedagogical practices in each country and then provided some information for policy-makers and educators to make ICT-related decisions. The findings showed that almost all participating countries had national initiatives to provide schools with ICT, however the average percentages of multimedia-ready computers in primary schools and in secondary schools were different, 50–75% in primary and about 25–50% in secondary schools. The principals in the participating schools were generally positive in adopting ICT in their schools and some school even established own policies to support teachers' ICT-integration which indicated the schools' echoes to the national policy. As regards the features of the computer-using classrooms, the researchers noticed that teachers were more like an advisor and monitor to students' learning activities rather than a knowledge-provider.

Similarly, in 2006, the IEA conducted another SITES Study (SITES 2006) in 22 educational systems to examine changes in ICT use in education since 1998 (Plomp & Voogt, 2009). Unlike the previous study which only surveyed school principals and technology coordinators, this study also collected data from eighth-grade mathematics and science teachers. Almost all the participating educational systems reported an increase in the ICT investment in schools during the last five years which was supported by national policies and government funding, while the percentage of teachers who reported their use of technologies in instruction was still relatively low. The data revealed a huge difference of the percentage of ICT-uptake in schools among countries, ranging from 20% to 80%. The data also suggested that in most countries and regions, sciences teachers were more often than mathematics teachers in using ICTs in instruction. As regards how the technologies were used, according to Law (2009), the highest international mean percentage of mathematics teachers in using ICTs was for 'Looking up ideas and information' (53.24%), followed by 'Processing and analysing data' (46.2%), and 'Short-task project' (41.85%), while the international mean percentages for inquiry activities (including 'studying natural phenomena through simulation' and 'Field study activities') were the lowest two.

In 2011, the IEA conducted Trends in International Mathematics and Science Study (TIMSS 2011) in over 60 countries and regions, including Chinese Hong Kong, Chinese Taipei, and England. Besides the test for students, teacher of grade 4 and 8 were also sent questionnaire upon instructional resources and activities. According to the report (Mullis *et al.*, 2012), at grade 8, computer software were adopted as an instructional resource supplementing textbooks. The researchers also revealed that although internationally, one-third of students on average had computers available in learning mathematics, computers were not used by many students, and the main activities that 8^{th} grade students involved in with the help of computer software were exploring mathematics principles and concepts; processing and analysing data, and practicing skills and procedures.

Pang *et al.* (2015) did a small-scale survey on South Korean teachers' perceptions and use of ICT in instruction, and compare the results with their previous study which collected data of US teachers, and revealed that computers connected to the Internet, IWB were less easily available for Korean teacher than their US counterparts. However, for all the items that described the way teachers used the technology, the frequency and importance rate responded by Korean teachers were higher than those by US teachers.

Through reviewing relevant literature on mathematics teachers' use of technology in instruction, some characteristics can be pointed out:

First, more and more studies and investigations on the discussion of teachers' instructional behaviours toward technology integration have been conducted in various countries and regions, indicating a global trend of this issue, which echoes the internationally educational reform trend.

Second, although many countries and regions conducted investigations, international comparisons of high quality is still lacking. It goes without saying that good international comparative studies can provide useful information for researchers, educators as well as policy-makers to reflect their own educational system, position their system in the world, and learn from others.

Third, the majority of the studies discussed what technologies were used in school instruction, teachers' attitude towards tech-integration as well as their opinions upon usefulness of different technologies, while relatively less discussions on how these technologies were used has been done, and discussions focused specially on mathematics teachers are lesser. Besides, among those studies which explored how different technologies were used by teachers, there was no common understanding and consensus on how to describe the way teachers use technologies in instruction, resulting in various and sometimes contradictory conclusions.

Finally, along with the previous feature, most studies talked about how teachers use technology just in a general way, rather than in detail to reflect characteristics of the discipline. In other words, although some investigations explored mathematics teachers' tech-related behaviours, the studies just focused on teaching rather than teaching mathematics. It can be easily seen that many studies explore teachers of different disciplines and the instruments were designed to cover various disciplines, resulting in the sacrifice of the characteristics of a certain discipline (such as mathematics), which is a very significant reason that drives me to design and conduct this study.

2.5 Factors Influencing Teachers' Use of Technology

Realising the use of technology in practices is unsatisfactory for both researchers and policy-makers, various discussions have been conducted in finding and describing what factors that encourage or impede teachers' use of technology in instruction.

Ertmer is one of the earliest scholars elaborating on barriers that block teachers' change of instructional strategies as well as their adoption of technology as innovations to pedagogy. In one of his articles, Ertmer (1999) discussed two types of barriers which hindered ''teachers' technology implementation efforts'' (p. 48). The first-order barriers termed by the author as extrinsic barriers, referred to types of resources (like equipment), being able to access to, time, and trainings and supports provided for teachers; and the second-order barriers, described as intrinsic barriers, dealing with teachers' underlying beliefs about teaching and learning. According to Ertmer (1999), first-order barriers could frustrate teachers even before beginning the implementation process, while second-order barriers were deeply rooted and considered to result in more difficulties.

Becta (2004) provided a detailed literature review on the barriers to the uptake of ICT by teachers, and seven barriers were identified and grouped. These barriers were lack of access to resources, lack of time, lack of effective training, technical problems, lack of confidence, resistance to change & negative attitudes, and no perception of benefits. By reflecting on the findings, the author also noticed that some of the above barriers were just related to individual (teacher-level), such as lack of confidence, resistance to change & negative attitudes, and no perception of benefits; some were just related to institutions (school-level), such as technical problems, lack of effective training; but some were related to both, such as lack of time and lack of access to resources.

Similarly, by reviewing literatures on mathematics and sciences education, Bingimlas (2009) suggested that teachers had strong desire to embrace technology but they faced considerable barriers. The author adopted Becta's (2004) classification of teacher-level and school-level, and found that lack of access, resistance to change, lack of time, lack of training, and lack of technical support were the most commonly mentioned barriers across a large number of literatures. Afshari *et al.* (2009) considered the factors in terms of whether or not they could be directly influenced and changed by teachers and schools, and re-summarised them into Non-manipulative and Manipulative school and teacher factors. The non-manipulative school and teachers factors referred to those could hardly be influenced directly by schools, such as age, teaching experiences, government policy, external support for schools, etc.; whilst the manipulative factors referred to teachers' perspectives, ICT-knowledge and skills, as well as school support with respect to availability of ICT resources and implementation process, etc.

Realising the fact that it is important for teachers to identify the potential obstacles on the way of embracing technologies, so that they can increase the likelihood of successful tech-integration, Groff and Mouza (2008) summarised six categories of potential barriers: (as shown in the figure below) firstly, legislative factors, which contained policies and research evidence focusing on answering the question why should we use technologies to support instruction; secondly, technology factors, which described the nature of technology itself and dealt with the question that what made technology difficult to integrate, and how did technologies interact with classroom dynamics; thirdly, district/school level factors, which talked about the administrative communities' support for teachers' use of technology in education; fourthly, teacher-related factors, which highlighted teachers' competence, efficacy, and change of practices for an effective technology use; fifthly, technological project, which indicated that the quality of tech-based projects could significantly influence the success of tech-integration in the classroom; and finally, student-related factors, in which students' prior experiences, knowledge and skills, as well as their attitudes towards change of pedagogy and classroom environment were considered. This framework, unlike other perspectives, take students' factors into consideration, making it a more comprehensive view of obstacles for teachers' success of tech-integration.

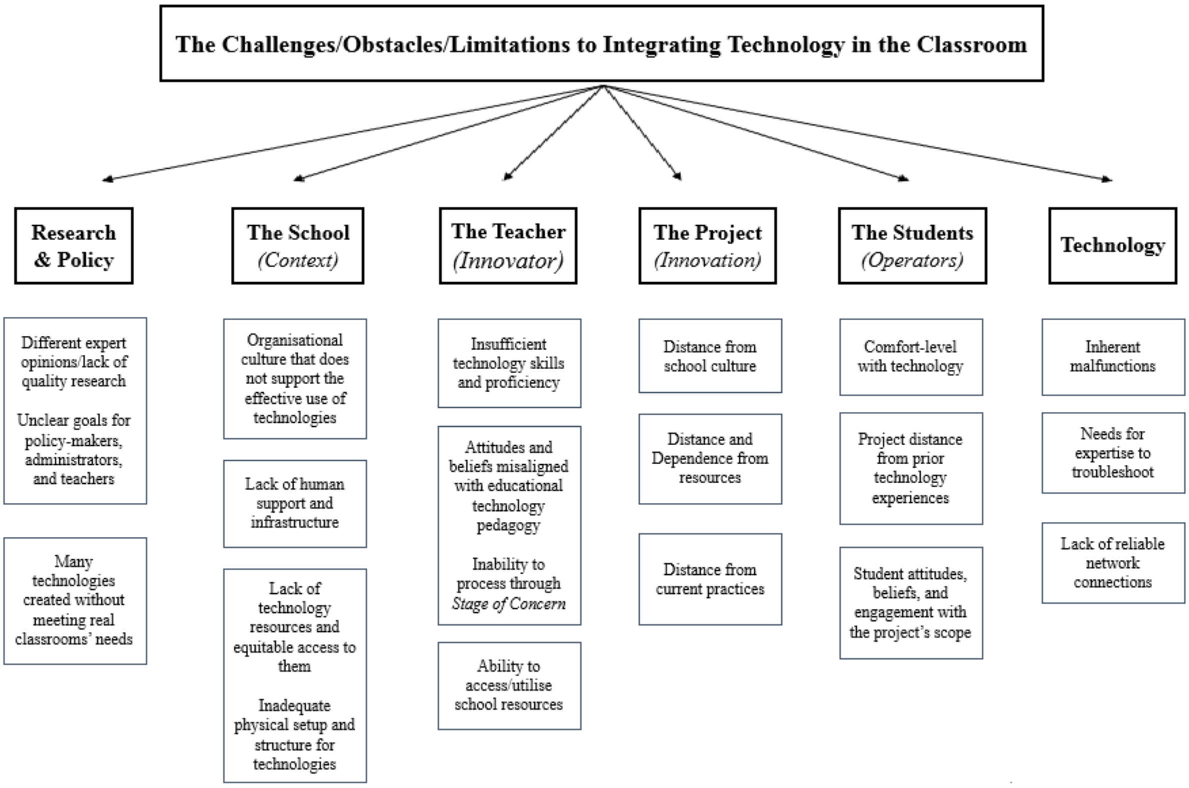

Figure 2-1. The challenges/ obstacles/ limitations to integration technology in the classroom (Sourced from Groff & Mouza (2008))

Ten Brummelhuis and Kuiper (2008) proposed a framework for practitioners and researchers to understand factors that influence the implementation of ICT in instruction. The core elements in their framework were teachers, students, content and ICT infrastructure, and the learning process took place. According to them, when these elements interacted with each other, figuring out how they exerted impact on teachers' choices and up-take of technologies could be difficult. Besides, school organization and local environment were implicit powers which shaped all the above elements and finally impacted on the implementation of ICT in classroom. Ten Brummelhuis and Kuiper's framework was similar to Fullan's (2007) discussion of educational change, in which Fullan presented three interactive factors which exerted influences on an educational change: one is the characteristics of the change itself, one is the local characteristics (principals and teachers in particular), and one is external factors (mainly referred to governments). Their works remind me that government and policy elements should not be underestimated in the issues of the use of technology in school education.

Some empirical study in different geographical areas provided evidences on what has been discussed. Zhao *et al.* (2002), for example, followed a group of K-12 teachers for one year and recorded and compared the difficulties that they met when they implemented tech-rich projects and lessons. Eleven salient factors which influenced the success of technology innovations were extracted and classified into three categories: the innovator (teacher), the innovation (project), and the context (school). According to Zhao *et al.* (2002), factors associated with teachers ‘‘appeared to play a more significant role than the other domain’’ (p. 507), and the study confirmed the fact that ‘‘teachers’ technology proficiency plays a major role in classroom technology innovations’’ (p. 489), and those who use technology in a manner consistent with their pedagogical beliefs and those who could better understand and negotiate the school culture with respect to the technology implementation were more likely to experience success in the classroom. The authors also emphasized the innovation itself as a prime determinant, and explained that the success of adopting technology in classroom, from the view of innovations, depended on two dimensions: distance and dependence. The former one referred to how much the project deviated from the status quo of school culture, available resources and teachers’ existing practices, and the latter one referred to the degree of the innovation depending on people and resources that beyond the innovators’ immediate control. Regarding the context, three aspects were found that were of great importance: the human resources, which meant the organizational arrangement to tech-support; the technological infrastructures, and the social support, which highlighted the peers support and encouragement for technology innovations. Finally, the authors described classroom technology integration as a ‘‘complex and messy process’’ (p. 482), and suggested that there was no one unique explanation that could help us understand the process.

Wen and Zhou (2007) investigated 963 Chinese primary and secondary mathematics teachers, via questionnaire, on their use of technology in instruction, with 486 valid questionnaire obtained. The study, adopting structural model equation approach, aimed at exploring factors influencing levels of teachers’ technology integration, and three levels were identified: low level (e.g. using Word to write lesson plan); medium level (e.g. using technology to highlight important content and to help student overcome the difficulties), and high level (e.g. using technology to create new learning environment and support students to change their learning methods). In the study, three components were designed in addition to level of technology integration, which contained external support (including curriculum resources, software and hardware facilities, and school management); internal motivation (including self-efficacy, emotion and attitude, and value identification); and knowledge and skills (including tech-related, pedagogy-related, and integration-related), and the relationships among all the four components were examined by the data. The finding showed that external support influenced the level of teachers’ technology integration indirectly through other two component, within which the internal motivation played a more important role in deciding the level.

Harvey-Buschel (2009) conducted a study in exploring what factors impacting mathematics teachers' use of technology in urban public secondary schools in the U.S. In this study, teachers' experiences and their professional development related to technology were considered, and the findings were not surprising that teachers' experiences didn't affect their use of technology in instruction; however, those who had attended professional development trainings were found to be more likely to adopt technology in teaching mathematics. Besides, the data also revealed that the availability (numbers) of computers in the classroom contributed to teachers' technology integration in urban schools.

A survey conducted by Player-Koro (2012) in Sweden with 210 teachers as participants indicated that ''positive attitude related specifically to ICT as a useful tool… and a strong sense of self-efficacy in using computers in education seem to influence the use of ICT the most'' (p. 93), whilst positive attitude to ICT generally didn't contribute much to teachers use of ICT in classroom. There are also other articles support that teachers' confidence is an important predictor of their use of technology, and fear and anxious of failure stop teacher adopting technology in front of a class of children. (Becta, 2004; Balanskat, Blamire & Kefala, 2012)

Ng and Nicholas (2009) examined the use of handheld technologies in schools, and they found that school support for teachers' tech-integration was important, and ''level of support from the principals varied greatly between the primary and secondary schools'' (p. 473) with primary school principals being more active in encouraging teachers to adopt mobile devices and in recruiting staffs to provide necessary technology supports.

In a survey conducted in England, Bretscher (2014) identified more than 10 factors which potentially influenced mathematics teachers' ICT adoption behaviour, and these factors were divided into school-factors and teacher-factors. The former one included school environment; colleague support; access to resources; training and professional development; relationship between resources and curriculum. The latter one includes teachers' confidence and pedagogical beliefs; and their time in preparing courseware.

Some international comparisons have also been conducted to discuss this topic and useful findings were demonstrated which deepened researchers' understanding.

Peralta and Costata (2007) did a comparative study among five European countries (Greece, Italy, Portugal, Spain and the Netherlands) by using focus groups as the main technique for data collection and reported that even though different factors were emphasised by teachers from different countries, the technical knowledge and competence were regarded by almost everyone as the very important reason for teachers' not use of technology in classrooms.

Pelgrum and Voogt (2009) explored teachers and school factors associated with the mathematics teachers' frequency of use of ICT by adopting the SITE 2006[14] data. They revealed that the percentage of frequent ICT-using teachers (defined as 'use ICT at least once per week') varied among different educational systems, with Chinese Taipei being 7% (as a typical country with low percentage of frequent ICT-using teachers), and Canada Ontario being 43% (as a high percentage of frequent ICT-using teachers). The findings showed that teachers in the school with more active leaders in term of stimulating and encouraging teachers' use of technology were more likely to enact technology innovation in classrooms; teachers who paid more attention on life-long learning and with a learner-centred instructional philosophy and approach were found to present a more positive attitude of adopting technology in classroom practices. This comparison also indicated that teachers working in a school where leaders used technology more often were more likely to use technology, and the successful classroom technology innovations were more likely to be found in a school where the change of school culture followed a bottom-up orientation.

Chai, Hong and Teo (2009) did a comparative study between Taiwanese and Singapore pre-service teachers of their beliefs and attitudes towards ICT in instructions. Although findings supported the influence of pedagogical beliefs upon teachers' practice on the use of technology, the study revealed that both Taiwan and Singapore teachers of their behaviour were congruent to the corresponding educational reform, which indicated that professional development program might be more influential in shaping teachers' practices.

It should be mentioned that although various studies depicting factors which potentially hinder teachers' use of technology in practice, the complex and nuance relationship between these factors are still unclear on which more efforts need to be put.

Teachers' tech-related knowledge and skills, for example, is one of the factors, within the teacher level, recognized by scholars in a very early time as an import factor that played an important role in deciding the success of educational innovations (Pelgrum, 2001; Knezek & Christensen, 2002). However, owing knowledge and skills to manipulate technology applications and devices, as indicated by Koehler and Mishra (2009), didn't automatically enables teachers to perform well in tech-rich classroom, and therefore they proposed the framework TPACK to describe a compound knowledge of technology, content and pedagogy which served as foundation for technology integration. Tsai and Chai (2012) adopted the term 'design thinking' to describe a more critical and comprehensive way of thinking content to be instructed with technologies, which reflected the

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[14] SITES is short for Second Information Technology in Education Study, Which is an international comparative study organized by International Association for the Evaluation of Educational Achievement (IEA). SITES 2006 data consists of surveys of schools and teachers of mathematics and science. The aim of the study was to understand pedagogy as well as the use of ICTs in different educational systems.

complex concept of TPACK, and referred it as the third-order barriers complementing Ertmer's (1999) framework aforementioned. They suggested that teachers' lack of design thinking could be a major barrier in teaching practices, especially in the 21st century. The findings from Goktas, Gedik and Baydas (2013) investigating 1373 Turkish teachers' use of technologies confirmed Tsai and Chai's (2012) conclusion and showed the importance of the knowledge and skills of considering technology together with the content and pedagogy.

In school and community level, a large number of research indicated that teacher training course could be one of the most effective factors. For example, Hartsell *et al.* (2009) reported an improvement in middle school mathematics teachers' skills in utilising graphing calculators and other software programs, as well as an increasing in overall confidence in helping students' learning various concepts. Their findings were later confirmed by Rienties, Brouwer and Lygo-Baker (2013), who studied 73 teachers from various disciplines including mathematics and found that 12 weeks' training enables the teachers to become more confidence in integrating technology into their daily instructional practice. Polly and Orrill (2012) explored how a technology-rich training course would improve teachers' perception of technology integration in teaching practices, and found that most teachers reported a gain in both their general knowledge about technology as well as the support provided by adopting the technology to teach mathematics.

But there are also studies obtained opposite conclusions to previous literatures, and that teachers' change of their perceptions on or attitudes towards ICT-integration were also influenced by teachers' demographic data, which made it hard to predict that professional development (PD) training had direct effect and would lead teachers to become more likely to use ICT in teaching mathematics. Jimoyiannis and Komis (2007), for example, by analysing data from 1165 primary and secondary teachers who attended a national PD training session focusing on ICT in education, found that mathematics teachers were skeptical about the efficiency of ICT in teaching mathematics and thus many of them remained negative upon using technology in classrooms. Hohenwarter, Hohenwarter and Lavicza (2009) examined a three-week training program about GeoGebra, and showed that little significant difference had been found in both middle and high school mathematics teachers' subjective evaluation of the software or its features in classroom teaching. Jimoyiannis and Komis (2007) also found that teachers' age, gender and teaching experience could exert huge impact on their post-training beliefs upon the usefulness of ICT in education. Lau and Yuen's (2013) study mirrored previous findings of teachers' attitudes and beliefs about ICT, and they also reported a difference on self-efficacy about technology between teachers with different teaching years. By investigating teachers from different subject backgrounds in a Canadian school, Chow (2015) found that when facing a new technology, training or instruction organized by school has little effect on the change of teachers' attitude towards that technology.

Overall speaking, researchers agreed that classroom technology integration was a complex and messy process, and there was no one unique explanation that could help us understand the process. According to the existing literature, discussions of influencing factors about teachers' technology integration focused on teachers themselves (including their knowledge, tech-competence, beliefs and attitudes, self-efficacy, etc.) and the school environment where they work (including facilities and resources, leadership attitudes, other tech-related support, etc.). Training programs and courses were also widely studied, in the way of considering its connection with teachers' changes in knowledge and attitudes. Not many studies considered student issues when exploring teachers' use of technology in classroom, and fewer studies explored policy and social influence, though some studies include policy issues into training programs.

In addition, most studies in the field collected data from teachers in various subjects. Although the findings provided information based on teachers as a whole, it limited our understanding of the issue for a specific subject, and sometimes misleading findings could be possible. Consequently, more detailed and specific studies are needed for our better understanding of such issue.

2.6 Comparisons on Mathematics Education between Different Countries

The previous section talks about personal and contextual factors influencing teachers' use of technology, but if we want to understand how teachers from different countries behave differently, it is necessary to review some comparative works in this field. It should be mentioned that specific comparative studies on teachers' use of technology between China and England are rarely found, but there are some discussion upon the features of East (including China) and West (including England) in terms of general mathematics education or technology up-taking in education.

In an early study, Cogan and Schmidt (2002) analysed classroom observation data collected by a multi-national research team, and the data was about 9-year and 13-year-old students' mathematics and science classroom instruction from 6 countries including the U.S., Norway, and Japan. According to the authors, lessons from the different countries varied in characteristics. Lessons from Norway and Switzerland highlighted students' activities such as exploration and investigation of mathematics concepts; the US lessons also emphased students' activities, but they were more teacher-led; Japanese lessons, however, were characterized as ‘‘built around a consideration of multiple approaches to carefully chosen practical examples’’ to led students to a deep understanding of mathematical concepts and relationships.

Law, Pelgrum and Plomp (2008) analysed mathematics teachers' practice orientations in using technology based on the SITES 2006 Study, and found that in all systems, teachers were more likely to use technology in traditional ways (presenting information/demonstrations or giving whole-class instructions), than in enhancing students' individual learning and self-inquiry activities. Besides, using technology to assist peer-collaboration and to assist within and outside classroom connections (such as organize communications between students/teachers with external experts) was found to be the least likely way that would be adopted by teachers. By reflecting system-based factors, the authors pointed out that although the overall trend of teachers' use of technology seemed similar cross nations, there was evidence showed that more centralized systems were more likely to influence teachers' tech-integration behaviours by either official, system-wide technological programs or policies.

A comparison between English and German mathematics instruction has been done by Kaiser (2002), who found that English mathematics held a more pragmatic understanding view of mathematics comparing to their German counterparts. More specifically, in England, the introduction of both new mathematics concepts and methods were less-important than German lessons and were done in a pragmatic way. The understanding of mathematics theorems were based on practical examples and application rather than the subject structure itself. Similarly, proofs and precise mathematical notations and language were not highlighted in England, however, application of the school mathematics in real life was of high importance in England. Besides, the author analysed teaching style in both nations, and pointed out that English lesson focused more on individual work, either on one task for a long period of time or on several problem-solving activities. Teachers were worked as assistances to guide students' own learning processes.

Different features of mathematics instruction can be found in different countries, and to understand and explain these international differences, many researchers tried to think and discuss from cultural perspectives.

An early effort in discussing the culture differences between China and the West societies and their influences on mathematics education have been made by Leung (1992), who described Chinese culture as a super stable structured and social oriented culture, and thus typical characteristics of the culture could be summarised as ''compliance, obedience, and respect for the superiors and filial piety'' (p. 91), which were seen as ''the influence of the thoughts of Confucius'' (ibid). In addition, Leung also mentioned other relevant characteristics to the practices of mathematics education, including that firstly, Chinese educational practitioners stressed on memorisation and practice; secondly, Chinese teachers and parents had high expectation on students' achievements; thirdly, Chinese believed that the success could only be gained by the price of diligence and perseverance, and studying and learning should be a hardship, rather than enjoyable.

Li (2006) stated that West countries usually put emphasis on understanding in mathematics instruction, while China had a long history in highlighting routine or manipulative practice in mathematics education. By explaining so, Li cited an idiom ‘Practice makes perfect’, and further stated that Chinese believed that practice enabled people to be familiar with as well as be proficient at something they were focusing on. This belief worked as a key belief in guiding Chinese mathematics teachers’ teaching style.

Similar to Li’s words, Prof. Zhang from East China Normal University summarised the differences between East and West education as:

> *High vs. low pressure of examination; teacher-centredness vs. students-centredness; emphasizing exercises vs. emphasizing understanding; over-loaded vs. less homework; formal deduction vs. informal reasoning; stressing imitation vs. stressing innovation; work hard for reducing individual differences vs. polarization, and so on.*
>
> *(quoted by Zheng, 2006, p. 385)*

It should be pointed out that with several times of educational reform, mathematics education in China now changed a lot and some afore-mentioned differences became less-obvious. For example, now Chinese mathematics teachers put more emphasis on mathematical understanding and try to leave less homework for students so that they can have more time to pursue their own hobbies. Zheng (2006) admitted Zhang’s idea, and claimed that the more basic difference between Chinese and Western education laid on the difference between social-oriented and individual-oriented value. He detailed three main features of Chinese mathematics education: *Highly efficient classroom teaching*; *Seeking for deeper understanding*; and *The heuristic nature of teaching*, and four main weakness: *Long-term goals neglected*; *Little space for students’ innovation*; *Inadequate awareness of the application of mathematics*; and *Students’ individual differences de-emphasized*.

Reflecting on the differences between English and German mathematics education, Kaiser (2002) considered philosophies in both nations deeply. She stated that English teachers believed that ‘‘children grasp general principles as a result of active discovery and active work through a series of examples’’ (p. 148), which led to an example-based, individual work-emphasised English mathematics education. However, this feature also brought some problem in. For example, the idea that ‘‘mathematics could promote general goal as developing logical thinking has largely ignored’’ (p. 148) in England. From a more micro-view, Kaiser stated that these features also influenced the structure of English school system and their curriculum. ‘‘English curriculum is related to the age of the students, allowing a big spread in the achieved goals’’ (p. 149), while other system (including German and Chinese) were related to year-group with one common goal for the whole class, and small differences among individuals.

Another work worth to be mentioned is done by Zhang (2007) where he proposed a framework for viewing the use of technology in Eastern education systems. The framework consists of four parts: *Epistemological beliefs*: Eastern people highlight moral principles, and they think learners should show full respect to and follow teachers; they also believe that great minds create knowledge, which is then communicated to the publics; *Social values and issues*: Eastern people like seeking social recognitions. They like orders and disciplines, and they encourage learning together. *Centralised educational system*: Central government design and execute policies and standards; teachers should teach unified content, and also based on a standard pace in reference to official teachers' guides; *Culture of Examination*: Education is considered as an essential way to compete for higher social status; the exam score largely reflect learners' performance and abilities; and preparing for high-stakes exams poses high pressure to learners, teachers, parents and administrators.

Overall, many scholars have tried to understand international difference on mathematics education from various aspects, and they value culture differences a lot. Based on their discussions, the following aspects are extracted to help us understand mathematics teachers' instruction in different nations as well as understand the differences in general mathematics education among various countries.

Epistemological beliefs: Different epistemological beliefs lead to different content-selection and teaching style. People who believe that knowledge should be grasped by students would be more likely to teach in a lecture-demonstration method; while people who believe in children's own abilities and think that knowledge should be discovered by students would be more likely to encourage students' inquiry and investigation. People who hold knowledge-oriented views and believe in practices and attribute learners' success to their efforts and hardworking may emphasise the deep understanding of the knowledge and spent more time in routine exercises; while people who hold application-oriented views and believe in understanding knowledge by problem-solving may provide more chances to explore and apply knowledge in real-life situations.

Social values on education: Social values on education may impact inter-personal relationships in schools, as well as influence the paces that teachers teach and students learn. In a society where individuals' differences are de-emphasised and people are considered should perform equally are more likely to learn unified knowledge and in the same pace than their counterparts in the society where individuals' characteristics are highlighted. Besides, in a society where discipline and order are highlighted, it is more likely that students follow teachers' steps rather than learn individually.

Educational System: Different countries have different educational system, and this could influence how students are grouped, how curriculum is implemented, and even the distribution of educational resources (including technological resources) in different regions and schools. Besides, centralised system might be effective in teachers' recruits and professional development, while leaves less space for teachers themselves to decide the content to be taught, the pace of instruction, and even pedagogical approaches.

Culture of examination: Examinations may exert impact on what content and how they are taught and learned in schools. For example, a society, where examinations are regarded as the only (or the principle) way to reflect student' abilities and potentials, is more likely to focus their education on examination-required content and adopt the approach of intensive exam-highly-related exercises and practices; similarly a society, where gaining higher scores in examinations than others is regarded as more successful, is more likely to cultivate a competitive atmosphere among learners rather than a cooperative atmosphere, which may then promote a more individualised instructional style.

2.7 Summary

Based on the research questions, this chapter reviews relevant literature and reveals the followings:

(1) Although 'technology' is commonly used in educational field, there is no single definition accepted universally. In mathematics education, the word 'technology' has not been well defined either and it is utilised by researchers as a collective term to cover a range of tools. Actually in most cases, researchers just used 'technology' to refer to specific devices without defining the term beforehand.

(2) In the discussion of educational technology, researchers adopt 'affordance' to describe the action-related relationship between a user and a technology, in the hope that this term can help us understand the potential of technology in enhancing instruction. However, the majority of studies fail to discriminate among affordances, strategies and instructional aims, making the discussions confusing to some extent.

(3) Increasing studies and investigations can be found in discussing teachers' instructional behaviours towards technology-integration, which reflects a global trend of this issue. However, studies of high quality in this field are still lacking, and in addition, most of the investigations explored mathematics teachers' tech-related behaviours without reflecting characteristics of the discipline. In other words, these studies just focused on teaching rather than teaching mathematics.

(4) As regards the influencing factors upon teachers' use of technology, researchers realise the complexity of classroom technology integration, which calls for detailed exploration that could help us understand the process. The review of relevant literature shows that most studies just

partially addressed the question of what factors influencing teachers' tech-integration in instruction, and along with the previous point, the majority collect data from teachers with various discipline backgrounds and thus more detailed investigation is needed for us to develop our understanding for a specific subject (mathematics).

(5) Finally, some studies and discussions have been reviewed upon mathematics education and teachers' use of technology in international comparisons. Researchers and scholars reflected similarities and differences of mathematics education between different countries from various perspectives. However most of their reflections are from cultural and system's perspectives. Specifically, the following four aspects are extracted: Epistemological beliefs; Social values on education; Educational System; and Culture of examination.

Chapter 3 Conceptual Framework of the Study

In this study, I will investigate teachers' use of technology in teaching mathematics. For a better understanding of the question to be addressed, some explanations pertaining to key terms and concepts are necessary, and then a framework would be constructed to guide the investigation.

3.1 **The Meaning of Key Term: Use**

By saying 'the use of something', I mean '**the adoption of something as an instrument (for a certain purpose)**'. This definition is built on previous works done by researchers including Vygotsky (1980) and Rabardel (Verillon & Rabardel, 1995; Beguin & Rabardel, 2000; Rabardel, 2002) who developed the concept of 'instrument' and proposed a theory of '*instrumental genesis*'. In 2008, Drijvers and Trouche (2008) adopted the concept to explore students' mental development in a technology-rich mathematics learning environment, and provided suggestions for teachers to guide students' development. Later on, Drijvers and his colleagues re-adopted and further developed the concept of 'instrument' to discuss teachers' integration of technology in classrooms in the hope that how teachers orchestrated students' learning in a technology-rich environment could be interpreted (Drijvers *et al.*, 2010a; Drijvers *et al.*, 2010b; Drijvers *et al.*, 2013). Here I adopt the concept of 'instrument' mainly discussing teachers' adoption of technology in classroom instruction in my study. Some further explanations are needed to make the statement clear.

What does 'Instrument' mean?

Rabardel and his colleagues (Verillon & Rabardel, 1995; Beguin & Rabardel, 2000; Rabardel, 2002) discussed a lot about the complexity of instruction in technological environment, and proposed a theory of *instrumental genesis*, which is built upon Vygotsky's (1980) works. In the theory, artefact is distinguished from instrument where the former is a cultural or historical concept, and the latter is a psychological concept.

Artefact can be any object or material, and it may be meaningless for a user as long as s/he doesn't know what kinds of tasks and how the tasks can be solved by this tool. Artefact is connected with people's experiences or knowledge, and in this way, it is regarded as a cultural or historical concept. For example, eggcup is an artefact to Western people, because eggcup is commonly used in western countries, so they have experience of using eggcups, and have knowledge of how to use them (by observing or learning from other people in the society). However, eggcup is unknown to most of Asian people, like Chinese, because they do not have any experience with eggcup, so even though an eggcup is put in front of a Chinese, s/he can only see this physical entity, but cannot connect it to the previous experiences[15], and have no idea about the way to use it, so eggcup for the Chinese is just an object.

Instrument is a psychological concept and is built from the artefact (Beguin & Rabardel, 2000). When a man faces a situation, and he has a goal to achieve, he may think about the artefact and use the artefact to accomplish the goal. In such situation, the man has to make a mental connection between the potential function of the artefact and the goal to be achieved, so he turns the artefact into an instrument. The main difference between them is that when we talk about artefact, we refer to the object and the pre-experience about it; but when we talk about instrument, we face a goal to achieve and connect the goal with the artefact. With or without a goal at the moment to achieve is the determinant factor to distinguish artefact from instrument. The figure below may help in explaining how the artefact turns into an instrument.

Figure 3-1. Difference between artefact and instrument

The 'goal' is the key word in understanding instrument, and once a mental connection between the artefact and the goal has been established, the 'instrument' comes out. However, 'instrument' at this stage is just a mental preparation, and it is until the user takes actions that adopting the instrument to try to achieve the goal, that realises the 'instrument' and enables the 'instrument' to go beyond pure mental preparation. This process of adopting instrument to achieve the goal is activity. For example, for students, a mathematics textbook is an artefact, and when the students face a mathematics question, and they consider to find the clues from the book, they turn the book into instrument. However, it is until they open the book to find the relevant content that realises the instrument (the book in this case).

One thing that should be mentioned here is that realising the instrument doesn't indicate the achievement of the goal. The achievement of the goal depends on a myriad of factors including the user, the instrument itself, ways that the user use the instrument, and so on. For example, when a man faces a problem of cutting pork into pieces, he may think about using a knife, but whether or not he succeeds depends on things such as what kind of knife he chooses, how blunt the knife is,

[15] Some people may try to think about it and try to make it meaningful by guessing it as an ashtray, but this is just the way people try to understand and learn things, and it is still different from having knowledge about the 'eggcup', so at this point the 'eggcup' is still not an artefact to them.

how good his knife skills are, as well as the degree of freezing of the pork, etc.

After clarifying the concepts between instrument and artefact, I shall point out that in my study, various technologies are actually instruments, and the corresponding goal is teaching mathematics. Therefore, it is necessary to provide detailed explanations on what do I refer to when I use the term 'technology' and 'teaching mathematics'.

3.2 **The Meaning of Key Term: Technology**

3.2.1 Technology

Technology, as I summarised before, is difficult to define in a precise way, especially in the domain of mathematics education. Edwards (2012) expressed similar idea that ''technology is a particularly difficult concept to grapple with'' (p. 13). Several reasons could attribute to the difficulty. Firstly, technology, despite the substantial efforts made by researchers and scholars, has still not be embraced intensively in educational practice (Borba & Villarreal, 2006b), so that experiences and competences of technology within teachers and practitioners varies, and thus it is hard for teachers to reach a consensus upon what should be counted as technology in mathematics instruction. Secondly, last 40 years witnessed a huge change of technology in terms of both devices and functions, and the updating is still continuing, resulting in the concept of educational technology being dynamic, rather than still (Edwards, 2012). For example, calculators have changed a lot during the last three decades (from simple calculators to graphic ones to symbolic ones), and therefore calculators in classrooms in different ages differ in types. Thirdly, the trend of integrating multiple functions into one device makes it common that increasing technologies which are not originally designed for educational purposes, now can be found in educational settings. This phenomenon aggravates the difficulty of distinguishing the edges among different technologies (Jones & Younie, 2014), so it is impossible to find a precise definition covering all technologies just in mathematics education.

However, this does not mean that the term 'technology' can be used arbitrary, especially in a scientific study where at least some kind of definition is necessary (Fan, 2014). Due to the topic of my study, I restrict my definition within the field of mathematics education, rather than discussing technology in a general way. In the study, **technology in mathematics education are electronic devices (together with the tool kits based on them) which are used for teaching and learning of mathematics**.

It should be noted that this definition is still broad, and vague to some extent, so more detailed explanations are provided below in the hope that they can make it clear what are covered in my definition:

Firstly, I restrict the technology as electronic, and this is necessary. I agree with many researchers (e.g. Bruce & Hogan, 1998; Monaghan, 2004; Mishra & Koehler, 2006; Drijvers & Trouche, 2008) of their opinion that technology is a set of tools for a specific purpose. Following this ides, chalks, books and mathematical tables also belong to technology, but these tools are obviously not included in my research (nor do they included in most studies which discuss about educational technologies), so I adopted 'electronic' in my definition to exclude all the tools which is not driven by electricity. Besides, I didn't adopt the term 'traditional' in the definition, as Mishra and Koehler (2006) did, to distinguish non-electronic tools from the electronic ones. Because in my view, 'traditional' is relative and people's opinions varies on what is traditional and what is non-traditional. For example, simple calculators which can neither draw graphs nor manipulate symbolic expressions have been introduced to mathematics classroom for a long time[16], and people may argue that they are actually traditional tools as pencil and pen. However for teachers working in schools of remote areas, they lack enough resources for instruction, and still use simple calculators in the class, and they may emphasize the differences between these calculators and textbooks, and considered them as new and important technology (Xie & Yang, 2014). So the term 'traditional' is subjective and will potentially vague the definition.

Secondly, not every electronic device is included in my study, and the most important criterion for the inclusion is whether or not it is used for mathematics education. Electronic lights, for example, are commonly found in the classroom, and people even can state that they are used for educational purpose, because they help students read when the natural light is weak. A more convincing example of using electronic light for instruction is that physics teachers can use light and a prism demonstrate the principle of rainbow. But electronic lights are rarely used for teaching and learning mathematics, so they are excluded in my study. Besides, the criterion also serves for the reason of inclusion of 'together with tool kits' in the definition. Many devices, like computer, are not produced specially for education, and it is various educational software such as modelling package (Maple, Mathematica, etc.) and dynamic geometry software (GeoGebra, GSP, Autograph etc.) that made it an educational tool. Without the help of the software, little benefit can be obtained by mathematics learners via the use of the devices. In fact, for many teachers, when they claim their use of computers to teach, they actually mean that they use some software to teach. Hence technology in my study refers not only to hardware, but also to corresponding software tool kits.

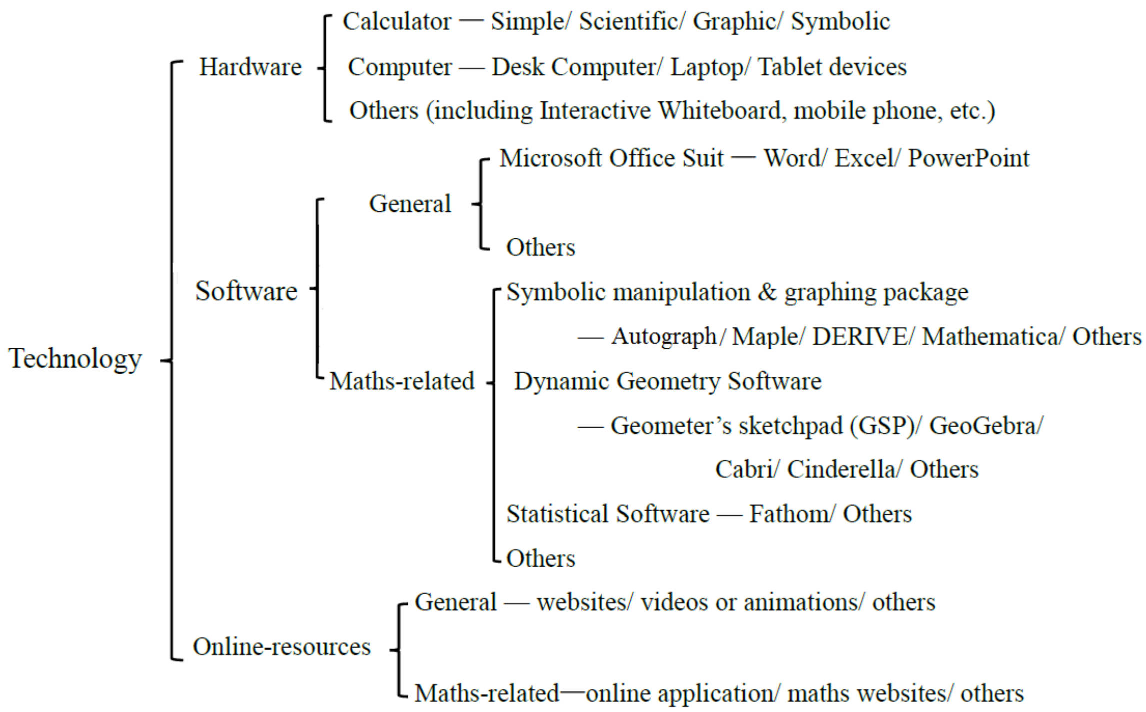
Thirdly, I use 'teaching and learning' in the definition of technology, because it is impossible to separate teachers' teaching from students' learning in practice, although learning can be separated

[16] According to Sigg (1982), it was before 1980s that calculators were used in school mathematics.

from teaching (i.e. self-learning). A good example here would be that one might observe that students use calculators for solving a problem, while if it happens in the classroom instruction, the problem is probably chosen or designed by the teacher, and how and when calculators are allowed to be adopted are also decided by the teacher, so students' use of calculator is actually a part of teacher's teaching, and they are interwoven and inseparable. I should point out that I won't focus on students' use of technology themselves unless it is a part of teachers' instruction. Following the example I made before, for the purpose of my research, I will focus on studying the case from teachers' pedagogical purposes rather than exploring students' cognitive process of problem-solving with calculator. Based on the same reason, handheld devices use by students in the classroom will also be covered and considered in the study.

Fourthly, 'technology' and 'technologies' are just different in forms and sometimes interchanged in the study, but they actually refer to the same concept. The only difference is that I use 'technology' to describe either one specific piece of device (or software) or all devices and tool kits as a whole. For example, teachers' use technology to teach. While I use 'technologies' to highlight different devices and tool kits at the same time. For example, different technologies are adopted to teach geometry.

For the convenience of the research, as well as due to the limitation of time and resources, it is impossible to cover all technologies satisfying the above definition in this work, nor is it necessary. Based to the literature review, the figure below shows the structure of various technologies considered in my study:



Hardware refers to different kinds of devices; software and online-resources are those which can operate concrete work (such as drawing or computing). The difference between software and online-resources is that normally software is installed in the hardware with files stored in the same hardware, and the software can always be accessed regardless whether or not the device is connected to the Internet; while online resources refers to those files and applications which can be only accessed via the Internet, and these files are normally stored somewhere else of the users' devices.

3.2.2 **Affordance of the technology**

According to the discussion before, instruments are firstly artefacts in logic, and artefacts are with their 'affordance'. This term was widely used by researchers studying educational technology (e.g., Kennewell, 2001; Conole & Dyke, 2004; Hammond, 2010) with various foci, however, the basic idea of affordance remains as ''the perceived and actual properties of a thing, primarily those functional properties that determine just how the thing could possibly be used''. (Pea, 1993, p.51) Following this understanding, various functions of technology which can be used for mathematics education are to be examined and discussions upon how these affordances can lead to the purposes are to be explained in the study.

Different researchers identified different affordances of technology in educational settings (John & Sutherland, 2005; Pierce & Stacey, 2008; Sead & Nihad, 2013). Based on the relevant literature reviewed in the previous chapter, three main affordances are identified for mathematics instruction: Data Generation; Multi-resources accessibility; and Dynamic Demonstration.

Data Generation refers to the functions that technology can provide immediate feedbacks related with numbers and data. For example, calculators and computers can do calculation work in a fast and accurate way; Dynamic Geometry Software can measure geometrical objects and provide feedback immediately; Excel can generate and analyse massive data; symbolic calculator can demonstrate how to solve a linear equation step-by-step for new learners.

Multi-resources presentation means that technology can help combine various types of resources to present one topic, as well as presenting a piece of information in different ways at the same time. For example, slides and websites can present information which contains words, pictures, sound and video files; Graphic calculators can present a function in its algebraic form, number table-based form, and graphic form at the same time; Excel can present different types of charts for a set of data; Interactive Whiteboard can save files and to retrieve them for later use and comparison.

Dynamic Demonstration refers to the functions of technology that reveal the changing processes and the forming process of certain mathematics topics. For example, geometric software can demonstrate the process of drawing geometric figures and graphs of functions; they can also demonstrate the geometrical transformation in a visual way such as folding and rotation, or cutting a solid to show the cross-section; Online applications and statistic software can demonstrate mathematics experiment such as flipping coins to help students understand the definition of probability; Calculators and some online applications are capable for showing how the change of a parameter of an algebraic expression influences the shape of the corresponding geometric curve.

3.3 **The Meaning of Key Term: Teaching Mathematics**

Mathematics is an important subject in school learning period for preparing children for future out-school challenges (Mullis *et al.*, 2012; Li & Lappan, 2014a), and there is an expanding body of literature in discussing what are valuable for pupils to acquire in learning mathematics in schools (e.g., Kilpatrick, Swafford & Findell, 2001; Jablonka, 2003; Ojose, 2011; Jablonka, 2015), with many terminologies adopted and developed by the researchers.

Mathematics proficiency, for examples, appeared in a report by the Study Committee on Mathematics Learning, chaired by Jeremy Kilpatrick, for the U.S. government. In the report, mathematics proficiency was defined as five strands:

- *conceptual understanding*—comprehension of mathematical concepts, operations, and relations;
- *procedural fluency*—skill in carrying out procedures flexibly, accurately, efficiently, and appropriately;
- *strategic competence*—ability to formulate, represent, and solve mathematical problems;
- *adaptive reasoning*—capacity for logical thought, reflection, explanation, and justification;
- *productive disposition*—habitual inclination to see mathematics as sensible, useful, and worthwhile, coupled with a belief in diligence and one's own efficacy.

(Kilpatrick, Swafford & Findell, 2001, p.5)

The authors believed that the five strands of mathematics proficiency provided a useful framework for developing ‘‘a coherent, well-articulated, widely accepted set of learning goals … that would detail what students at each grade should know and be able to do’’ (p. 36)

Another terminology—mathematics literacy—was firstly widely disseminated by the Program for International Student Assessment (PISA) organized by Organization for Economic Corporation and Development (OECD) in 1999. (OECD, 1999) In the book *Measuring Student Knowledge and Skills: A New Framework for Assessment*, ‘mathematics literacy’ was considered as an understanding of the role that mathematics played for individual's current as well as future life as a qualified citizen, and three component were discussed: Mathematics content; Mathematics competence (carrying out procedures, making connections, and mathematical thinking and generalisation); and Adopting mathematics in different contexts. In the latest version of PISA framework (OECD, 2015)[17], mathematics literacy is rephrased as ''an individual's capacity to formulate, employ, and interpret mathematics in a variety of contexts. It includes reasoning mathematically and using mathematical concepts, procedures, facts and tools to describe, explain and predict phenomena. It assists individuals to recognise the role that mathematics plays in the world and to make the well-founded judgments and decisions needed by constructive, engaged and reflective citizens'' (p. 5). This framework emphasized students' acquirement and understanding of necessary mathematics content and processes, as well as of ability to use mathematics in different situations.

In fact, researchers have different ideas in interpreting and understanding these terms, and their opinions enrich our understanding of the terms. Ojose (2011), for instance, suggested that mathematics literacy didn't refer to concrete mathematics content taught in the school, however it based on these contents and suggested ''a broad understanding and appreciation of what mathematics is capable of achieving'' (p. 89). He also claimed that people confused content knowledge and process knowledge, of which the latter one—knowledge about applying the learned into everyday life— was actually relevant to 'mathematics literacy' and 'quantitative literacy', but should be based on a learners' well acquirement and understanding of basic knowledge. Niss and Jablonka (2014) believed that 'mathematics competency' and 'mathematics proficiency' focused more on the content and skills in school education, while 'mathematics literacy', 'quantitative literacy' and 'numeracy' were trying to indicate an more comprehensive understanding of mathematics and an idea of applying and interaction between theoretical and practical activities[18]. (Niss & Jablonka, 2014; Jablonka, 2015)

However, in practices, it is hard to distinguish those terms and many researchers and scholars just utilized them synonymously. (Niss & Højgaard, 2011; Niss & Jablonka, 2014) One example is the term 'numeracy' used in Trends in International Mathematics and Science Study (TIMSS)—organized by International Association for the Evaluation of Educational Achievement (IEA). In its latest report (TIMSS, 2015), even though TIMSS highlighted mathematics problem-solving, the 'numeracy' also included fundamental mathematical knowledge and mathematical procedures.

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[17] This is just a draft version of the framework, and it is about to be tested in field.

[18] Jablonka even asserted that pure mathematics tasks would not probably be regarded as mathematical literacy or numeracy.

In my opinion, applying what was learnt from school mathematics to different contexts and problems is both a purpose of learning and a way of learning (to gain a deeper understanding).

Some similarities can also be discovered from the above discussions. Firstly, all the researchers agreed and stressed that basic mathematics knowledge and skills are important, because they are the foundation for other mathematical activities like problem-solving, and should never be underestimated in schools (Burton, 2002; Beswick, 2012); Secondly, mathematics thinking and reasoning were highly emphasised. Researchers highlight the importance of conceptual understanding in learnings, and regarded mathematical thinking, and making connections between different concepts as well as between different contexts as essential goals for school mathematics. A very important approach to connect different concepts and skills is through problem-solving, as Van den Heuvel-Panhuizen and Drijvers (2014) said that unlike mathematicians' research activities, school mathematics should be focused on learners' meaning-development of existing mathematics by connecting it to real life and students' experiences, which serves as a sources to promote students' understanding of mathematics concepts, thinking, and procedures. Thirdly, students should form a positive disposition towards mathematics through the instructional process. Students should be exposed to various views of mathematics, and see the usefulness of mathematics in solving real problems and gradually being interested in and confident in handling mathematics.

The discussions and public educational discourses disseminated by researchers and international reports are significant in many countries and are thus influencing in shaping various education policies and curricula (Jablonka, 2015), which are the most important and direct documents to reflect what should be included in school mathematics. China and England are considered in my study, so it is necessary to introduce mathematics curricula in these countries.

The latest Mathematics Curriculum Standard in China—*Mathematics Curriculum Standard for Compulsory Education, 2011 version*— was promulgated by The Chinese Ministry of Education in January 2012. The document identified three aspects as the main objects for students' learning mathematics through the compulsory education period: firstly, students should acquire basic mathematics knowledge, basic mathematics skills, basic mathematics thought, and basic mathematics activity experiences for adapting to social life and further development; secondly, students should realise the connections between different mathematics knowledge, mathematics and other disciplines, mathematics and real life; be able to think mathematically, and enhance the ability to discover and ask questions, to analyse and solve problems; thirdly, students should understand the value of mathematics, increase the interest in learning mathematics and form a good learning habit; be able to have initial innovation consciousness and scientific attitude of seeking truth from facts.

The main objects are explained further in detail as below:

Table 3-1. Goals of Chinese curriculum

Knowledge and skills	• Experiencing the abstracting, operation and modelling of number and algebra, mastering basic knowledge and basic skills of number and algebra; • Experiencing the abstracting, classifying, discussing, moving and position identification of geometric figures, and mastering basic knowledge and basic skills of figures and geometry; • Experiencing the processes of collecting and analysing data from real-life problems, of utilising data to analyse problems and to obtain information, mastering basic knowledge and basic skills of probability and statistics; • Participating in comprehensive practical activities, and accumulating mathematics activity experiences of using mathematics knowledge, skills and methods to solve simple problems.
Mathematics thinking	• Establishing sense of number, symbol consciousness, and space concepts; preliminarily formatting geometric intuition and operational capability; developing image thinking and abstract thinking; • Realising the meaning of statistical methods and random phenomena; developing concepts of data analysis; • Through participating in various mathematics activities including observing, experimenting, conjecturing, proving, and comprehensive practices to develop plausible reasoning and deductive reasoning, and to clearly express own ideas; • Learning to think independently; realising basic mathematics thoughts and ways of thinking.
Problem-solving	• Preliminarily learn to discover and ask questions mathematically, and comprehensively use mathematics knowledge to solve simple real-life problems; enhancing the consciousness of application, and practice ability; • Acquiring basic methods of analysing and solving problems; realising multiple approaches to problem-solving, and developing innovation consciousness; • Learning to collaborate and communicate with others; • Preliminarily forming consciousness of evaluation and reflection.
Emotion and attitude	• Actively participating in mathematics activities, being curious and thirsty for mathematics knowledge; • Experiencing the happiness of being succeed through learning mathematics, as well as enhancing the wills of conquering difficulties; • Realising features of mathematics and understanding the value of mathematics; • Forming a good learning habit including being conscientious and diligent, think independently, being able to collaborate and communicate, and being reflective and questioning, as well as forming a scientific attitude of seeking truth from facts.

(Ministry of Education, 2011, p 11-12)

The mathematics curriculum documents for secondary education in England were promulgated by

Department for Education in September, 2013 (for key stage 3), and July, 2014 (for key stage 4). These documents highlighted the necessity of mathematics in daily life for citizens in the 21st century and its important functions in the development of other disciplines such as science, technology and engineering. The documents identified high-quality mathematics education as a provider of ‘‘a foundation for understanding the world, the ability to reason mathematically, and appreciation of the beauty and power of mathematics, and a sense of enjoyment and curiosity about the subject’’. (DfE, 2013, p. 2; 2014, p.3)

The document explains the aims of mathematics learning in detail in three aspects, and points out that the national curriculum aims at ensuring all pupils:

- become fluent in the fundamentals of mathematics, including through varied and frequent practice with increasingly complex problems over time, so that pupils develop conceptual understanding and the ability to recall and apply knowledge rapidly and accurately;
- reason mathematically by following a line of enquiry, conjecturing relationships and generalisation, and developing an argument, justification or proof using mathematical language;
- can solve problems by applying their mathematics to a variety of routine and non-routine problems with increasing sophistication, including breaking down problems into a series of simpler steps and preserving in seeking solutions.
  (DfE, 2013, p. 2; 2014, p. 3)

In summary, both Chinese curriculum standard and English curriculum documents reflect key points of school mathematics, and point out general as well as concrete goals of mathematics education for teachers to prepare, implement and reflect their instructions. Although these documents were designed and implemented in two different countries, similarities in learning requirement are still found, and these similarities reflected different researchers’ opinions on the content for school mathematics. Based on the above review, I will define ‘teaching mathematics’ in my study as ‘the teaching of Mathematics Knowledge and Skill’, ‘the teaching of Mathematic Thinking and Reasoning’, and ‘the cultivation of Positive Disposition towards Mathematics’.

Mathematics Knowledge and Skills (MKS)

Herein, Mathematics Knowledge refers to basic mathematics concepts, statements, theorems, rules and skills. Just like words and phrases in English languages, knowledge and skills are fundamental bricks of school mathematics, and are regarded as one of the most important content for students to learn (Kilpatrick, 2014; Woolcott *et al.*, 2014). Research evidences also showed that how well students learn and acquire mathematics knowledge exert great impact on their understanding of mathematics and ability to apply the knowledge to solve problems (Allsopp, Kyger & Lovin, 2007; Richland, Stigler & Holyoak, 2012), indicating that the acquisition of basic mathematics knowledge and skills is the foundation for reasoning, problem-solving and other mathematics activities. The teaching of MKS here refers to the quantitative increase of information, fact, skill, and so on, but all the elements are presented independently. Teachers highlighted single knowledge or skill via technology by demonstrating, confirming and asking students to drill and practice.

Mathematics Thinking and Reasoning (MTR)

Thinking mathematically is always a big target of mathematics education, and it is the mathematics thinking that distinguish mathematics from other disciplines (Mevarech & Kramarski, 2014). It should be noted that mathematics thinking and reasoning is developed based on mathematics knowledge and skill. If we use points to indicate specific knowledge and skills, mathematics thinking and reasoning connect the points together and make them a network. Therefore, MTR here refers to teachers' and students' use and linking different knowledge and skills for mathematics activities. The teaching of MTR refers to the qualitative increase of knowledge and skills. Teachers connect different knowledge and skills via technology by explaining, justifying, applying, analysing and inquiring, or by asking students to do so.

Positive Disposition towards Mathematics (PDM)

Besides the previous two aspects, helping student form a positive disposition is also a significant task for mathematics education. With the help of various technologies, researchers realised that school mathematics had been changed in terms of both mathematical skills acquired and the way people view mathematics. For example, students are encouraged to use technologies to do inquiry activity and mathematical experiments and then form a perspective that mathematics is not just a set of concepts and theorems, but also a history of mathematicians' inquiries; Calculators free students from calculation so that students won't need to worry about the calculation, and may feel more confident in thinking and solving problems (Ruthven & Hennessy, 2002). In addition, teachers' adoption and integration of various resources can attract students and raise their interests in the learning process.

It should be noted that the terms used here are more or less different compared to other similar discussion and thus some remarks are necessary to explain the differences of MKS and MTR in my study:

First, MKS just refers to specific knowledge (concept, statement, theorem, rule etc.) or skill, but MTR means the connection between different knowledge. So the teaching of MKS doesn't aim at constructing and expanding a knowledge network, which is the aim of the teaching of MTR. For example, a teacher may teach students how to solve an equation or draw the graph of a certain function, and these are teaching of MKS; however, if the teacher joint them together to explain how to solve an equation through its corresponding functional graph, it becomes the teaching of MTR. It should be mentioned that in some cases, teachers may use exploratory method to introduce new knowledge. At that time, a meaningful situation is constructed with a core question to be addressed. Due to its exploratory nature, students need to reflect their existing knowledge and experiences, explain why the existing knowledge is unsuitable for the new problem, or how existing knowledge can be adapted and synthesize to attack the problem, and in this process, new knowledge or skill is formed. By doing so, students not only obtain new knowledge, but also understanding the relationship among it and others, and therefore their knowledge network is expanded. So learning new knowledge and skill by teacher-guided or self-guided exploratory method is also regarded as MTR.

Second, I split problem-solving into two categories. One is straightforward situation which are always followed by similar or same examples. In this case, the instructional purpose is to enable students to remember and to be familiar with the taught knowledge or skill by practicing, and what students need to do is just follow what was taught by the example. For instance, after the introduction of Pythagoras theorem, students will be demonstrated some examples that given length of two sides of a right-angled triangle to find the length of the third side, and then they will be asked to do exercises of the same nature. Technologies here are normally used for demonstrating the questions, manipulating calculation work, and sometimes for confirming the conclusion visually. The other category of problem-solving refers to comprehensive problems and real-life problems where different knowledge are logically intertwined. In such cases, students need to involve in various mathematical activities including observing, conjecturing, testing, calculating, reasoning, inquiring and so on. Technologies can be used in any steps from introducing real-life situations which provides necessary background for solvers to mathematize the problem, to generating enough data to be observed, and to assisting forming and confirming conjectures. The first category of problem-solving belongs to MKS, whilst the second category belongs to MTR.

Third, the differences of MKS and MTR can be also explored from the perspective of cognition. The taxonomy of educational objectives proposed by Bloom *et al.* (1956) is one of the famous cognitive models recognised by many researchers. In the taxonomy, learning objectives are classified into six levels: knowledge, comprehension, application, analysis, synthesis, and evaluation. Later on, other researchers (e.g., Anderson, Krathwohl & Bloom, 2001; Krathwohl, 2002) reflected on and modified the Bloom's taxonomy and proposed a new one as: remember, understand, apply, analyse, evaluate, and create. These two version although word differently, share some common ideas: knowledge (or remember) described the lowest cognitive level which dealt with accumulation of facts, information and skills; the other five levels described the requirement, in various degree, of connecting different knowledge and information together and recognising them in different contexts. However, due to that these taxonomies are not developed specially for mathematics, they haven't distinguished simple problem and complex problem in application (or apply) level. Thus, the MKS in my framework can be understood as knowledge (or remember) and application (or apply) with simple problems in Bloom's (and revised Bloom's) taxonomy; and the MTR includes other levels in Bloom's (and revised Bloom's) taxonomy. Likewise, Webb and Coxford (1993) distinguished lower- and higher-order mathematical thinking, with the former one containing doing simple mathematical operation, applying and working on direct procedure and algorithm; while the latter one containing connecting and understanding mathematics in depth, making analogy and forming generalisation, formulating conjectures, explaining and reasoning logically, and solving un-routine mathematical problems. In this case, the lower-level mathematical thinking (although the author adopted the word 'thinking') refers to MKS and the higher-level thinking refers to MTR in my study.

3.4 Pedagogical Strategies to Achieve the Affordance

Although affordances are identified, they are just potential functions to be used to achieve the goal. As Hammond (2010) claimed that ''the affordance is there, it has always has been there, but it needs to be perceived to be realised'' (p. 206). Research evidences revealed that concrete strategies with technology chosen by teachers varied according to contextual situations and teaching content (Pierce, Stacey & Wander, 2010; Goos, 2014; Lagrange & Kynigos, 2014), however pedagogical strategies involving technologies in general adopted in the classrooms can be divided into several categories as follows:

(1) Illustrating and Demonstrating: Multimedia resources are presented in front of students with little explanation or discussion; or technology is used to present a topic that has already been taught and explained in another way;

(2) Calculating and Checking: Technology is used for calculating for routine problems, and for checking the correctness of answers obtained by students.

(3) Explaining and Justifying: Technology is used for explaining how a concept or idea of problem-solving comes, how is it related to previous knowledge and why it works.

(4) Reflecting and Discussing: Technology is used for providing topics to be thought and discussed;

(5) Inquiring and Exploring: Technology is used for assisting problem-solving process and seeking for new knowledge.

The first two categories mainly refers to superficial use of technology. Illustrating and Demonstrating mainly refers to the simple presentation of content and multi-resources in the classroom, with two kinds of reason: to provide various resources to attract students; or to show a specific piece of knowledge that had already been explained in another way (usually in a visual way). For example a teacher may present many pictures to students to show that the circular shape is ubiquitous in daily-life to attract pupils' attention; or the teacher may explain the difference between 'frequency' and 'probability', and then present a flash courseware or simulation program to show the fact that with the number of test increasing, the numerical difference between 'frequency' and 'probability' will become smaller and smaller. Of course, a simpler way to present content in front of the class is presenting exercises for students to practice, which enables the inclusion of more content within one lesson. Calculating and Checking refers to the use of technology to generate answers for routine questions, or students compare their paper-pen-calculated answers to tech-generated answers so that they know whether they succeed in solving the question or they need to re-do it.

The other three categories reflect the cognitive-assisting nature of technology in mathematics education. Explaining and Justifying refers to situations where technology is used to explain how the knowledge (be it a concept or a theorem, or other forms) come to its final form or why it is always true. For example, when introducing the formula for calculating the lateral area of a cone, Geometer's sketchpad can be used to demonstrate the unfolding process of the cone to a sector. During this demonstration, a teacher can pose several questions to guide students' thinking and finally lead to the formula. Reflecting and Discussing describes the fact that content displayed on the screen can be used to lead to comparisons and in-depth discussions, which can develop students' understanding of the subject matter. For example, teachers may use a simulation program to simulate a mathematical experiment that flipping a coin for hundreds of time, however, students may find that the times for heads and tails being showed are un-equal, so this phenomenon can cause a discussion on 'probability' and 'frequency'. Inquiring and Exploring means to use technology for solving complex problems and seeking for new knowledge. By saying complex problems, I mean two kinds of problems. One is situation-based problems, or real-life problems, which needs to be mathematised and modelled. For example, given two sets of data including weight and height of a group of people, what questions could they inquiry with the data? How to rephrase the question mathematically? How to implement the solving plan? And after the implementation, how to interpret the solution? Is it valid and always true? etc. The other kind of problem is from the subject of mathematics itself. These problems can be selected purposely by the teacher, and also can be those expanded from exercises. For example, after learning Napoleon's Theorem, the teacher can ask students to change some of conditions of the theorem and to see whether the conclusion still holds, or what else can be found. By saying ‘seeking for new knowledge’, I mean that teachers may use inquiry method to introduce new learning topic by making it a problem and encouraging students to solve it and it is during this solving process that new knowledge comes out. A good example is that when teach the sum of exterior angles of a polygon, a teacher may present various polygon with different number of sides to student and use GSP to measure the sum of exterior angles and ask students to guess the pattern or relationship, then he/she may use GSP to confirm or reject students’ hypotheses and provide more hints through the use of technology until when students get the right form of the theory as well as understand how it comes to the form.

The strategies described above reflect pedagogical actions teachers may take and these strategies bridge the affordances of technology and the goals of mathematics instruction. The figure below shows the process of turning artefact into instrument and also serves as a framework for the first question of my exploration.

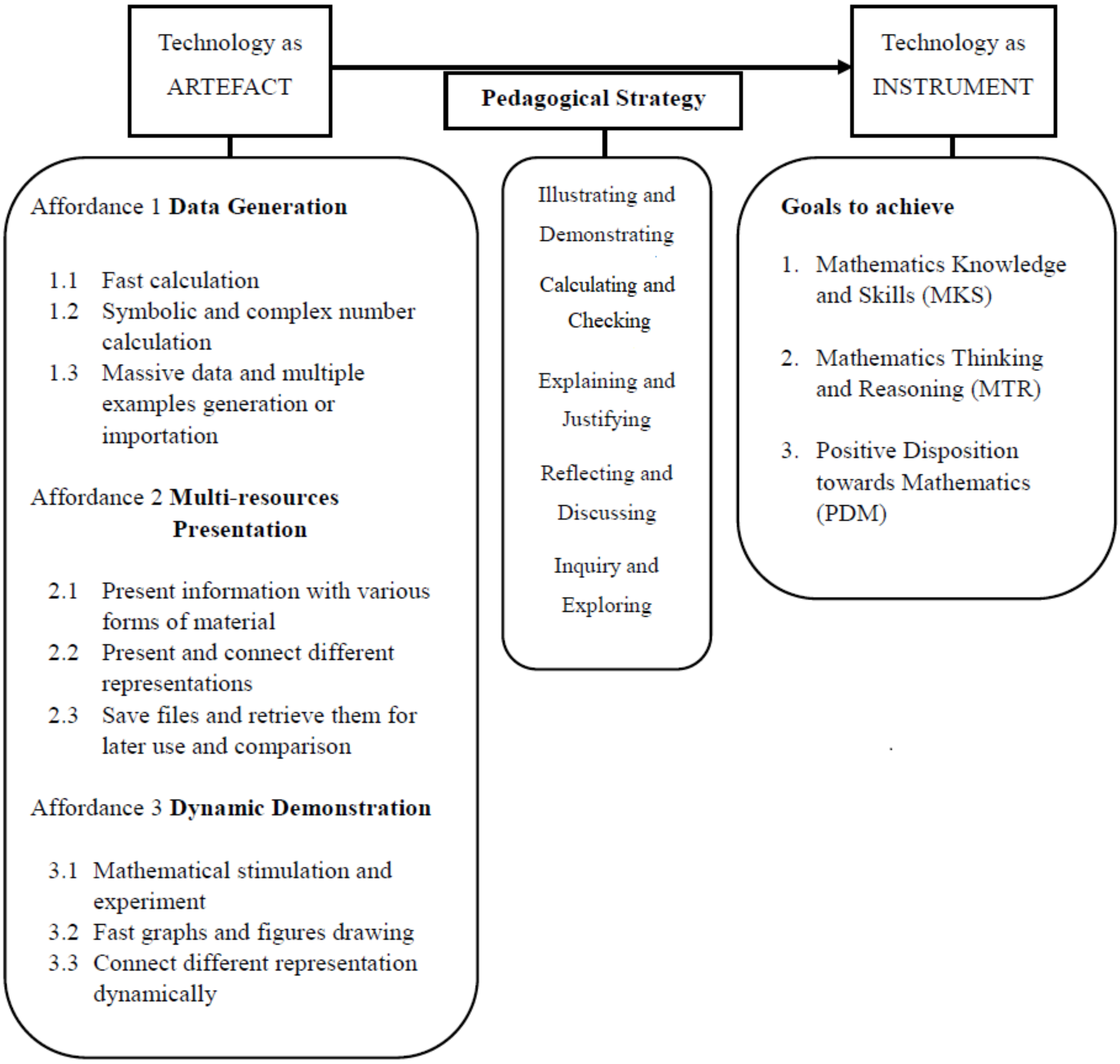

Figure 3-2. A framework to explore teachers’ use of technology

3.5 **Influencing Factors**

According to the literature, as well as my experience of teaching in high schools. Two categories of factors are identified with each of them containing several components. The categories are Personal Factors (PF), and Contextual Factors (CF). It is necessary to notice that my study aims at exploring the use of technology in teaching mathematics *from teachers' perspective*. The framework for questions one reflect the principle by highlighting the goal of teaching[19], and the framework for the second question is consistent with the principle. The first one describes teachers themselves and reflects some reasons of the teachers' own, i.e. personal factors (PF); the other one reflects reasons which are caused by the professional environment and context where teachers work, i.e. contextual factors (CF), and it contain a broader coverage, so I split CF further into two levels: school level and regional/national level.

3.5.1 **Personal factors**

Across all literatures, factors related to teachers themselves attract the most attention from researchers, among which 'Knowledge' and 'skills' (Koehler & Mishra, 2009; Sahin, 2011; Player-Koro, 2012) are regarded as of great importance and can directly influence teachers' up-taking practices. 'Pedagogical beliefs' (Hung & Jeng, 2013; Chow, 2015), and 'Confidence' pertaining to utilization of technology (Becta, 2004; Player-Koro, 2012) have been also widely discussed as they influenced how teachers view the usefulness of technology in mathematic instruction, including how successful teachers' uses of technologies are.

Here I refer 'knowledge' to teachers' familiarity of different commonly used technologies, and teachers' knowledge of choosing appropriate technologies to support instruction; I refer 'skills' to teachers' competence of operating different technologies for classroom teaching practices, and handling technical problems in the process of instruction; I refer 'pedagogical beliefs' to teachers' idea of their role in classroom instruction, and the importance and usefulness of technology in helping students' learning, as well as whether teachers are confident when they use technology in front of the class, and when they manage the whole classroom.

3.5.2 **Contextual factors**

Many studies have been conducted in discussing school-based factors that encouraged or hindered teachers' uptake of technologies, although different terms were used by researchers in talking about this issue. According to the literatures, I split the contextual factors into two levels: school level

[19] When considering teaching mathematics, an clear goal (or object) should be the first which enters teacher's brain, and all the work that he/she is going to do should centre on achieving the goal (or objective).

and regional/national level.

School level

A number of studies pointed out that whether teachers had access to a variety of resources, and what support they obtain from school and department hugely shaped teachers' tech-related instruction. (e.g., Harvey-Buschel, 2009; Perrotta, 2013; Bretscher, 2014) When talking about facilities and resources in schools, researchers noticed that not only quantity (which refers to whether there are enough facilities for teachers and students to use) should be concerned, the quality (which refers to whether the resources are obsolete, and whether the network in the school is strong and fast enough) as well as how were these resources managed (whether or not there were computer suite dedicated to mathematics) should also be considered, because these aspects reflected how easy teachers could have access to the facilities to support different instructional needs. (Bingimlas, 2009) In terms of school supports, researchers suggested that the two main elements should be covered in this component: Leadership encouragement; and Professional supports (Bingimlas, 2009; Harvey-Buschel, 2009; Perrotta, 2013). In the study, Leadership encouragement explore the attitude of the head of the department (and school) towards technology-integration. Professional support refers to whether teachers can easily go to technical staffs for help, and the collaboration and exchange between colleagues to promote teachers' use and skill of technology-integration.

Besides, curriculum should not be excluded as a potential factor. Curriculum reflect educators' and subject experts' understanding of the nature of education as well as vital knowledge and competences for students to grasp, and it has been recognised by many researchers as one of the most important factors guiding teachers' instruction (e.g., Fan, Zhu & Miao, 2013; Li & Lappan, 2014b). I refer 'curriculum' here mainly to textbooks, and other curriculum materials (such as teachers' instructional handbook) which provide teachers with detailed explanation on subject matters and various suggestions on relevant pedagogical strategies. According to Li (2004) and Fan, Miao and Mok (2015), for a great number of teacher, how a certain piece of knowledge is introduced and presented in the curriculum materials greatly shapes the way how teachers teach in the classrooms. Therefore, content showed in the curriculum materials which are technological related may exert impact on teachers' classroom instructional strategies.

Finally, students will also be considered as a potential factor in my study, and I believe that a successful lecture should be planned on the base of careful consideration of students' situations, including cognitive factors (e.g., their prior knowledge and skills) and non-cognitive factors (e.g., their ages, hobbies and interests). Because some researcher mentioned that big class with a large quantity of students might impede teachers' adoption of technologies, and students' prior experiences upon and abilities in using technology might change teacher' choice of devices in classroom teaching, especially for those with instructional strategies like group work and cooperative learning (Groff & Mouza, 2008; Ten Brummelhuis & Kuiper, 2008). Handal *et al.* (2013) also found that students' lack of basic technology as well as lack of basic skills hampered the teachers' use of technology in instruction. In my study, I just explore factors related to technological use, and hence two sub-components are considered in the study. One is the scale of the classroom, and the other sub-component is students' prior experiences and competence of technology.

Regional/national level

Out-school contextual factors mainly refers to those related to educational policies and relevant professional activities which exert impact on teachers' instruction. According to the literature, although it is reasonable to believe that policies matters in considering educational problems, only few studies discussed such issue and provided us with empirical evidence, especially in discussing teachers' tech-integration instruction (e.g., Groff & Mouza, 2008; Vanderlinde, van Braak & Dexter, 2012), indicating that more studies are needed to consider the influence of policies in the field of tech-integration mathematics education. According to a report from UNESCO (2011), national educational documents of almost every country value technologies and their use in changing the nature of education and societies. The document (UNESCO, 2011) highlights the embracement of technology in education in providing pupils with opportunities to gain deep understanding of subjects by applying them in various contexts; as well as in equipping pupils with significant competences for being 21st century citizens. Therefore administrative department for education in many countries take actions to reflect the policies, with the hope that the actions could encourage or continue encouraging teachers' uptake of technologies. In the study, two aspects within this component are discussed and considered as those might exert big impact on teachers' instructional behaviour: (1) educational inspection and exchanging activities organized by educational authorities of different level; (2) out-school trainings (including conference, lectures, as well as formal professional development programs) with technology-related content.

The graph below represent the framework in a visual way:

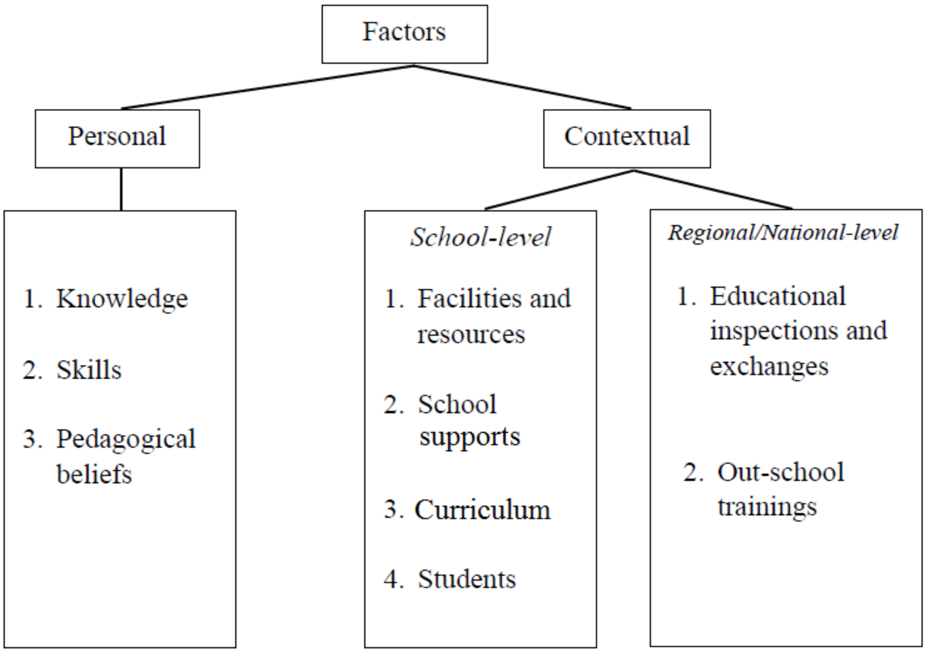

Figure 3-3. A framework to explore factors influencing mathematics teachers' use of technology

3.6 **Summary**

The focus of my study is mathematics teachers' use of technology in the instruction, and this chapter explains the framework for the study in detail.

''The use of something'' is understood and explained as ''the adoption of something as an instrument (for a certain purpose)''. From this view of point, I regard ''technology'' in my study as the ''instrument'', and ''teaching mathematics'' as the ''purpose''. Following this definition, technology is defined as ''electronic devices (together with the tool kits based on them) which are used for teaching and learning mathematics'', with three types of technologies considered: hardware facilities, software and online resources. Teaching mathematics is defined as the instruction of Mathematics Knowledge and Skills (MKS); Mathematics Thinking and Reasoning (MTR) and; the cultivation of Positive Disposition towards Mathematics (PDM).

One thing I need to mention is that although I realise the fact that mathematics teacher is at first a teacher logically, so other tasks which are irrelevant to content instruction are also included in mathematics teacher's professional life, my study focuses only on mathematics education with technology, and therefore those content-irrelevant instructional behaviours are not discussed in the study. For example, a teacher may spend some time and use some strategies to manage classroom discipline, and in this process some technologies may be adopted, however this is irrelevant to mathematics, and the technologies therefore here are just for education in general, rather than for mathematics education. So, these kinds of utilization of technology are not included in my study.

To investigate what factors influence teachers' adoption of technology in mathematics instruction, a framework is built up based on previous research and discussions. There are two main categories, namely personal factors (PF) and contextual factors (CF), with each one includes several sub-components.

Chapter 4 Research Methodology and Procedure

The previous chapters reviewed relevant literature, based on which, conceptual frameworks have been developed. This chapter discusses methodology foundation of the study, before describing research process, on which the investigation is based, and finally the methods chosen for the study are evaluated.

4.1 An Overview of the Research Methodology

In the study, I take a pragmatism view and adopt mix-method approach to collect the data. According to Johnson and Onwuegbuzie (2004), pragmatism balanced different paradigms, and mixed methods were useful in ‘‘[fitting] together the insights provided by qualitative and quantitative research into a workable solution’’ (p. 16). A fundamental feature of pragmatism in scientific research is that research questions are regarded as the most important, and all methods and approaches ‘‘should follow the questions in the way that offers the best chance to obtain useful answers’’ (ibid. p. 17-18).

I conduct the study investigating what technologies and how they are used by secondary teachers in teaching mathematics, as well as what factors influence their use. Mixed-methods approach is adopted in my study with anonymous questionnaire survey being the main method, and classroom observation and interview as the qualitative supplements.

The anonymous questionnaire survey is taken as the main method because firstly, the research questions are about ‘behaviours’ and ‘fact’ rather than only ‘opinions’, and thus variables in the study are observable, making questionnaire suitable here. Secondly, I’d like to report objective facts and try to reduce the probability of obtaining social desirability reports. If it is possible to find the provider of every single answer (for instance by face to face interview), then the participants are more likely to give answers thought to be socially desirable (for example in my research, respondents may assume that the more technologies are used, the better) rather than their truthful current situation. Finally, I am trying to infer my findings to the population, and this statistical inference has to be based on relatively large data, which makes the questionnaire appropriate especially when considering the limitation of time, expenses and the number of researchers.

In order to further strengthen the credibility of my research, classroom observation and interview have been adopted as the supplements, and some strategies were used to maintain the objectivity as much as possible when utilizing these two methods. For classroom observation, videotaping was adopted to replace the researcher’s on-site observing (when permitted by teacher and students), because when facing researchers, participants are inclined to modify their behaviours, which will weaken the reliability of the conclusions. The device was positioned at a place that was as non-obtrusive as possible to minimise the impact on students' learning and teachers' teaching, but allowed all the participants to be seen for ethical consideration. For interview, the interviewees were the teachers who were videotaped before and thus questions of the *facts-related* recorded by the device rather than *mere opinions* have been asked.

I believe that the methodology and data triangulation enhanced the reliability of my research conclusions.

4.2 A Brief Introduction to Chinese and English Education Systems

This study aims to explore and compare Chinese and English mathematics teachers' use of technology in instruction. So before explaining how samples are selected, a brief introduction to the basic information of education in China and England is given.

4.2.1 Schooling in China and England

According to official data from Chinese government website, China is located in the east of Asia. China's land area is around 9630 thousand square kilometres and its population is over 1.3 billion. There are 34 provincial regions in China (including Hong Kong, Macon and Taiwan, and the area excludes those three regions are commonly named as Chinese mainland). (China, 2015)

The Chinese education system is a centralised and hierarchal system with the Ministry of Education creating educational policies and supervising educational activities of provincial educational authorities. In 1986, China has launched the Nine Years Compulsory Education Act, and since then every Chinese child aged between 6 and 15 is required to attend school to accept basic education which takes place in primary schools (aged from 6 to 12, grade 1 to 6) and secondary schools (aged 12 to 15, grade 7 to 9), followed by a Senior High School Entrance Examination (SHSEE), which marks the end of compulsory education period. Subsequently, students can choose to enter a 3-year senior high school or a 3 or 4-year vocational middle school before they go to higher education institutes or job market. (Ministry of Education, 2015)

The United Kingdom of Great Britain and Northern Ireland (commonly known as the UK) is located off the north-western coast of European mainland and it is surrounded by North Sea, English Channel, Celtic Sea, Irish Sea, and Atlantic Ocean. There are around 65 million inhabitants living in the UK whose area is about 240 thousand square kilometres. The UK, as an important sovereign state in Europe, consists of four countries: England, Scotland, Wales, and the Northern Ireland, and the latter three have devolved administration in various matters including education system. (Government, 2013)

Generally, children in the UK are required to accept compulsory full-time education from the school year when they turn 5 (4 in Northern Ireland) until they turn 16. During these years, children need to enter three stages of education including Early Years, Primary and Secondary, before they go to Post-16 Education between 16 and 18, and Higher Education afterwards. In England, for example, children aged 5 should go to a 6-year primary schools which contains 2 Key Stages including year 1 to 2 at children's age of 5 to 7, known as Key Stage 1, and year 3 to 6 at children's age of 7 to 11, known as Key Stage 2, and then go to a 5-year secondary schools, which also contains 2 Key Stages including year 7 to 9 at children's age of 11 to 14, known as Key Stage 3, and year 10 to 11 at children's age of 14 to 16, known as Key Stage 4. By the end of the secondary education, children are normally attend a national examination for the General Certificate of Secondary Education (GCSE). After that, students can go to six-form College for a two year Advanced Level course if they want to purse higher education in universities and other Higher Education institutes. (MoD, 2013)

It should be mentioned that in UK, the age at which a pupil choose to stop education is commonly known as 'leaving age' for compulsory education, and the Education and Skill Act 2008 has raised the leaving age from 16 to 18. However, students who finished secondary education can still choose to stop full-time school education, but they have to stay on in education or training at least part-time until they turn 18. (DfE, 2015)

According to the official data and government documents from China and England, the following picture shows the comparison of English and Chinese mainland students' schooling period according to their age.

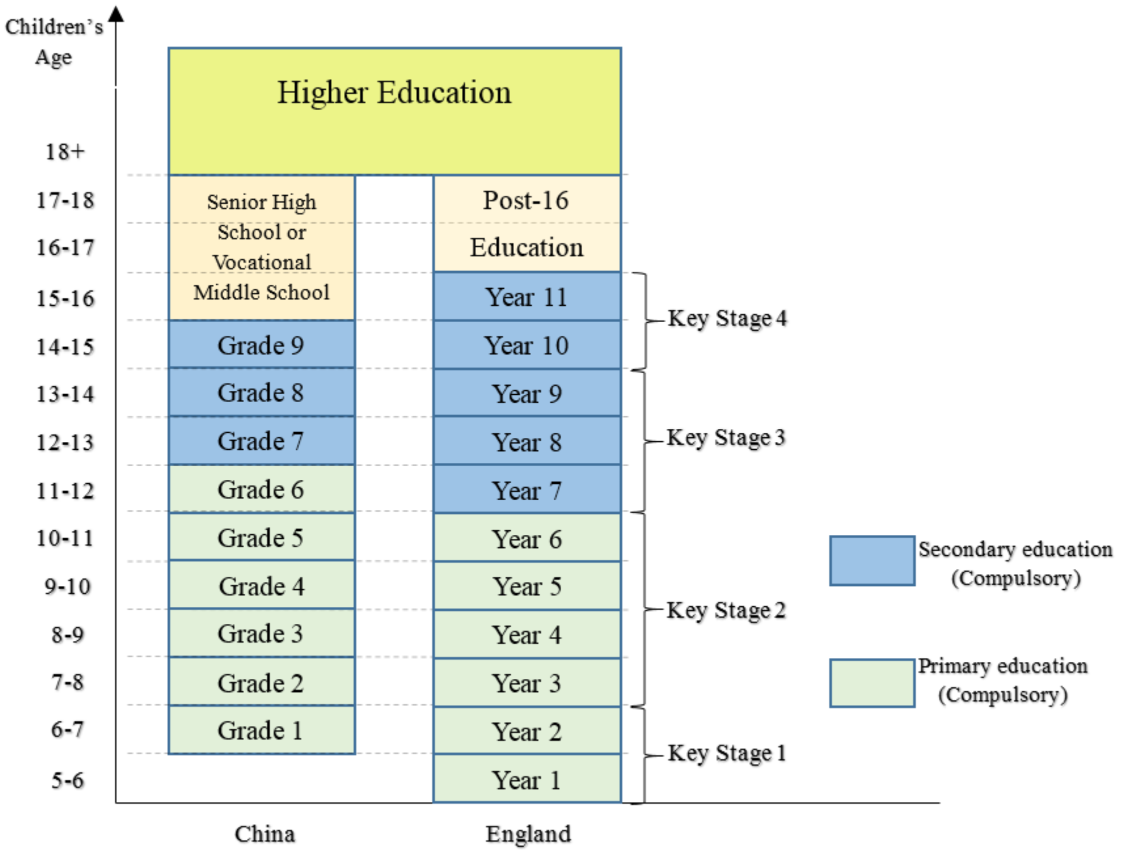

Figure 4-1. A comparison between Chinese and English school system

4.2.2 Teacher management in China and England

This study discusses teachers' practices and it is worthy to briefly introduce how mathematics teachers in China and England are recruited and managed.

Chinese education system used to be highly centralised, all educational practices were managed by the Ministry of Education (MoE), but over the last two decades, more managing power is released gradually to provincial and municipal educational bureaus. Previously, almost all teachers were graduated from Normal universities and were distributed to certain schools by the MoE (manipulated by the local educational bureaus). Now, the recruitment of teachers is in charge by municipal educational bureaus. Each municipal educational bureaus organize public subject-based examinations every year to recruit teachers for schools, and all teacher qualification holders can participate in the examination. Each school will publish the recruitment information on their school website where all participants can look up. After the public examination, all passers can freely submit applications to any schools which need new teachers of the corresponding subject. At this stage, schools can arrange interviews and mock classroom teaching to the applicants to examine their professional skills, based on which schools make their own decisions on recruitment. It should be mentioned here that in most cities in China, applicants for mathematics teacher are with (at least) bachelor degree majoring in mathematics or relevant specialist (such as statistics), and only a few applicants who are non-mathematics learner would be accepted.

Besides, municipal educational bureaus also administer teachers' professional development. There is a national unified ranking and promotion system for Chinese teachers to develop professionally, and this system provides teachers with professional titles, which contains *Junior Grade Teacher*, *Intermediate Grade Teacher*, and *Senior Grade Teacher*. Recently in some regions, excellent teachers are awarded *Full Senior Grade Teacher* after they got the Senior title. Besides, a few of Senior Teachers who have made significant contribution in education and pedagogy, and are reputable would be further awarded as Master Teacher as an honour-title. Although the promotion route is established nationally, the assessing and awarding are manipulated locally (wherever teachers get the promotional titles, they are normally recognised cross the whole country). China also has established hierarchical organisations to support in-service teachers' professional development of nearly every subject. Take the mathematics as an example, the bottom level is Lesson Planning Groups (LPG, also known as '*bei ke zu*'), which is consisted by teachers teaching same year level. Usually, teachers in the same LPG meet regularly (usually weekly or so) to prepare lesson together during which discussions on how different topics should be taught are conducted; different LPGs in the school are managed by the school Mathematics Teaching Research Group (TRG, also known as ''*jiao yan zu*'' in Chinese, and in a sense, it is equivalent to 'Department of Mathematics' in England schools), and there is a head of TRG taking charge of all teachers in the school of their professional development; then the upper level is District Teaching Research Office (TRO, also known as ''*jiao yan shi*'' in Chinese) at district, city, and provincial levels, with several teaching and researching fellows working in each level[20], and the TROs are subject-based as well and are responsible for inspecting teaching quality and organising various professional training and cross-school exchanges. For example, TRO fellows regularly visit schools to observe classroom teachings and then make comments to help teachers improve subject-teaching. Fan, Miao and Mok (2015) stated: ''working as a team, teachers in the TRG or its LPG meet weekly, prepare lessons together, observe each other's lessons, reflect and comment on observations collectively, and conduct open lessons regularly.'' (p. 52)

In England, in most cases, potential secondary mathematics teachers should meet two basic entry criteria: a standard equivalent to a GCSE grade C/Grade 4 in mathematics and English; and a Degree. All teachers are trained before working at schools. The training routes comprise university-leads and school-leads. All the entry criteria are judged by the training providers who make the

[20] More detailed information on Chinese in-service teachers professional development support can be found in Fan, Miao and Mok (2015).

final decision on whether one person is eligible for training. Different training routes take various length in time but all routes end up with Qualified Teacher Status (QTS) which is a must to teach as a qualified teacher in English schools, and most courses include a Postgraduate Certificate in Education (PGCE) as well. (DfE, 2017) According to Department for Education (DfE), mathematics teachers are highly demanded in England and the teacher training courses welcome all eligible applicant regardless of their academic and working backgrounds. When necessary, a Subject Knowledge Enhancement (SKE) courses will be provided before the training courses for those who need extra help on the subject they may teach later. The length of the SKE course varies depending on applicants. For example, a physics graduate or an engineering, who had already learned a good amount of mathematics knowledge in the universities, may need to spend 12 weeks on the SKE course for the refreshment of relative knowledge; while a politic graduate may need to spend 28 weeks on the SKE course, because s/he didn't study any mathematics knowledge at university.

For in-service teachers, there are different organisations and professional groups which provided various activities for teachers' professional development in England. The organisations and groups include National Centre for Excellence in the Teaching of Mathematics (NCETM), Maths Hubs, Institute of Mathematics and its Applications (IMA), and so on. (NCTL, 2016)

4.3 Research Process

4.3.1 Population and sample

In my study, China refers to the Chinese mainland, excluding Hong Kong, Macao, and Taiwan. Due to various historical factors, Chinese mainland is different from the other three regions in terms of political and economic systems, and due to limitations in time, expenses and accessibility, the choice of population would be just focused on one area in China and England, rather than whole countries.

For England part, the criteria for choosing population area is based on 2015 state-funded schools national GCSEs dataset, which has been published by the Department for Education in January 2016. The dataset provided the information on the percentage of pupils at the end of key stage 4 achieving at 5+ A*-C grades including English and mathematics GCSEs by regions (DfE, 2016a). According to the data, London, South East, East and South West regions performed better than English average percentage (57.3) and can be regarded as regions with better educational quality. My data collection focused on South East region, and for convenience reasons, I chose Hampshire and Southampton Educational Local Authorities (ELAs) as the target area for my study.

Table 4-1. Regional percentage of pupils achieving at 5+A*-C grades in GCSEs in England

Region		the percentage of pupils in 2015 at the end of key stage 4 achieving at 5+ A*-C grades including English and mathematics GCSEs
London		60.9
South East		59.9
East		58.2
South West		58.0
North West		55.9
North East		55.4
West Midlands		55.1
Yorkshire and the Humber		55.1
East Midlands		54.2
Total	All schools	53.8
	State-funded schools	57.3

According to the official data from the Department for Education, there are 162 secondary schools within my target area, of which 36 are special schools, and 43 are independent schools. Special schools are set for pupils with special educational needs, and these schools don't belong to mainstream schools (DfE, 2016b). The exclusion of independent schools is because that they are financially independent of the government, and there is no compulsory requirement for them either to follow national curriculums or to be inspected for achievements. Besides, independent schools are free to participate national assessment (GCSEs), though most schools do. (New Schools Network, 2015) Therefore, neither special nor independent schools are included in the study, making the population schools of my study consisting of 83 mainstream secondary schools.

The selection of sample school was also based on the 2015 state-funded schools national GCSEs performance. First, z-test is adopted to test whether each school's 2015 GCSEs result is significantly different (at 95% level) from the average level (57.3%), and then all population schools are divided into three categories: schools with performance significantly above (School category I), insignificantly different from (School category II), and significant below (School category III) the average level; second, 20 schools were selected via stratified sampling from each category and invitations were sent to ask them join in my study. The statistical analysis shows that the number of schools of these three categories (I, II, and III) are 22, 31, and 30 respectively. Therefore the number of schools to be selected in each category are 5, 8, and 7.

However, there are only 13 schools agreed to participate in the study, so I expanded the target areas to the area attached to Hampshire ELA to get more data. Finally, I got 4 more schools in my sample, with two coming from Portsmouth and two from Dorset. Although Dorset is located in South West of England, its 2015 GCSEs performance[21] was 58.3, and the GCSEs performances of South East (59.9) and South West (58.0) are close, and both are above national average performance, so it is acceptable to include Dorset schools in my study. In summary, there are 17 English schools participating in my study with 13 coming from Hampshire and Southampton LEAs, 2 from Portsmouth LEA and 2 from Dorset LEA. Within the 17 schools, 5 are category I schools, 6 are Category II schools and 6 are Category III schools.

In China, there is no national unified examination for all secondary schools across the whole country, so I used a research result as a reference to select target region. Wang *et al.* (2013) adopted Education Development Index (EDI) proposed by UNESCO to compare the level of educational development of different regions in China. Table 4-2 presents the average EDI of each region in China. To ensure the comparability of the data between China and England, I chose East China region on which the population schools are located.

Wang *et al.* (2013) calculated EDI for each province, and the decreasing order of province in terms of value of EDI of East China region are Shanghai (0.917), Zhejiang (0.824), Jiangsu (0.707), Fujian (0.700), Jiangxi (0.649), Shandong (0.646), and Anhui (0.579). Considering the average EDI of this region as well as the order of different province, I decided to choose Jiangsu Province to select schools for data collection. Although Jiangsu Province has been selected, the area of Jiangsu is actually over 20 times as bigger as Hampshire, and hence I finally decided to just focus on Nanjing, the capital city of Jiangsu, whose area is just 0.79 times bigger than Hampshire area[22].

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[21] percentage of pupils in Dorset state-funded schools in 2015 at the end of key stage 4 achieving at 5+ A*-C grades (including English and mathematics) GCSEs

[22] According to data from Hampshire County Council website (http://www3.hants.gov.uk/planning/factsandfigures) and People's government of Jiangsu Province (http://www.js.gov.cn/), the area of Hampshire is 1420 square miles (about 3678 km^2), and the areas of Jiangsu province and Nanjing city are around 107200 km^2 and 6597 km^2.

Table 4-2. Regional EDI of Chinese mainland

Region	Average EDI	Provinces within the region
North China	0.7302	Beijing, Tianjing, Hebei, Shanxi, Inner Mongolia
East China	0.72	Shanghai, Zhejiang, Jinagsu, Anhui, Fujian, Jiangxi, Shandong
Northeast	0.68	Heilongjiang, Jilin, Liaoning
Central and Southern China	0.616	Hunan, Hubei, Henan, Guangdong, Guangxi, Hainan
Northwest	0.612	Shanxi, Gansu, Qinghai, Ningxia, Xinjiang
Southwest	0.604	Sichuan, Chongqing, Guizhou, Yunan, Tibet

The population teacher consists of secondary mathematics teachers in 6 districts of Nanjing. The sample selection process is based on the 2015 students' official examination (i.e. Senior High School Entrance Examination, hereinafter I will abbreviate the exam as SHSEE) result. According to the data, there are 173 secondary schools within Nanjing area (which contains 12 districts, of which 4 are urban districts, and 8 are suburban districts), of which 19 are independent schools, but these independent schools are still required to be inspected by government and are required to follow national curriculums and to participate national assessment. However, there are two districts (Gaochun and Lishui) which have not merged to Nanjing until 2013, so students in these districts attending 2015 SHSEE are not fully managed under Nanjing's educational policy. Therefore I shall exclude data of this two district for rigorous analysis. After deleting these two districts, there are 151 schools shared with 10 districts, so the average number of schools in each district is 15. In order to have a comparable scale of population schools to England, I selected six districts from which sample schools were chosen. The choices of districts and schools are based on the previous examination data which includes information on each school, each district in Nanjing, as well as the whole Nanjing area of the number of students participating SHSEE, the number of students passing the exam, etc. Similar to the school selection in England, z-test was used to check if the proportion of students passing the SHSEE in each district is significantly different from that of whole Nanjing area. The result shows that there is one district whose proportion of students passing the SHSEE is not significantly different from that of whole Nanjing area, and the numbers of districts whose proportion of students passing the SHSEE is significantly higher and lower than that of whole Nanjing area are 5 and 4 respectively. Therefore proportionally, I will randomly select 3 districts, 1 district, and 2 district whose proportion of students passing the SHSEE is significantly higher than, not significantly different from, and significantly lower than that of whole Nanjing area respectively to form the population district[23]. All schools in the selected districts are going to form the population school of China part.

Following the previous steps, the selected six districts are Gulou (with 15 schools), Jianye (with 9 schools), Qinhuai (with 13 schools), Qixia (with 14 schools), Jiangning (with 28 schools) and Yuhua (with 7 schools), and in total there are 86 secondary schools.

The proportion of students in the whole Nanjing passing the SHSSE is 77.22%, which is used to compare to the figure of each schools at 95% significant level so that all population schools are divided into three categories: schools with SHSSE result significantly above (School category I), insignificantly different from (School category II), and significant below (School category III) that of whole Nanjing area. Then, 20 schools are selected via stratified sampling from each category to form the school sample. The statistical analysis shows that the number of schools of these three categories (I, II, and III) are 26, 19 and 41 respectively. Therefore the number of schools selected in each category are 6, 5, and 9.

4.3.2 Instruments

There are three instruments for collecting data for the study: questionnaire; classroom observation and interview. Overall speaking, the design of the three instruments are based on the frameworks constructed in the previous chapter, and more detailed information of the instruments are as follows:

(1) Questionnaire

There are some large international studies which explored, via questionnaire, the use of technology in education settings, however, their instruments are more or less inappropriate for my study. For example, the SITES project conducted by IEA in 2006 developed a questionnaire covering a wide range of tech-related aspects including ‘curriculum goals’, ‘teacher practices’, ‘student practices’, etc. This survey is not discipline-specific, and hence questions for various subjects were mixed together, and questions about teaching mathematics via technology were just a small part. In 2011, the IEA conducted TIMSS 2011 within over 60 countries and regions, and in TIMSS 2011, a questionnaire is adopted for mathematics teachers only aiming at collecting information on the instructional resources and activities. This survey, however, is not focused on educational technology, so only 4 questions out of 30 were tech-related, and these tech-related questions were relatively too general to get deep information. In contrast, questions on the instrument of another international study-PISA organized by OECD-were more concrete and clear (for example,

[23] Due to the fact that only one district whose proportion of students passing the SHSEE is insignificantly different from that of whole Nanjing area (i.e., Qixia District), so this district is included in the population. However, for other two categories, random sampling is adopted for choosing districts.

participants were asked to indicate how often within the last month computers were used for drawing the graph of a function, such as y=4x+6), but the questionnaire was for students to fill in, and no information upon teachers' practices was obtained. Although the existing instruments are not suitable for my study, I am still inspired by those questions based on which I construct my own.

Appendix B is the questionnaire adopted in the study, and it is the main instruments for my study and the answers are based on teachers' self-reflection and self-evaluation.

The questionnaire contains four parts with 58 questions in total: part A (question 1 to 4) is for collecting teachers' background information; Part B (question 5 to 7) is for collecting information of what technology is used in mathematics instruction with the questions focusing on hardware, software and web-based resources respectively. For this part, multiple choice questions are adopted and the participants are asked to tick all that relevant. Part C (question 8 to 26) is for information of how the technologies are used. In this part, 5-point semantic differential scale (Cohen, Manion & Morrison, 2011, p. 387) is used, where teachers can choose to what extent (from never to daily) they use a certain technology for an identified aim. According to Osgood, Suci and Tannenbaum (1957), the Likert scale is good for surveying attitude, while the semantic differential scale is more appropriate for evaluation (such as valuable-valueless) and activity description (such as active-passive, or always-never) which are more fact-based. Finally, part D (question 27 to 58) collects information of what factors influence teachers' use of technology. In this part, the 4-point semantic differential scale is used to ask teachers, based on their own reflection of their instructional behaviour and experience, to rate from strongly agree to strongly disagree upon a certain statement, and finally, an open question is attached to let teachers write down any factors that have not been covered.

It should be mentioned that in order to avoid a tendency that participants are inclined to choose mid-point of 5- or 7-point scale, which has been found by many researchers globally but notably true among East Asian people (Cohen, Manion & Morrison, 2011), I use the even number scaling system (4 point scale) to try to push participants think carefully rather than letting them 'sitting on the fence' (ibid, p. 389).

The tables below show how each item in part C and D of the questionnaires reflect the framework constructed in chapter 3.

Table 4-3. Distribution of questions in Part C of the questionnaire in terms of pedagogical strategies and goals of using technology

Strategy / Items	Illustrating and demonstrating	Calculating and checking	Explaining and justifying	Reflecting and discussing	Inquiring and exploring
	15, 17, 23, 25	8, 9, 21	11, 16, 19, 24	12, 20, 22	10, 13, 14, 18, 26

Goal / Items	Knowledge and Skills	Thinking and Reasoning	Positive Disposition
	8, 9, 12, 17, 21, 24, 25	10, 11, 13, 18, 19, 20, 22, 26	14, 15, 16, 23

Table 4-4. Distribution of questions in Part D of the questionnaire in terms of factors influencing teachers' use of technology

Personal Factors	Knowledge		27, 28, 29
	Skill		30, 31, 32
	Pedagogical beliefs		33, 34, 35, 36, 37
Contextual Factors	School-level	Facilities and resources	38, 39, 40, 41
		School supports	42, 43, 44, 45
		Curriculum	46, 47, 48
		Students	49, 50, 51
	Regional/National-level	Out-school training	52, 53, 54
		Educational inspection and exchange	55, 56, 57

Although questionnaire is a time-saving instrument for systematic and a great amount of data, where each person is asked the same question and provided the same answers to choose from, the outcome from the questionnaire can be hardly comprehensive. This is because, in order to get a good response rate, questions should be concise and in addition, not all questions can be put in the questionnaire. In order to make up for the shortcoming, I will also use another two qualitative instruments for data and method triangulation: classroom observation and interview.

(2) Classroom Observation

Classroom observation is used for capturing what technologies are used in the classroom as well as how exactly they are used, and later on more specific questions can be raised for a further understanding.

As mentioned by many researchers, teaching is a complex and sometimes a messy process (Zhao *et al.*, 2002; Koehler & Mishra, 2009; Fan, 2014), and complete information upon what really happens in the classroom can be hardly obtained just by reflection. This is because on the one hand, memory is not as reliable as we believed; on the other hand, teachers, unlike researchers, may ignore some phenomena and facts happened in the classroom, which may be particular interests of a study, (Punch & Oancea, 2014) and thus data collected by the researchers on site based on the research plan is important. Besides, instructional behaviours are strongly related to instructional planning and decision making, which are 'situated' and cannot be separated from actual classroom contextual. Therefore classroom observation is adopted as a method in my study for obtaining factual information from researchers' perspective as well as for providing specific topics and examples for the interview afterward. The following information will be observed and recorded: one is background information of the class including various devices in the classroom for teachers and students to use; number/age of students, as well as how students are arranged; the second is the instructional process, which is the main part of the observation. In this part, although some general pedagogical information will be recorded (such as what teaching strategy is adopted?) my attention will mainly be focused on technology-related information (like what technology is used? Or is any difficulty that teacher or students encountered when they use the technology?)

Rich information can be generated from classroom observation so as a researcher, a specific and clear guide for observation is a must. The focus of the classroom observation is on what technologies and how they are used in mathematics instruction, and what difficulties users encounter in using the technologies. The attached Appendix C is the observation guide. In addition, both video-record and field notes are to be used (if possible) to document classroom observation.

(3) Interview

A semi-structured interview is conducted after the classroom observation, with the purpose of collecting teachers' in-depth ideas and opinions directly upon the research question.

Questions for the interview consist of three categories: The first part deals with the observed lesson, and some questions which are concrete and specific are to be raised. For example, 'what was the purpose of the lesson I observed? (What topic you introduced?)', or 'I observed that you have used several technologies in instruction (specify the technologies), are you familiar with these technologies? How do you think of the function of the technology (or technologies) in this lesson? (To introduce new knowledge in an interesting way? To demonstrate the most difficult part of the lesson? To attract students' attention? Etc.)' This part of questions are for obtaining teacher's reflections of the observed lesson, and being a stimulus for teachers to recall their behaviours and instructional strategies in daily teaching practices. So questions connecting the observed lesson and usual lessons are also raised, like ‘Let’s talk about the topic you taught today, is it the usual way that you teach? (How do you compare today’s lesson with previous ones that you taught in a different way?)’.

The second part of question encourages teachers to recall and provide more example of their daily teachings which have not been observed, so richer information can be obtained. For example, ‘Let’s discuss more on the technology we’ve mentioned before. Do you know other functions of the technology for teaching mathematics? Have you adopted these functions in recently? Can you give me some examples?’

The final part focus on the contextual background where teachers work. Questions about the school, including facilities and other administrators’ support, would be raised. For example, ‘how do you think about the devices in the school? Are they enough and new for you to use? How about the network at school?’ Or ‘Do you know the attitudes of your HoD or other administrative? Is it encouraged to use a specific technology or different technologies in teaching?’

Appendix D is attached as the outline guide for the interview. The semi-structured interview is adopted because firstly, I want the data to be focused and specific on the research questions; secondly, the interviews can remain conversational and situational which is quite helpful for interviewees (Cohen, Manion & Morrison, 2011). Besides, using similar questions to different people makes the responses comparable. However, not all questions are relevant to every participant and as individuals work differently, they may have different information to provide, so the questions should be flexible to some extent and changeable according to different situations, so a guide would be appropriate to notice the researcher of the focus of the study as well as to keep the researcher open to other opinions and ideas. The actual questions would be slightly different to the guide according to the participant and the lesson observed.

(4) Pilot testing of the instruments

After I drafted all the instruments in my study, my supervisors reviewed the instruments to make sure whether each item in the instruments was consistent well with my research framework, so that problematics items could be changed or rewritten.

For the questionnaire, some secondary school teachers (4 for China and 5 for England) were asked to read the instruments to see if each question was clear. In this stage, the teachers were asked to provide concrete examples for the part C of teacher questions so that all the items in this part could be understood easily. Next, several other teachers (5 for China and 5 for England) were asked to read the revised questionnaire and explain to me individually that how he/she understood each question, and what he/she thought about when read the questions, as well as all the provided examples to see whether they were appropriate and accurate in explaining the described situations.

If there was an inconsistency between the teacher's understanding and my intended information to be collected, I would explain my ideas to the teacher and asked them whether I could get such information through the items, or how I should re-word the question, and therefore some questions would be re-worded again before small-scale field pre-test. The previous steps were for ensuring the validity of the instruments, namely, to ensure that the information that has been collected from the instruments was the same as I planned to obtain. Finally, small-scale pre-test with 9 Chinese teachers and 6 English teachers were implemented for checking the revised instrument as well as the completing time.

In order to test qualitative instruments, three teachers in Nanjing (one from a school, and the other two from another school), and a teacher in England were asked to be observed classroom teaching and interviewed. By observing the lessons, I can have an idea of whether questions of the draft version of classroom observation guide can be answered, and if there are new information relating to the topic can be obtained; by interviewing these teachers, I can make sure if all questions can be understood clearly and not difficult for teachers to answer. Besides, by analysing the answers from these teachers, I can know if I should delete some, add more or just change some questions of the draft version.

Overall, the pilots show that all the instruments are workable although some modifications and improvements have been made for a better quality.

It should be mentioned that in China part, according to the pilot-testing of the questionnaire, all the respondents stated that they never linked the electronic devices (such as computers and laptop) to the Internet during the classroom instruction, however they did sometimes download resources for classroom instruction (such as flash mini-videos or some pictures), and more often they used the online resources for preparing teaching materials. One reason is that for most of the school, neither the classroom technological devices are linked to the Internet, nor there is wireless network covering the whole school area. In addition, some of them said that there are some smart phone-based applications which were related to mathematics education or could be used for idea-sharing among teachers. Thus I changed options for question 7 in the Chinese version of the questionnaire to cover online resources which worked for functions that had been mentioned by the respondents.

In the England part, teachers in the pilot period not only modified some language problems of my instrument but also provided me with some specific applications that were commonly used as well as approaches that teachers integrated their teaching with technology. For example, some teachers mentioned that MyMaths and NRICH were the most frequently used educational based mathematical websites; Desmos and Logo were two online applications that were quite familiar with most mathematics teachers here. The information was helpful and has been used to modify my instruments.

4.3.3 Data collection and analysis

(1) Data Collection Process

In both China and England, an invitation email was firstly sent to the administrator/head of mathematics department of the selected schools to briefly introduce the study and to ask about whether they were willing to participate the study, and how many mathematics teachers are working at the school. (For those which were unwilling to participate, I selected another school within its category to replace it and send the email again.) Later on, telephone calls were made to the schools without replying the invitation emails to get their response. By doing so, the sample schools were identified. Secondly, paper questionnaires (or online questionnaires) were sent to the administrator/head of mathematics department of the schools for teachers to fill in. On the questionnaire, I asked the participants whether he/she would like to be classroom-observed and interviewed.

In China, there were eight teachers ticked 'yes', with the number of teachers belonging to the three categorical schools (I, II and III) being 3, 3 and 2 respectively. So I randomly selected 2 teachers in each school categories to form the sub-sample, and then called each teacher to confirm their participation as well as to negotiate dates for my visits. While in England, only five teachers ticked 'yes' to the qualitative data collection. Only one of the five teachers is working in category I school, two teachers are working in category II schools, and two in category III schools. I called all these teachers to confirm their participation as well as to negotiate dates for my visits.

(2) Data analysis

Data collected from questionnaires is firstly read and examined by the researcher to exclude invalid responses before analysed for answering research questions, and during the analysing process, different techniques are adopted.

Before discussing how the two questions are to be answered, it is necessary to introduce how teachers' use of technology and influencing factors are measured in the study. The teacher questionnaire contains 19 questions in part C to measure how often teacher use different technology to teach in various situations. For each item, teachers are asked to indicate that how often they use different technologies to do a certain pedagogical action. The score 0,1,2,3 and 4 are given to the answer of Never, Occasionally, Monthly, Weekly, and Daily respectively for each technology in each item. These 19 questions can be grouped by different criteria, including affordances of technology, goals of mathematics teaching, and pedagogical strategies taken by teachers, as explained in the previous chapter. So the average score of each participant is calculated for each technology based on these criteria. For example, question 14, 15, 16 and 23 are designed for the goal of Cultivating Positive Disposition towards Mathematics (PDM), so the average score of the 4 questions are calculated for the five technologies separately for each participant, and then how often these five different technologies are used for achieving this particular goal can be compared. Besides, average scores of each technology are calculated for the other goals, so that for a specific technology, how often it is used for different goals can be compared as well. Similar, calculation method is used in measuring influencing factors, which is the purpose of part D of the teacher questionnaire. There are 31 questions in this part and each item contains a statement for teachers to indicate that to what extent they agree with the statement. The score 1, 2, 3, 4 are assigned to the answer of Strongly Disagree, Disagree, Agree and Strongly Agree respectively. Then average scores are calculated for the items belonging to the same factor. For example, question 27 and 28 are for measuring teacher's knowledge, so the average score of these two questions is used to present the score for this factor for the model establishment. Question 29 is used to obtain teachers' self-evaluation of the knowledge factor on their use of technology, so both teachers' self-evaluation and model prediction of the influence of certain factors can be obtained.

For the first question, both statistical measurement, such as mean, standard deviation, and more complex statistic inference, such as chi-square and repeated measures ANOVA tests are adopted to depict Chinese and English mathematics teachers' patterns of technology-embraced teachings. For example, analysis of variance is used to see if teachers from different school categories of their mean scores on certain technology significantly varies.

For the second question, Multilevel Modeling (MM) is employed to establish a quantitative model (i.e. equation) due to the multi-level nature of the data. In this part, the dependent variable y is the use of technology (average scores of question 8 to 26), while independent variables x_i are potential factors (scores from part D of the questionnaire).

It should be mentioned that the choice of MM is because that multilevel structure (or hierarchical structure) is common in educational settings, including studies on teachers' instruction. Various studies have demonstrated that besides teachers' own situations (such as knowledge and skills being the first level data), contextual factors (such as school facilities and support being the higher level data) always exert important influence in teacher' choice of pedagogical method and tools (O'Connell & McCoach, 2008; Goldstein, 2011; Raudenbush & Willms, 2014; Heck & Thomas, 2015), and the hierarchical data calls for multilevel model implementation (Garson, 2013). However previous researchers didn't fully pay attention on either the multilevel nature of the problem or particular method of data analysis on such topics, and thus conventional single-level analysis leads to various conceptual and empirical problems: researchers either aggregate variables at individual level into school level, conduct regression analysis at school level, and make inferences from school level back to teachers, which leads to ‘ecological fallacy’ (Robinson, 2009), or just work at individual level, ignoring the school level (i.e. ignoring the context that each teacher works in a particular school), which violate regression assumption that error terms are independent with equal variances (Garson, 2013). My sampling procedure established a data hierarchy with teachers nested within schools, which makes multilevel analysis a necessary for such data. So by employing Multilevel Modelling, I can avoid aforementioned credibility-causing statistic problems such as aggregation bias, mis-estimated standard errors and heterogeneity of regression. Besides, the multilevel analysis ‘‘takes into account differences in sample size across schools’’ which attributes to imprecise of ‘‘level-one (i.e. teachers) effects across groups’’ (Ma, Ma & Bradley, 2008, p. 71).

Actually, researchers discussed a lot on the necessary number of higher level unit in multilevel modelling. In other words, how many level-2 units (school in my case) are appropriate for a multilevel analysis? The literature provides varying rules of thumb, from 10 or 12 (Kreft, De Leeuw & Aiken, 1995) to 40 (Afshartous, 1995) to 50 or even 100 (Moineddin, Matheson & Glazier, 2007). Based on such discussions and considering the fact that large number of groups were not always possible, Stegmueller (2013) conducted a simulation study analysing ‘‘the behaviour of maximum likelihood (ML) and Bayesian estimation strategies’’ (ibid. p. 749) on multilevel modelling with small number of level 2 unite (5 to 30). The results proved that for models with random coefficients, both procedures generated quite reliable coefficient estimates, while algorithmic strategies mattered when variations at second level were estimated. Bayesian estimates were within ±5% of the true population value at even 5 second-level unite, while ML estimates ‘‘are sharply biased upwards when the number of country is fewer than 20’’. (p. 753) However, when cross-level interaction effect is considered, the minimum size for level 2 unit should be 25 if Bayesian estimation is used, and if ML estimation is used, the number should be more than 30, otherwise, huge bias would come out when estimations are made.

According to Stegmueller’s (2013) analysis as well as the relatively limited amount of data collected in China and England. In this study, complex analyses (such as cross-level interactions) are hard to achieve, and thus the multilevel model analysis just ends with the examination of random-slope model to test if factors influence teachers in different schools differently, and Bayesian MCMC algorithm is adopted. The analysis undergoes three periods: firstly, unconditional model is constructed without any predictors to examine if multilevel model indeed improve the data fitness; if so, then secondly, random-intercept model is constructed with both demographic variables and predictors collected from part D of the questionnaires; thirdly, random-slope model is constructed based on the previous model with all independent variables whose coefficients are significantly different from zero.

For the classroom observations, a field note is used, and for interviews, an audio-recorder is used, and then the verbal information was transcribed into words for further analysis[24]. After being examined by the researcher, all word-based qualitative data is coded. Coding system is consist of three topics, which correspond to the two research questions: Technology, which refers to different kinds of technologies adopted by teachers; Purposes and Strategies, which refers to how the technologies are used; and Factors, which refers to reasons announced by the participants of their (not) uptake of certain technology. It should be noted here that firstly although topics for qualitative coding have been determined, the actual words and descriptions being coded are from teachers themselves, and therefore actual coding process is based on the actual qualitative data I have; secondly, due to the relatively low number of classroom observations and interviews, generalisations are not drawn from the qualitative data, which is only used to obtain detailed information for a better understanding of what has been found in the questionnaire. In other words, the qualitative data is just used as supplements to the questionnaire data.

The establishment of Advanced Quantitative Model and its analysis as the main methodology, together with some qualitative approaches adopted to verify quantitative results can mutual confirm and complement each other and thus it is necessary for a valid result.

4.4 Evaluation of the Methodology

This study aims to investigate the use of educational technology from teachers' perspectives. Comparing with the majority studies in this field, my study can be distinguished from the following aspects: first, it is designed based on a more specific framework which is specially constructed for mathematics, and therefore more information and fact about mathematics teachers' use of technology in instruction can be uncovered in detail; second, relatively substantial number of teachers of a wide range of teaching experience in both countries are selected, making the study representative and potential in comparing Asian and Western mathematics education; third, mixed-method approach is adopted so that blending different methods ''offers the possibility of combining their strengths, while compensating for their weakness'' (Punch & Oancea, 2014, p. 340), so reliable findings are more likely to be discovered.

However, like all other studies, my study is also restricted by various factors including time, money

[24] All Chinese interviews are transcribed and translated by the researcher, and English interviews are transcribed by a professional transcription service firm and rechecked by the researcher.

as well as experience and knowledge of the researcher, hence there are inevitably limitations can be found. First, the participating schools are selected within certain areas in China and England, so results of the study should be interpreted and applied cautiously when discussing and thinking of schools outside of the selected areas. However, I have carefully examined each mainstream school in the target area of their educational quality based on the GCSEs or SHSEE, and have selected schools from three different categories to try to make my sample as representative as possible, which I believe to a large extent, increases the reliability of my study. Second, the quantitative data being collected is teachers' teaching practices and is from teachers' self-report. It is hard to guarantee that teachers would remember their every instruction practice in detail, and therefore I just ask about their routine practices within one academic year. However, as a study discussing from teacher's perspective, teachers themselves' words should be valued. Third, although both quantitative and qualitative methods are adopted with data of different nature being collected, the questionnaire is treated as the main instrument with other two complementary, and this is due to various restrictions including time and expense limitation. So more qualitative data should be collected and analysed as one of the directions for future studies.

4.5 Ethical Consideration

Ethical issues are very important in any form of social studies and it is a necessity to adhere to certain codes of practice for protecting both participants and researchers. My data is collected by questionnaire, classroom observation, and interview, and to collect these data, I used overt methods and declared my true purposes to all participants.

Initially, I made contact with an administrator within each selected school (usually headmaster or head of the mathematics department) by email and telephone, and explained my study in detail of the aim, process, importance to teachers' professional development, as well as data confidentiality, and asked for their consent. I was particularly keen to stress the importance of participants' rights that they should be informed the precise nature and purpose of the study, and that their participation was voluntary.

If I was given the consent to do the research, paper questionnaire (online-questionnaires for some schools) with the introduction letter were sent to teachers in a sealed envelope. Every teacher was informed of their right to complete the questionnaire voluntarily. I also left my e-mail at the beginning of the questionnaire to any queries, and asked volunteers to join in the observation and interview part. Every questionnaire was anonymous, and every personal information was asked cautiously.

In classroom observation, teachers, all the students and their parents were informed of the research, and they were asked for consent before being videotaped. During the lesson, devices were positioned at a place that were as un-obtrusive as possible to minimise the impact on students' learning and teachers' teaching, but which allowed all the participants to be seen; if they were not willing to be videotaped, I just used paper-based note. During the classroom observation, if any participants feel really distressed, I'll stop data collection and try my best to keep the lesson going on; Later on, I might talk to the participants (with teacher if possible) to see if he/she needs some help; When problems are settled, I will negotiate all participants to set another time, or I'll contact other teachers for data collection;

For interviews, the venues were decided by researcher, teacher, and school-related staffs to keep the venues safe place for both interviewer and interviewee. Interview questions were framed in a way that respondents had the freedom to choose their response according to their experiences. In the case of teachers not agreeing to have the interview audio recorded, I just relied on taking down notes. When the transcript of the interview was formed, it was sent to the corresponding teacher by email to let him/her check all the information. During the interview, when participants feel distressed and uncomfortable, I'll immediately stop data collection and ask him/her if he/she needs some help; I may chat with the participants for a while to make him/her relax and won't continue the interview unless the participant shows that he/she is ready to continue; If he/she feels uncomfortable constantly I would stop collecting data from him/her and contact others.

In addition, ethical considerations are also brought to other relevant public stakeholders. For those schools where I collected the research data, their information is presented as little as possible in the thesis so that the confidentiality is assured. For the university and the sponsor of this study, I have provided honest and complete details of my competence and capacity to undertake the proposed research. Besides, during the implementation of the study, I have frequently discussed and negotiated with my supervisors and relevant staff members in ESRC about the theories, philosophies and methods that I adopted so that I conducted my research to the highest standards. In writing up the thesis, special ethical considerations are also given to educational researchers as a group. When reviewing literature, I always made sure that I criticised other studies in a professional way and cited and quoted them correctly. When presenting the findings and results, I always made sure to focus on describing factual information and not to make value judgement so that my study would benefit researchers from all around the world.

4.6 Summary

This chapter deals with the methodological issue of the study, with methodological foundations of the study, and the research procedure is introduced.

Twenty secondary schools in China and seventeen secondary schools in England participated in the study and all the mathematics teachers in these schools formed the sample in my study.

Data is collected through three instruments which are designed based on the conceptual frameworks of chapter three:

First, questionnaire is designed with 58 questions for teachers to fill in, and the questionnaire collects information of four aspects: background information; adopted technology; how the technologies are used; and influencing factors.

Second, classroom observation is designed to capture what technologies are exactly used in the classroom as well as how exactly they are used. Eleven teachers (6 in China and 5 in England) are selected to form a sub-sample to be observed.

Third, semi-structured interview is conducted after the classroom observation within the same sub-sample, and the purpose is to collect teachers' in-depth ideas and opinions directly upon the research question. The interview guides teachers to reflect the lesson observed and questions about their daily use of technology in instruction, as well as what factors influence their tech-use would be raised.

Chapter 5 Chinese Teachers' Use of Technology in the Instruction

Chapter 5 and 6 discuss main findings. In this chapter, research questions are answered based on Chinese data, and next chapter on the English data. The chapter is composed of six sections: section 5.1 introduces demographic information of Chinese participants; section 5.2 deals with question of what technology is used by teachers; section 5.3 discusses in detail how different technology is used in the teaching of mathematics; section 5.4 discusses how different factors influence teachers' use of technology; and section 5.5 presents and analyses the qualitative data from classroom observations and interviews. Finally, a summary of findings (section 5.6) is provided.

5.1 Demographic Information of the Chinese Respondents

298 questionnaires are sent to twenty secondary schools in Nanjing, and 229 valid returned, making the response rate being 76.8%. The table below present the response rate at each category of schools in the population.

Table 5-1. Valid response rate by school categories in China

	No. of questionnaire sent	No. of questionnaire back	Response rate
Category I Schools* (9 schools)	149	116	77.8%
Category II Schools* (5 schools)	79	63	79.7%
Category III Schools* (6 schools)	70	50	71.4%
Total	298	229	76.8%

*Here and after, Category I, II, and III Schools refers to schools with performance above the average of the population, with average performance of the population, and with performance below the average of the population respectively.

According to the respondents' answers to the part A of the questionnaire. 131 out of 229 are females (57.5%), and 97 are males (42.4%), with 1 missing data. The numbers of teachers who teach seventh, eighth and ninth-grade students are roughly equal (80, 77 and 73 respectively, with one teacher taught both 7th and 9th grade). The largest age group in which the participants dropped is between 30 and 39 (45.9%), and the average teaching year of all teachers is 15.8. As regards the professional title, there are 134 (58.5%) teachers are Intermediate Grade. More information on the profile of all participants is presented in Appendix E.

5.2 Technology Being Used

Part B of the questionnaire is designed for obtaining information on what technology is used by teachers. Items 5, 6 and 7 ask teachers to tick what hardware, software, and online resources respectively are used. Here, I will just analyse the questionnaire data, and the qualitative data will be analysed in section 5.5.

5.2.1 Hardware and devices

In question 5, five categories of hardware are listed, which contains calculator, computer, Interactive Whiteboard (IWB), mobile phone, and others. For respondents who tick 'others', a blank space is provided to let them specify what other hardware and devices are. The Tables below depict teachers' responses to this question.

Table 5-2. Number of Chinese teachers using calculator to teach

Type	None [a]	Simple	Scientific	Graphical	Symbolic
Number of user	54 (23.6%)	98 (42.8%)	128 (55.9%)	34 (14.8%)	11 (4.8%)

[a] Hereinafter numbers of teachers in 'None' refers to those didn't choose any option in this sub-question.

Table 5-3. Number of Chinese teachers using computers to teach

Type	None	Desk-computer	Laptop	Tablet
Number of user	6 (2.6%)	184 (80.3%)	91 (39.7%)	10 (4.4%)

Table 5-4. Number of Chinese teachers using other hardware to teach

Type	None	IWB	Data Projector	Mobile phone	Other
Number of user	23 (10.0%)	85 (37.1%)	195 (85.2%)	66 (28.8%)	0 (0%)

The above tables show that firstly teachers adopt quite a variety of hardware and devices in teaching mathematics, and for different teachers, the adoption of technologies could be very different. However, in each category, there are some teachers who don't use any hardware and devices, which means there is no one hardware being adopted by all teachers in teaching mathematics. Secondly, although each option has been ticked by teachers, there are dominant technologies which are adopted by the majority of teachers. For example, in calculators, simple and scientific calculators are used by more teachers than graphical and symbolic calculators. Similarly, desk-computer is the most frequently used computer, followed by laptop, and only 10 teachers used tablets. In terms of other technologies, data projector is selected by 195 teachers, which is the highest of all technologies in the study. Besides, the proportion of respondents who used IWB and mobile phone are 37.1% and 28.8% respectively, making them the least frequently used devices.

As I mentioned previously, the 20 schools are classified based on their students' SHSEE scores into three categories: I (schools with performance above the average of the population), II (schools with the average performance), and III (schools with performance below the average performance). Now, whether teachers' school categories are related to their choice of hardware and devices are examined. Here, chi-squares test or the alternative Fisher-Freeman-Halton exact test (Freeman & Halton, 1951) is used to see if there exists statistical significance on the choice of technology among different teacher groups. Hereinafter, a probability of less than 0.05 will be taken as statistically significant.

Table 5-5. Distribution of the numbers of Chinese teachers among three school categories ticking different hardware and devices

Technology: Simple Calculator

	Category I School	Category II School	Category III School	Total
No	60	40	31	131
Yes	56	23	19	98
Total	116	63	50	229

Chi-square test: χ^2=2.910 df=2 p=0.233

Technology: Scientific Calculator

	Category I School	Category II School	Category III School	Total
No	41	26	34	101
Yes	75	37	16	128
Total	116	63	50	229

Chi-square test*: χ^2=15.397 df=2 p=0.000

Technology: Graphical Calculator

	Category I School	Category II School	Category III School	Total
No	94	58	43	195
Yes	22	5	7	34
Total	116	63	50	229

Chi-square test: χ^2=3.964 df=2 p=0.138

Technology: Symbolic Calculator				
	Category I School	Category II School	Category III School	Total
No	110	60	48	218
Yes	6	3	2	11
Total	116	63	50	229

Fisher-Freeman-Halton exact test: [a] p=0.999

Technology: Desk-computer				
	Category I School	Category II School	Category III School	Total
No	20	7	18	45
Yes	96	56	32	184
Total	116	63	50	229

Chi-square test*: χ^2=11.801 df=2 p=0.003

Technology: Laptop				
	Category I School	Category II School	Category III School	Total
No	41	26	24	91
Yes	75	37	26	138
Total	116	63	50	229

Chi-square test: χ^2=2.422 df=2 p=0.298

Technology: Tablet				
	Category I School	Category II School	Category III School	Total
No	109	62	48	219
Yes	7	1	2	10
Total	116	63	50	229

Fisher-Freeman-Halton exact test: [a] p=0.434

Technology: Interactive Whiteboard (IWB)				
	Category I School	Category II School	Category III School	Total
No	72	43	29	144
Yes	44	20	21	85
Total	116	63	50	229

Chi-square test: χ^2=1.322 df=2 p=0.516

Technology: Projector				
	Category I School	Category II School	Category III School	Total
No	19	11	4	34
Yes	97	52	46	195
Total	116	63	50	229

Chi-square test: χ^2=2.410 df=2 p=0.300

Technology: Mobile Phone				
	Category I School	Category II School	Category III School	Total
No	84	46	33	163
Yes	32	17	17	66
Total	116	63	50	229
Chi-square test:	χ^2=0.844	df=2	p=0.656	

a: Due to the fact that more than 20% of all cells (1 cell) have an expected frequency smaller than 5, Fisher-Freeman-Halton exact test was employed hereinafter as alternative to chi-square test. (Freeman & Halton, 1951)
*: significance level at 95%

According to the above results, teachers from the three categories of schools are rather close in using all hardware and devices except for scientific calculator and desk-computer. By employing chi-square test again to conduct one to one comparison between different school category, we can see that for using scientific calculator, there exists significant differences between School I and School III (χ^2=15.043, with df=1 and p=0.000), and between School II and School III (χ^2=7.998, with df=1 and p=0.008), and for using desk-computer, there exists significant differences between School I and School III (χ^2=6.965, with df=1 and p=0.008), and between School II and School III (χ^2=10.023, with df=1 and p=0.002). While no significant difference has been found between School I and School II in either using scientific calculators (χ^2=0.612, with df=1 and p=0.518) or using desk-computers (χ^2=1.198, with df=1 and p=0.382).

In summary, it can be seen that data projector, desk-computer and scientific calculator are three hardware used by the most majority of teachers. However, the proportion of teachers who ticked the latter two devices are significantly different among different school categories, and higher proportion of teachers in School I and School II had used desk-computer and scientific calculator.

5.2.2 Software

Questions 6 asks teachers to tick what software and programs they have used. The options contain four categories: *general office tools*, including Word, Excel and PowerPoint; *symbolic manipulation and graphing package*, including Maple, DERIVE, Mathematica, and other; *dynamic geometry software*, including Geometer’s Sketchpad (GSP), GeoGebra, Z+Z Super Sketchpad[25], and other; and *data analysis software*, including Fathom, general statistical software (such as SPSS, Stata and R), and other. The Tables below depict teachers’ responses.

[25] This is part of ‘Z+Z smart educational platform’ which is developed by Chinese scholars and research.

Table 5-6. Number of Chinese teachers using Micro-office tools to teach

Type	Microsoft Word	Microsoft Excel	Microsoft Power Point
Number of user	197 (86.0%)	167 (72.9%)	219 (95.6%)

Table 5-7. Number of Chinese teachers using symbolic manipulation and graphing package to teach

Type	Maple	DERIVE	Mathematica	Other [a]
Number of user	13 (5.7%)	5 (2.2%)	17 (7.4%)	3 (1.3%)

[a] Here, one teacher mentioned Matlab, one teacher mentioned Mathtype, and the other one left the blank empty.

Table 5-8. Number of Chinese teachers using dynamic geometry software to teach

Type	GSP	GeoGebra	Z+Z Super Sketchpad	Other
Number of user	199 (86.9%)	5 (2.2%)	7 (3.0%)	0 (0)

Table 5-9. Number of Chinese teachers using data analysis software to teach

Type	Fathom	General statistical software	Other
Number of user	3 (1.3%)	11 (4.8%)	2 (0.9%)

The figures indicate that teachers are more frequently using Microsoft office packages and dynamic geometry software (especially GSP) to teach mathematics, while symbolic manipulation and graphing packages are not quite embraced, and data analysis software is used by fewer teachers. Now let us use chi-square to see how the teachers' school categories are related to their use of different software.

Table 5-10. Distribution of the numbers of Chinese teachers among three school categories ticking different software

Technology: Word				
	Category I	Category II School	Category III School	Total
No	19	8	5	32
Yes	97	55	45	197
Total	116	63	50	229
Chi-square test:	χ^2=1.300	df=2	p=0.522	

Technology: Excel				
	Category I	Category II School	Category III School	Total
No	30	20	12	62
Yes	86	43	38	167
Total	116	63	50	229

Chi-square test: χ^2=1.022 df=2 p=0.600

Technology: Power Point				
	Category I	Category II School	Category III School	Total
No	5	3	2	10
Yes	111	60	48	219
Total	116	63	50	229

Fisher-Freeman-Halton exact test: p=0.999

Technology: Maple				
	Category I	Category II School	Category III School	Total
No	110	60	46	216
Yes	6	3	4	13
Total	116	63	50	229

Fisher-Freeman-Halton exact test: p=0.748

Technology: DERIVE				
	Category I	Category II School	Category III School	Total
No	115	59	50	224
Yes	1	4	0	5
Total	116	63	50	229

Fisher-Freeman-Halton exact test*: p=0.047

Technology: Mathematica				
	Category I	Category II School	Category III School	Total
No	109	58	45	212
Yes	7	5	5	17
Total	116	63	50	229

Fisher-Freeman-Halton exact test: p=0.606

Technology: Other Symbolic Package				
	Category I	Category II School	Category III School	Total
No	114	62	50	226
Yes	2	1	0	3
Total	116	63	50	229

Fisher-Freeman-Halton exact test: p=0.999

Technology: GSP

	Category I	Category II School	Category III School	Total
No	8	11	11	30
Yes	108	52	39	199
Total	116	63	50	229

Chi-square test*: χ^2=8.452 df=2 p=0.015

Technology: GeoGebra

	Category I	Category II School	Category III School	Total
No	114	60	50	224
Yes	2	3	0	5
Total	116	63	50	229

Fisher-Freeman-Halton exact test: p=0.232

Technology: Super Sketchpad (Z+Z)

	Category I	Category II School	Category III School	Total
No	112	62	48	222
Yes	4	1	2	7
Total	116	63	50	229

Fisher-Freeman-Halton exact test: p=0.781

Technology: Fathom

	Category I	Category II School	Category III School	Total
No	114	63	49	226
Yes	2	0	1	3
Total	116	63	50	229

Fisher-Freeman-Halton exact test: p=0.602

Technology: General statistical software

	Category I	Category II School	Category III School	Total
No	113	57	48	218
Yes	3	6	2	11
Total	116	63	50	229

Fisher-Freeman-Halton exact test: p=0.110

Technology: Other statistical software

	Category I	Category II School	Category III School	Total
No	115	62	50	227
Yes	1	1	0	2
Total	116	63	50	229

Fisher-Freeman-Halton exact test: p=0.999

The table shows that teachers' uses of all software, except for the DRIVE and GSP, are not associated with the school categories where they work. A further analysis shows that there is significantly higher proportion of teachers in School I used GSP than their counterparts in School II (χ^2=4.802, with df=1 and p=0.041) and in School III (χ^2=7.864, with df=1 and p=0.007). For DRIVE, Fisher exact test was further conducted, and the results show that the only a near-marginal significance is found between School I and School II (p=0.053).

It is interestingly to be noted that there were 5 teachers ticking 'DERIVE' in the questionnaires, but 4 of them came from the same school, which might imply that school technological culture, school-based training and technical support influenced teachers' use of technology.

5.2.3 Online resources

Questions 7 asks teachers to tick what online resources (including mobile apps which receive data package from the Internet) they have used for teaching mathematics. The options contain two categories: General web-based resources, which include search engines, downloaded pictures and videos, instant information exchange packages, and other general resources; and Mathematics-related web-based resources, which include subject-based websites, interactive programs (such as Interactive Flash), subject-based educational mobile apps, and other subject-based resources. The Tables below depict teachers' responses to this question.

Table 5-11. Number of teachers using general online resources to teach

Type of resources	Search engine		Downloaded Pictures and videos	Instant information exchange			Other
	Baidu	Other		QQ	Wechat	Other	
Number of users	195 (85.2%)	3 (1.3%)	70 (30.6%)	93 (40.6%)	79 (34.5%)	0 (0%)	3 (1.3%)

Table 5-12. Number of teachers using mathematics-related online resources to teach

Type of resources	Subject-based Websites	Interactive programs	subject-based educational mobile apps			Other
			Yuantiku	Zuoyebang	Others	
Number of users	183 (79.9%)	28 (12.2%)	35 (15.3%)	60 (26.2%)	1 (0.4%)	4[a] (1.7%)

[a] Only one teacher here specified that s/he used school local network where resources can be obtained.

The figures show that a majority of teachers used a search engine (here Baidu 85.2%) and subject-based websites (79.9%) for teaching. Besides, 62.4% of the teachers used instant information exchange packages (either QQ or Wechat), followed by subject-based educational mobile apps (either Yuantiku or Zuoyebang) which had been used by 40.2% of the teachers in the study. There are 30.6% of teachers mentioned that they had downloaded pictures and videos from the Internet for their instructions. By using chi-square tests, it can be found that there is no significant difference among different groups of teachers of their use of any online resources. (More detail can be found in Appendix F)

5.3 The Way of Using Technology

Part C of the questionnaire contains 19 items which describe different situations where technologies could be used, and teachers are asked to indicate how often they use different technology in each situation. For each option, a score was given: Never to Daily being given the score from 0 to 4. By using these data, I will discuss that through which pedagogical strategy and for what purposes Chinese teachers use different technology in their teaching practices.

Figure 5-1 presents the mean score of all respondents on each technology, and Table 5-13 shows the statistical test of the average scores. In general, the higher the score, the more often one technology is used. Hereinafter, before conducting statistical tests, the normality of the data is checked and if it violates the assumption, Non-parametric will be adopted.

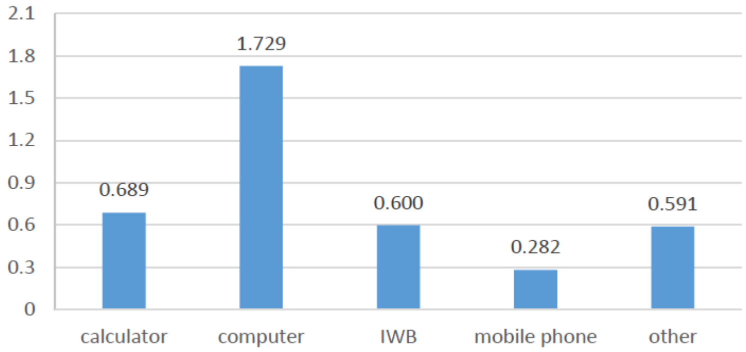

Figure 5-1. Mean scores of Chinese respondents on each technology

Table 5-13. Repeated measures ANOVA Test of mean scores of different technology

Within Subject Effects	Mauchly's W	Approx. Chi-square	df	Sig.
Mean scores	0.755	63.519	9	0.000

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Greenhouse-Geisser	280.396	3.472	80.771	1255.575	.000
Huynh-Feldt	280.396	3.532	79.393	1255.575	.000

Mean differences (A-B); A / B	Calculator	Computer	IWB	Mobile phone	Other
Calculator		1.040*[a]	-0.089*	-0.407*	-0.098*
Computer			-1.129*	-1.447*	-1.138*
IWB				-0.318*	-0.009
Mobile phone					0.309*
Other					

[a] Hereinafter * refers to statistical significant at 95%.

The first table shows the result of Mauchly's test of sphericity, which is the assumption under the repeated ANOVA test. The p-value of this test is less than 0.05, so the data violates the assumption of sphericity, and thus corrections are made in the degree of freedom to produce a valid F-ratio. According to Field (2009), when the assumption of sphericity is violated, Greenhouse-Geisser correction and Huynh-Feldt correction should be adopted (otherwise Sphericity Assumed test should be checked). The second table shows that both of the corrections producing p-values less than 0.05, indicating that there are significant differences in the mean scores among the five different technologies.

The final table presents the result of pairwise comparison based on LSD test, which gives information on how each score statistically differs from other scores. The figures provided above, to a great extent, reflects teachers' answers to question 5. The mean score of computers is much higher than those of other technologies, whose mean scores are all less than 1, and the mobile phone is the least frequently used technology. The table also shows that the difference of mean scores between IWB and Other is not significantly different from 0, indicating that in general, teachers' scores on IWBs and Others are similar but significantly higher than that of mobile phone.

Next, how teachers use each device in their instructions is analysed in detail. The comparison on the mean scores of each technology between three categories of schools is conducted, before analysing how the technology is used in different pedagogical strategies and goals respectively.

5.3.1 Calculator

The table below presents mean score of calculators for each category of school and the analysis of variance, and the figures show that the mean scores of calculators of the three school categories are rather similar and there is no significant difference.

Table 5-14. Mean scores of calculators of three Chinese school categories

School Category	Category I School	Category II School	Category III School
Mean Score	0.699	0.698	0.652

ANOVA test: F=0.664, p=0.516

Now, let us analyse if teachers use different pedagogical strategies for adopting calculators in their teaching. According to the framework constructed in chapter 3 (see figure 3-2), this study examines five pedagogical strategies: Illustrating and demonstrating (ID), Calculating and Checking (CC), Explaining and justifying (EJ); Reflecting and discussing (RD); and Inquiring and exploring (IE), with several items under each strategy (see table 4-4). The mean score for each strategy will be calculated and compare for all participants, and then comparisons will be conducted among different categories of schools. Similar methods will be employed to the analysis of other four technology as well.

Below, the figure presents all Chinese respondents' mean scores of calculators on different pedagogical strategies, and table 5-15 presents statistical tests of the mean scores.

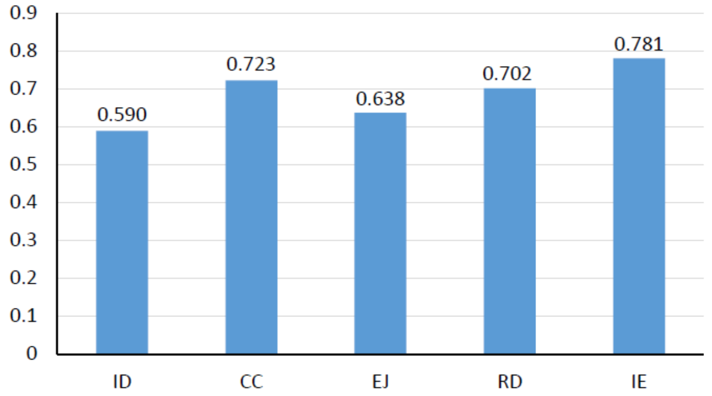

Figure 5-2. Chinese teachers' mean scores of calculators on different pedagogical strategies

Table 5-15. Repeated measures ANOVA test on Chinese mean scores of calculators on different strategies

Within Subject Effects	Mauchly's W	Approx. Chi-square	df	Sig.
Mean scores	0.849	37.011	9	0.000

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Greenhouse-Geisser	5.103	3.690	1.383	3.665	0.007
Huynh-Feldt	5.103	3.758	1.358	3.665	0.007

The highest score belongs to IE, followed by CC, and RD, although overall speaking the mean scores of Chinese teachers' use of calculators on different pedagogical strategies don't differ from each other a lot. However, the statistical test shows that there are significant differences among different scores. Further LSD tests of conducting pairwise comparisons reveal that overall, Chinese teachers' mean score on IE is significantly higher than that of CC and RD, whose mean scores are significantly higher than ID and EJ.

Table 5-16 presents the mean scores of calculators in each strategy of the three categories of schools. Based on the figures, a radar chart is formed as shown in figure 5-3.

Table 5-16. Comparison of three Chinese school categories in the use of calculators in different strategies

Strategy / Mean score / School category	Illustrating and demonstrating	Calculating and checking	Explaining and justifying	Reflecting and discussing	Inquiring and exploring
School Category I	0.623	0.647	0.582	0.845	0.798
School Category II	0.556	0.746	0.710	0.524	0.879
School Category III	0.555	0.873	0.675	0.593	0.616
Analysis of Variance	F=0.397, p=0.673	F=1.896, p=0.153	F=1.489, p=0.228	F=6.898, p=0.001*	F=3.946, p=0.021*

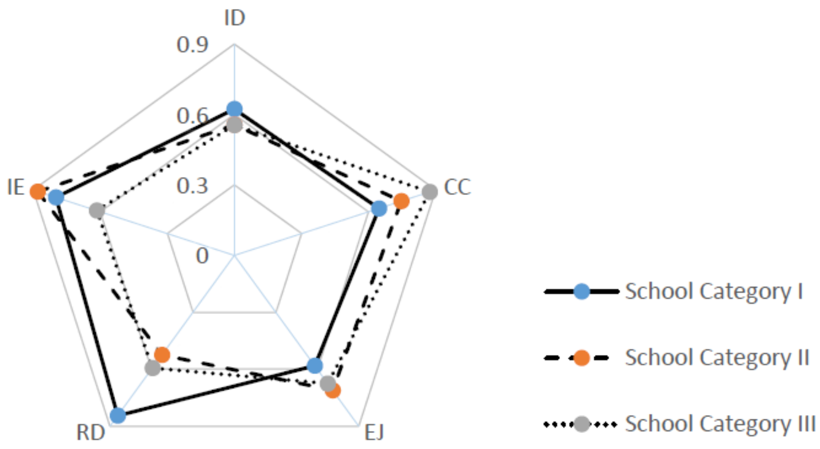

Figure 5-3. Radar chart of Chinese teachers' use of calculators

There is no significant difference in the mean scores of ID, CC, and EJ of using calculators among three school categories, but the mean scores on RD and IE are significantly different among the three school categories. By checking the LSD tests again, we can find that for Reflecting and discussing, the mean score of School I is significantly higher than that of School II (MD[26]=0.321, p=0.001), and that of School III (MD=0.252, p=0.014), but there is no statistical difference between School II and School III (MD=-0.069, p=0.541); for Inquiring and exploring, the mean score of School III is significantly lower than that of School I (MD=-0.182, p=0.034), and that of School II (MD=-0.263, p=0.006), but there is no statistical difference between School I and School II (MD=-0.081, p=0.305).

Finally, let us analyse teachers' use of calculators for different goals. Here the goals refer to the teaching of mathematics, namely: Mathematics Knowledge and Skills (MKS), Mathematical Thinking and Reasoning (MTR), and the cultivation of Positive Disposition towards Mathematics (PDM). Figure 5-4 presents mean score of Chinese respondents of calculators on different goals, and table 5-17 presents statistical analysis on the mean scores.

[26] Hereinafter, MD refers to 'Mean Difference'.

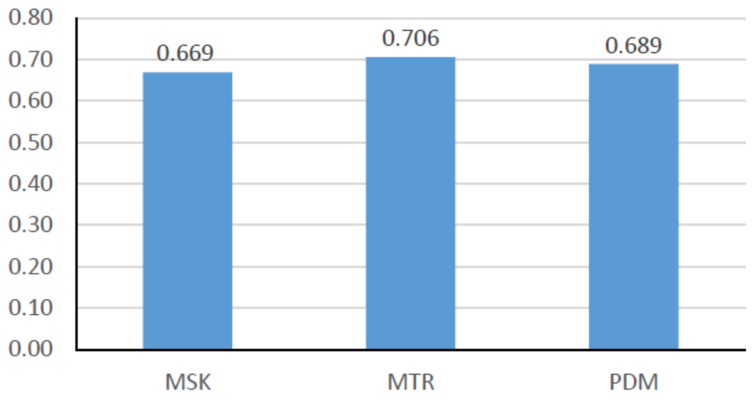

Figure 5-4. Mean scores of Chinese teachers of calculators on different goals

Table 5-17. Repeated measures ANOVA test on Chinese mean scores of calculators on different goals

Within Subject Effects	Mauchly's W	Approx. Chi-square	df	Sig.
Mean scores	0.956	10.244	2	0.006

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Greenhouse-Geisser	0.152	1.915	0.079	0.401	0.661
Huynh-Feldt	0.152	1.931	0.079	0.401	0.663

Overall speaking, there is no significant difference between Chinese teachers' mean scores of calculators on different goals, indicating that Chinese teachers use calculators for the three gaols to the similar extent. Table 5-18 below also shows that there is no difference among the three school categories in their use of calculators for the three goals, indicating that statistically, all teachers used calculators in a similar way in terms of achieving instructional goals.

Table 5-18. Comparison of mean scores of calculators of three Chinese school categories in different gaols *1*

Goals / Mean score / School category	MKS	MTR	PDM
School Category I	0.675	0.714	0.711
School Category II	0.674	0.706	0.726
School Category III	0.651	0.685	0.590
Analysis of Variance	F=0.069, p=0.933	F=0.087, p=0.917	F=1.249, p=0.289

Generally, the mean scores of calculators of all school category are less than 1, meaning that Chinese teachers don't often use calculators in their teachings. However, for teachers who use calculators, the adopted pedagogical strategies are associated with their school categories. Teachers in School I use calculators more via strategies of RD and IE; teachers in School II use calculators more via strategies of IE, EJ, and CC; while teachers in School III use calculators more via strategies of CC. It seems that teachers in better schools (in terms of students' academic achievements) are more likely to use calculators as a tool for inquiring or reflecting activities. In my opinion, the fact that students' mastery of basic subject knowledge and skill might contribute to such phenomenon, and therefore teachers in better school could design more inquiry-based lessons and put less effort in consolidating students' basic mathematics knowledge and skill.

5.3.2 Computer

The table below shows mean scores of computers for each category of school, and it shows that there is a significant difference on the mean score of computers across the three categories of schools, indicating that in general teachers in different school categories use computer variously.

Table 5-19. Mean scores of computers of three Chinese school categories

School Category	Category I School	Category II School	Category III School
Mean Score	1.839	1.823	1.355

ANOVA test: F=68.136, p=0.000*

A further pair analysis using LSD test leads to the results that the mean score of School III is significantly lower than that of School I (MD=-0.484, p=0.000) and School II (MD=-0.468, p=0.000).

Figure 5-5 and table 5-21 show the mean scores and the statistical analysis of all Chinese respondents on computers on each pedagogical strategy.

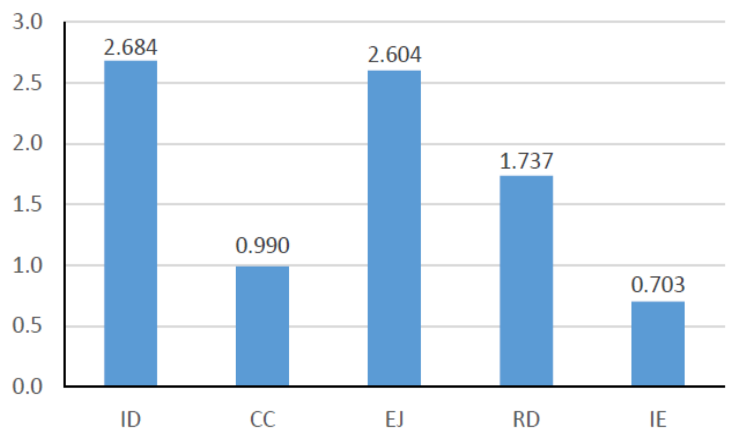

Figure 5-5. Chinese teachers' mean scores of computers on different pedagogical strategies

Table 5-20. Repeated measures ANOVA test on Chinese mean scores of computers on different strategies 1

Within Subject Effects	Mauchly's W	Approx. Chi-square	df	Sig.
Mean scores	0.709	77.714	9	0.000

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Greenhouse-Geisser	750.218	3.434	218.486	523.061	0.000
Huynh-Feldt	750.218	3.493	214.802	523.061	0.000

Table 5-20 reveals that overall the mean scores of Chinese teachers' use of computers on different pedagogical strategies significantly differ from each other. Further LSD tests reveal that the mean score on ID is not significantly different from that of EJ (MD=0.08, p=0.109), but they are significantly higher than scores of other three strategies. Besides, the mean score of RD is significantly higher than those of CC (MD=0.747, p=0.000) and IE (MD=1.034, p=0.000), and the mean score of CC is significantly higher than IE (MD=0.287, p=0.000) as well.

By looking at the mean scores of each school category on different pedagogical strategies, we can find that there is no statistical difference in the mean scores of Illustrating and Demonstrating, and Calculating and Checking across the three school categories, but the mean scores on Explaining and Justifying, Reflecting and Discussing, and Inquiring and Exploring are significantly different. Table 5-21 presents the mean scores and the analysis of variance, and figure 5-6 shows a general picture of how teachers in each school category use computers in different strategies.

Table 5-21. Comparison of three Chinese school categories in the use of computers in indifferent pedagogical strategies

Strategy / Mean score / School category	Illustrating and demonstrating	Calculating and checking	Explaining and justifying	Reflecting and discussing	Inquiring and exploring
School Category I	2.720	0.986	2.791	2.058	0.753
School Category II	2.702	0.984	2.952	1.783	0.743
School Category III	2.580	1.007	1.730	0.933	0.536
Analysis of Variance	F=1.554, p=0.214	F=0.021, p=0.979	F=81.912, p=0.000*	F=54.144, p=0.000*	F=4.603, p=0.011*

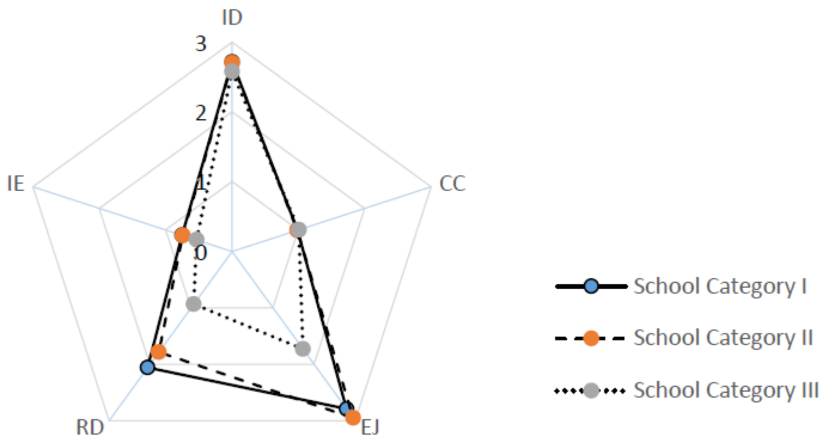

Figure 5-6. Radar chart of Chinese teachers' use of computers

According to the above chart, teachers in different school categories use computers in a rather similar way: computers are used for ID and EJ much more often, followed by RD. However, computers are less usually used for either CC or IE. The statistical analysis shows that there is no significant difference in the mean scores of Illustrating and demonstrating, and Calculating and Checking, but the mean scores on Explaining and justifying, Reflecting and discussing, and Inquiring and exploring are significantly different across the three school categories. A further checking on LSD test of the latter three pedagogical strategies shows that, for EJ, the mean score of School III is significantly lower than that of School I (MD=-1.061, p=0.000) and School II (MD=-1.222, p=0.000); for RD, the mean score of School I is significantly higher than that of School II (MD=0.275, p=0.007) and that of School III (MD=1.125, p=0.000), and the mean score of School II is also significantly higher than that of School III (MD=0.850, p=0.000); for IE, significant differences are found between School I and School III (MD=0.217, p=0.004) and between School II and School III (MD=0.207, p=0.014).

With respect to the use of computer for various goals, the mean scores of Mathematics Knowledge and Skills (MKS), Mathematical Thinking and Reasoning (MTR), and the cultivation of Positive Disposition towards Mathematics (PDM) for all participants as well as for teachers in each School category are compared, and the results are presented below.

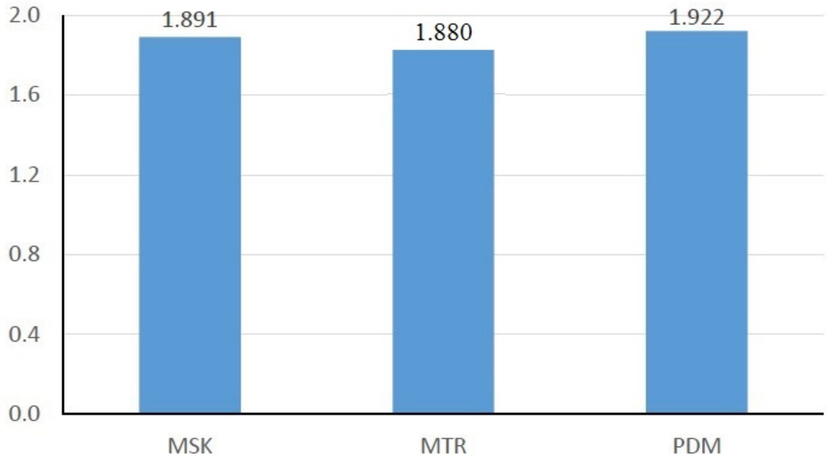

Figure 5-7. Mean scores of Chinese teachers of computers on different goals

Table 5-22. Repeated measures ANOVA test on Chinese mean scores of computers on different goals

Within Subject Effects	Mauchly's W	Approx. Chi-square	df	Sig.
Mean scores	0.984	3.762	2	0.152

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Sphericity Assumed	0.285	2	0.142	0.224	0.799

Although the mean score of MTR is slightly lower than that of MKS and PDM, there is no significant differences in the mean scores of computers on the three instructional goals. This fact indicates that in general, Chinese teachers used computers in a similar way in terms of achieving instructional goals.

Table 5-23. Comparison of mean scores of computers of three Chinese school categories in different gaols

Goals / Mean score / School category	MKS	MTR	PDM
School Category I	1.892	1.921	1.910
School Category II	1.919	1.637	2.028
School Category III	1.858	1.283	1.820
Analysis of Variance	F=0.341, p=0.711	F=82.691, p=0.000*	F=2.188, p=0.114

Table 5-23 reveals that there is a significant difference in the mean score of the goal of teaching Mathematics Thinking and Reasoning across the school categories. LSD tests among different school categories show that the mean scores of the three school categories are significantly different from each other: for School I and School II, MD=0.284, p=0.041; for School I and School III, MD=0.638, p=0.000; and for School II and School III, MD=0.354, p=0.005.

Considering the figures and statistical results above, we can generally conclude that Chinese teachers use computers in a relatively similar way. However, teachers of School I and II use computers more often for teaching Mathematics Thinking and Reasoning than their counterparts of school III. Besides, teachers of School I and II use computers as a tool for Explaining and justifying, Reflecting and discussing, and Inquiring and exploring more often than teachers of School III.

5.3.3 Interactive whiteboard (IWB)

Table 5-24 below presents the mean scores of IWB for each category of school. It can be seen that there is a significant difference in the mean scores across the three school categories, which indicates that teachers in different school categories use IWB differently. A further analysis shows that the mean score of School III is significantly lower than that of School I (MD=-0.103, p=0.006) and School II (MD=-0.089, p=0.032), while no significant difference on the mean scores of IWB has been found between School I and II (MD=0.014, p=0.696).

Table 5-24. Mean scores of IWBs of three Chinese school categories

School Category	Category I School	Category II School	Category III School
Mean Score	0.626	0.612	0.523

ANOVA test*: F=4.025, p=0.019

Figure 5-8 and Table 5-25 below show the mean scores and the statistical analysis of all Chinese respondents on IWBs on each pedagogical strategy.

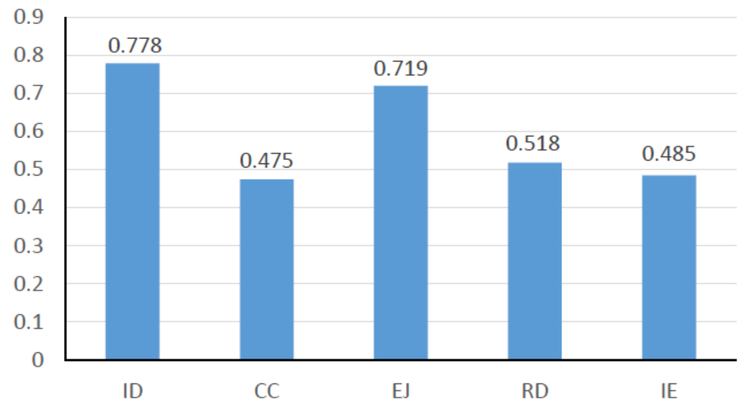

Figure 5-8. Chinese teachers' mean scores of IWB on different pedagogical strategies

Table 5-25. Repeated measures ANOVA test on Chinese mean scores of IWBs on different strategies

Within Subject Effects	Mauchly's W	Approx. Chi-square	df	Sig.
Mean scores	0.907	22.018	9	0.009

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Greenhouse-Geisser	18.707	3.833	4.881	19.678	0.000
Huynh-Feldt	18.707	3.906	4.789	19.678	0.000

Table 5-25 shows that overall, there are significant differences between the mean scores of teachers' use of IWB on different pedagogical strategies. Further LSD tests show that Chinese teachers' mean score on ID is not significantly different from that of EJ (MD=0.059, p=0.227), but they are significantly higher than scores of other three strategies, while no significant difference is found between any two scores of strategies of CC, RD, and IE.

By looking at the mean scores of each school category on different pedagogical strategies, we can find that there is no statistical difference in the mean scores of all strategies except for Illustrating and demonstrating (ID). Table 5-26 presents the mean scores and the analysis of variance, and figure 5-9 shows a general picture of how teachers in each school category use IWB in different strategies.

Table 5-26. Comparison of three Chinese school categories in the use of IWBs in different strategies

Strategy / Mean score / School category	Illustrating and demonstrating	Calculating and checking	Explaining and justifying	Reflecting and discussing	Inquiring and exploring
School Category I	0.892	0.471	0.750	0.460	0.505
School Category II	0.778	0.423	0.782	0.598	0.467
School Category III	0.515	0.547	0.570	0.553	0.460
Analysis of Variance	F=9.178, p=0.000*	F=0.879, p=0.417	F=2.788, p=0.064	F=1.607, p=0.203	F=0.373, p=0.689

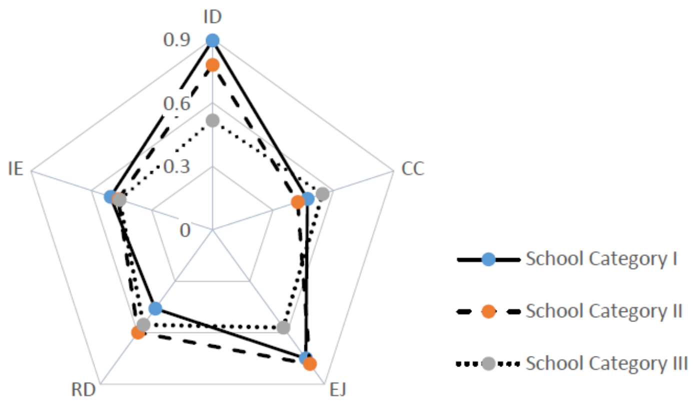

Figure 5-9. Radar chart of Chinese teachers' use of IWBs

The above chart shows that for school III, teachers' mean scores on different strategies are rather similar. Besides, teachers of School I and II use IWBs in a similar way, and they use IWBs for Illustrating and demonstrating, and Explaining and justifying more often than their counterparts of School III. However, the analysis of variance shows that there is no difference of the mean score of IWB in EJ, and the p-value is close to the cut point 0.05, so I will check the LSD test of multiple comparisons on EJ as well.

The LSD test analyses show that for ID, the mean score of School III is significantly lower than that of School I (MD=-0.377, p=0.000) and School II (MD=-0.263, p=0.008); and for EJ, the mean score of School III is significantly lower than that of School I (MD=-0.180, p=0.039) and School II (t=-0.212, p=0.030). No significant differences have been found in the mean scores of either ID or EJ between School I and School II. The above findings indicate that teachers of School I and II use IWB in a similar way in terms of pedagogical strategy, and they use IWBs for ID and EJ significantly more often than their counterparts of School III.

Now, I will examine how teachers use IWBs for various goals.

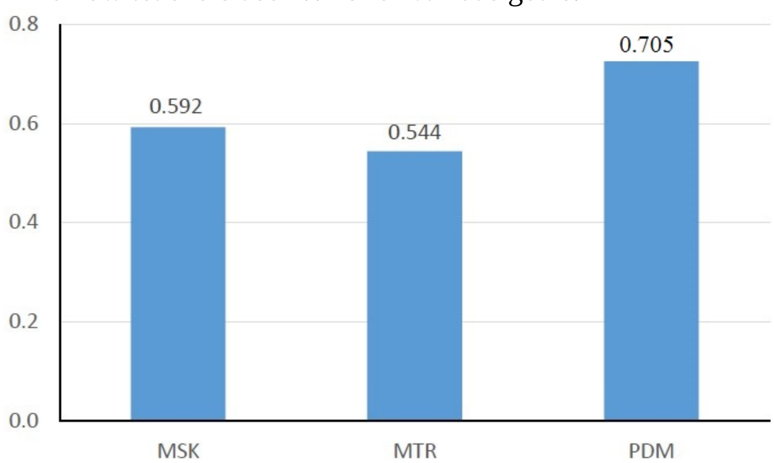

Figure 5-10. Mean scores of Chinese teachers of IWB on different goals

Table 5-27. Repeated measures ANOVA test on Chinese mean scores of IWBs on different goals

Within Subject Effects	Mauchly's W	Approx. Chi-square	df	Sig.
Mean scores	0.890	26.395	2	0.000

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Greenhouse-Geisser	4.033	1.802	2.238	13.445	0.000
Huynh-Feldt	4.033	1.816	2.221	13.445	0.000

The table shows that overall speaking, there are significant differences on Chinese teachers' mean scores of IWBs on the three goals: the mean score on PDM is much higher than that of MKS, which is slightly higher than that of MTR. Further LSD tests reveal that the mean score of MKS is not different from that of MTR, whose scores are significantly lower than that of PDM. This fact indicates that in general, Chinese teachers use IWBs less for the teaching of MSK and MTR, but more for cultivating PDM. Now, let me compare the scores between different school categories to see if there are differences among the three school categories.

Table 5-28. Comparison of mean scores of IWBs of three Chinese school categories in different gaols

Goals / Mean score / School category	MKS	MTR	PDM
School Category I	0.675	0.714	0.711
School Category II	0.592	0.577	0.718
School Category III	0.569	0.478	0.535
Analysis of Variance	F=0.147, p=0.863	F=1.592, p=0.206	F=5.978, p=0.003*

The mean scores of Positive Disposition towards Mathematics are significantly different across school categories. LSD tests reveal that the mean score of PMD of School III is significantly lower than that of School I (MD=-0.176, p=0.001) and School II (MD=-0.183, p=0.041), indicating that IWBs are more often used as a tool for cultivating students' positive dispositions towards mathematics by teachers in School I and II.

In summary, Chinese teachers' use of IWBs is associated with the school categories where they work. Although in general, IWBs are not often used in Chinese mathematics classroom, teachers in School I and II use IWBs significantly more often than their counterparts in School III. Such difference has been kept in both using strategies and instructional goals. The data analysis reveals that teachers in School I and School II use IWBs in the similar ways and they use IWBs more often as tools in Illustrating and demonstrating and in Explaining and justifying than teachers in School

III. Besides, teachers in School I and II use IWBs more for cultivating students' positive dispositions towards mathematics than teachers in school III.

5.3.4 Mobile phone

In section 5.2.1, we can see that only 28.8% of the participants expressed that they had used mobile phones for instructions. Actually, the mean scores of all participants on 'mobile phone' of each item of part C are less than 0.4 (ranging from 0.240 to 0.328), indicating that 'mobile phone' is the least frequently used device in classroom teaching compare to other devices.

Similarly, the mean scores of mobile phone for each school categories are calculated and compared, before analysing the mean scores on each pedagogical strategy and each goal. Table 5-29 to table 5-33 and figure 5-12 present the results.

Table 5-29. Mean scores of mobile phone of three Chinese school categories

School Category	Category I School	Category II School	Category III School
Mean Score	0.281	0.310	0.251

ANOVA test: F=2.204, p=0.113

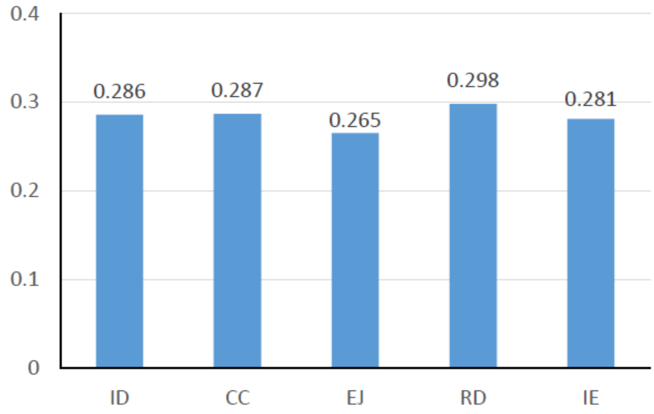

Figure 5-11. Chinese teachers' mean scores of mobile phones on different pedagogical strategies

Table 5-30. Repeated measures ANOVA test on Chinese mean scores of mobile phones on different strategies

Within Subject Effects	Mauchly's W	Approx. Chi-square	df	Sig.
Mean scores	0.882	28.353	9	0.001

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Greenhouse-Geisser	0.132	3.779	0.035	0.284	0.879
Huynh-Feldt	0.132	3.851	0.034	0.284	0.882

Table 5-31. Comparison of three Chinese school categories in the use of mobile phones in different strategies

Strategy / Mean score / School category	Illustrating and demonstrating	Calculating and checking	Explaining and justifying	Reflecting and discussing	Inquiring and exploring
School Category I	0.304	0.253	0.250	0.290	0.298
School Category II	0.286	0.349	0.309	0.359	0.279
School Category III	0.245	0.287	0.245	0.240	0.244
Analysis of Variance	F=0.509, p=0.605	F=1.366, p=0.257	F=0.953, p=0.387	F=1.420, p=0.244	F=0.564, p=0.569

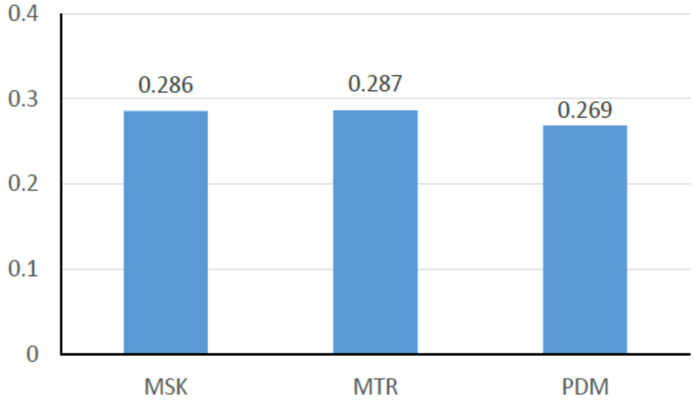

Figure 5-12. Mean scores of Chinese teachers of mobile phones on different goals

Table 5-32. Repeated measures ANOVA test on Chinese mean scores of mobile phones on different goals

Within Subject Effects	Mauchly's W	Approx. Chi-square	df	Sig.
Mean scores	0.968	7.280	2	0.026

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Greenhouse-Geisser	0.047	1.939	0.024	0.339	0.706
Huynh-Feldt	0.047	1.955	0.024	0.339	0.708

Table 5-33. Comparison of mean scores of mobile phones of three Chinese school categories in different gaols

Goals / Mean score / School category	MKS	MTR	PDM
School Category I	0.262	0.284	0.306
School Category II	0.277	0.296	0.270
School Category III	0.257	0.280	0.272
Analysis of Variance	F=2.026, p=0.134	F=0.074, p=0.929	F=0.094, p=0.910

As can be seen, the mean score of mobile phones is quite low (less than 0.3), which shows that Chinese teachers rarely use mobile phones in teaching mathematics, and this finding is consistent with the figure in table 5-4. There is no significant difference in the mean scores of the mobile phones across the three school categories. In addition, on neither pedagogical strategies nor instructional goals, differences are found on the mean scores, indicating that teachers from the three categories of schools used mobile phones in a similar way. Besides, no specific pedagogical strategy or instructional goal is found to be practiced more than others by Chinese teachers with mobile phones.

5.3.5 Other technology: projector

Table 5-34 shows the mean scores of three categories of schools on 'other' technology, and there is no significant difference in the mean scores across the three categories of schools.

Table 5-34. Mean scores of other technology of three school categories

School Category	Category I School	Category II School	Category III School
Mean Score	0.605	0.571	0.582

ANOVA test: F=0.565, p=0.569

However, 85.2% of teachers in part B of the questionnaire mentioned that they used projectors in their instruction, and there is no response for the 'other hardware and devices'. By answering the Part C of the questionnaire, some teachers even explicitly wrote 'projector' next to 'other' in some of the items, showing that they treated the 'other' option as 'projector'. So here I treat 'other' technology as 'projector', and analyse how they use 'projector' in their instruction.

Figure 5-13 and table 5-35 show the mean scores and the statistical analysis of all Chinese respondents' uses of projectors on each pedagogical strategy.

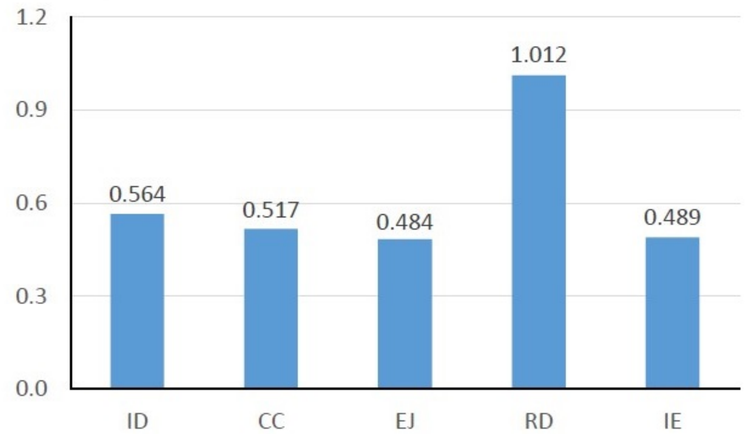

Figure 5-13. Chinese teachers' mean scores of projectors on different pedagogical strategies

Table 5-35. Repeated measures ANOVA test on Chinese mean scores of projectors on different strategies

Within Subject Effects	Mauchly's W	Approx. Chi-square	df	Sig.
Mean scores	0.886	27.403	9	0.001

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Greenhouse-Geisser	46.404	3.757	12.352	48.545	0.000
Huynh-Feldt	46.404	3.827	12.124	48.545	0.000

It can be seen from the figures above that the highest score belongs to RD, and table 5-35 shows that overall speaking, there are significant differences between the mean scores of Chinese teachers' use of other (projector) on different pedagogical strategies. Further LSD tests of conducting pairwise comparisons reveal that Chinese teachers' mean score on RD is significantly different from that of other four strategies, and no significant difference has been found in these four means. So it can be said that teachers use projector much more often for reflecting and discussing than other four strategies.

By looking at the mean scores of each school category on different pedagogical strategies, we can find that there is no statistical difference in the mean scores of any strategy, which indicates that statistically all teachers use projectors in a similar way, and they followed the pattern that has been discovered and explain before.

Table 5-36. Comparison of three Chinese school categories in the use of projectors in different strategies1

Strategy / Mean score / School category	Illustrating and demonstrating	Calculating and checking	Explaining and justifying	Reflecting and discussing	Inquiring and exploring
School Category I	0.547	0.523	0.539	1.037	0.493
School Category II	0.607	0.482	0.425	1.026	0.441
School Category III	0.550	0.547	0.430	0.933	0.540
Analysis of Variance	F=0.330, p=0.719	F=0.222, p=0.801	F=1.817, p=0.165	F=0.664, p=0.516	F=0.830, p=0.437

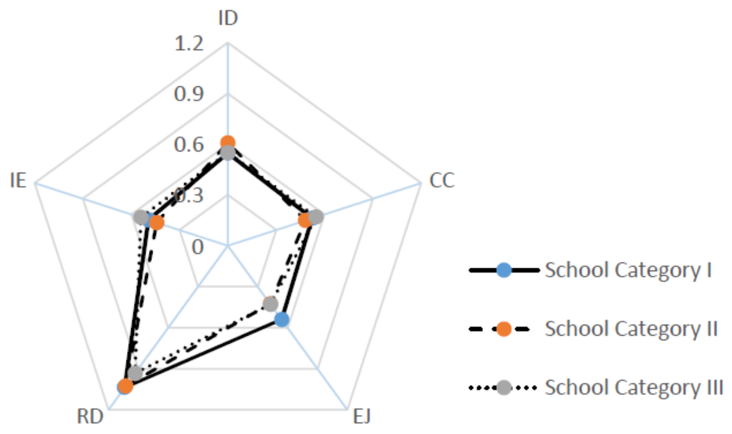

Figure 5-14. Radar chart of Chinese teachers' use of projectors

With respect to various goals, figure 5-15 and table 5-37 to table 5-38 below present the analysis of the mean scores of projectors in Mathematics Knowledge and Skills (MKS), Mathematical Thinking and Reasoning (MTR), and the cultivation of Positive Disposition towards Mathematics (PDM).

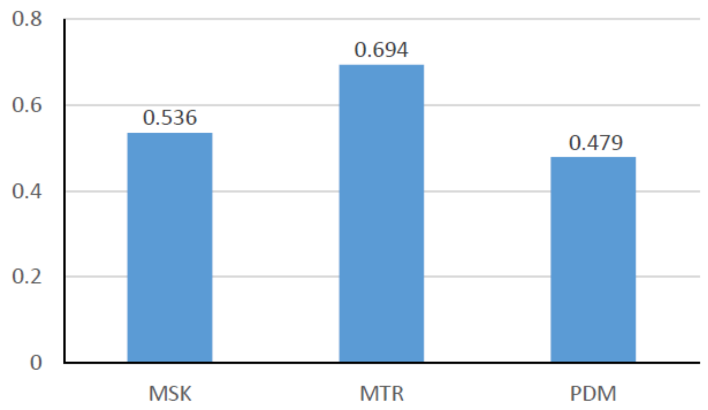

Figure 5-15. Mean scores of Chinese teachers of projectors on different goals

Table 5-37. Repeated measures ANOVA test on Chinese mean scores of projectors on different goals

Within Subject Effects	Mauchly's W	Approx. Chi-square	df	Sig.
Mean scores	0.975	5.730	2	0.057

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Sphericity Assumed	5.692	2	2.846	21.529	0.000

The table shows that overall speaking, there are significant differences in the mean scores of projectors on the three instructional goals. According to figure 5-15, the mean score on MTR is higher than that of MKS, which is slightly higher than that of PDM, and further LSD tests reveal that the mean score of MKS is not different from that of PDM, whose scores are significantly lower than that of MTR. This fact indicates that in general, Chinese teachers use projector less for teaching MSK and PDM, but more for MTR. Finally, let me compare the scores between different school categories to see if there are differences between different school categories.

Table 5-38. Comparison of mean scores of projectors of three Chinese school categories in different gaols 1

Mean score / Goals / School category	MKS	MTR	PDM
School Category I	0.537	0.714	0.504
School Category II	0.531	0.649	0.492
School Category III	0.540	0.708	0.405
Analysis of Variance	F=0.352, p=0.704	F=0.812, p=0.445	F=1.011, p=0.365

Table 5-38 shows that no significant difference has been found in the mean scores of any pedagogical strategy between teachers of different school categories, and therefore, teachers of all school categories use projectors in a similar way in terms of pedagogical goals.

Interestingly, there are 195 teachers ticking 'projector' in the item 5c of the questionnaire, but the mean score of 'other' technology (projector) is just 0.591. From the analysis above, it can be seen that although projectors are used by the majority of teachers, the devices are used in a limited way—mainly in reflecting and discussing, and therefore when calculated over all items, the mean score becomes quite low. I specifically examined all participants' mean scores of projectors in each item of part C, and the result shows that the mean score for item 20 is 2.079, which is much higher than all other items (mean scores ranging from 0.406 to 0.664), and this finding confirms my analysis. Actually, such phenomenon is also confirmed by the qualitative data, which will be presented in section 5.5.

In summary, the data of questionnaire reveals that firstly, besides calculator, computer, IWBs, and mobile phones, the majority Chinese teachers use projectors in their teachings. All teachers regardless of their school categories use projectors in a similar fashion. Specifically, projectors are mainly used as a tool in reflecting and discussing and rarely used in other strategies, and the devices are more often used for the teaching of Mathematics Thinking and Reasoning than other goals.

5.4 Influencing Factors

Part D of the questionnaire describes different factors which may influence teachers' use of technology based on the framework proposed in chapter 3, and teachers are asked to indicate the degree of agreement on each statement.

5.4.1 Teachers' self-evaluations

Within the 32 items, there are nine asking teachers to self-evaluate the influence of different factors on their daily technology integration. For example, item 29 states that 'Overall speaking, my knowledge about technologies influences whether I use technology in instruction.' Teachers were asked to choose from four options-strongly agree (4), agree (3), disagree (2) and strongly disagree (1)-with each option provided with a score (shown in the brackets). The answers indicate teachers' self-evaluations of the influence of certain factor, and the results are shown in the figure below where the percentages of teachers who ticked agree part or disagree part are presented.

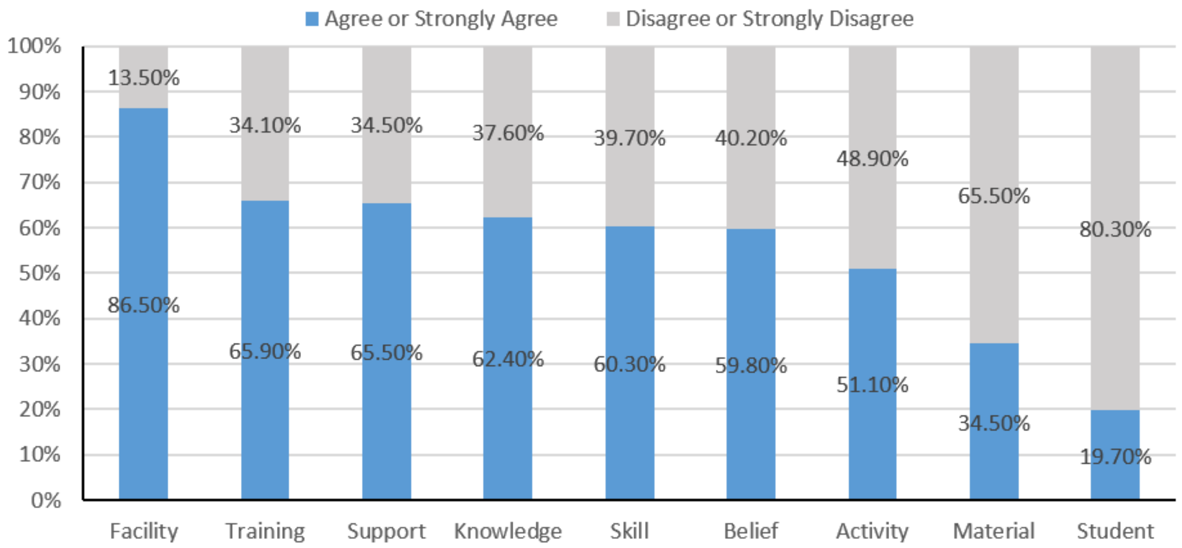

Figure 5-16. Percentages of teachers' self-evaluations on each factor

School facility and resources has been regarded by the most majority of teachers (86.5%) as influential to their technology integration, followed by Training (65.9%), School support (65.5%), Knowledge (62.4%), Skill (60.3%), and Beliefs (59.8%). Activity is regarded by just slightly more than half of the participants (51.1%) as influential. However, for the factor of Teaching materials and textbooks, and the factor of Students, over half of the participants believed that they are not influential.

Similar to analysis of different technology used by teachers, I am interested in seeing how school categories shape teachers' view on different influential factors, which will be answered by chi-square tests as follows.

Table 5-39. Distribution of the numbers of teachers in three Chinese school categories giving different evaluation of influential factors

Factor: Knowledge

	Category I School	Category II School	Category III School	Total
No [a]	50	21	15	86
Yes	66	42	35	143
Total	116	63	50	229

Chi-square test: χ^2=3.219 df=2 p=0.200

Factor: Skill

	Category I School	Category II School	Category III School	Total
No	44	26	21	91
Yes	72	37	29	138
Total	116	63	50	229

Chi-square test: χ^2=0.327 df=2 p=0.849

Factor: Pedagogical beliefs and attitudes

	Category I School	Category II School	Category III School	Total
No	48	24	20	92
Yes	68	39	30	137
Total	116	63	50	229

Chi-square test: χ^2=0.184 df=2 p=0.912

Factor: Facility and resources

	Category I School	Category II School	Category III School	Total
No	25	5	1	31
Yes	91	58	49	198
Total	116	63	50	229

Chi-square test*: χ^2=13.740 df=2 p=0.001

Factor: School support

	Category I School	Category II School	Category III School	Total
No	35	20	24	79
Yes	81	43	26	150
Total	116	63	50	229

Chi-square test: χ^2=5.205 df=2 p=0.074

Factor: Materials

	Category I School	Category II School	Category III School	Total
No	81	39	30	150
Yes	35	24	20	79
Total	116	63	50	229

Chi-square test: χ^2=1.991 df=2 p=0.369

Factor: Students				
	Category I School	Category II School	Category III School	Total
No	93	50	41	184
Yes	23	13	9	45
Total	116	63	50	229

Chi-square test: χ^2=0.127 df=2 p=0.938

Factor: Training				
	Category I School	Category II School	Category III School	Total
No	46	21	11	78
Yes	70	42	39	151
Total	116	63	50	229

Chi-square test: χ^2=4.870 df=2 p=0.088

Factor: Professional activities and exchanges				
	Category I School	Category II School	Category III School	Total
No	54	25	33	112
Yes	62	38	17	117
Total	116	63	50	229

Chi-square test*: χ^2=8.249 df=2 p=0.016

[a] ‘Strongly disagree’ and ‘Disagree’ are combined to the row of ‘No’; ‘Strongly agree’ and ‘Agree’ are combined to the row of ‘Yes’.

Table 5-39 shows that teachers’ evaluation of all factors are not associated with the school categories where they work except for the following two factors: *Facilities and resources*, and *Professional activities*. By further conducting one to one comparison, it can be found that for factor of Facilities and resources, there exist significant differences in teachers’ evaluations between School I and School II (χ^2=5.425, with df=1 and p=0.014), and between School I and School III (χ^2=10.111, with df=1 and p=0.001), which indicates that fewer teachers in School I think that facilities and resources influenced their teachings. To me, the possible reason could be that in general, schools of category I are equipped with adequate facilities and devices, so that teachers were less likely to face the circumstance that original lesson plans had to be changed due to the unavailability of certain technologies, and hence teachers in school I have less strong feelings than teachers in school II and III on the importance of facility and resources provision. For factor of Professional activities, the significant differences exist between School I and School III (χ^2=5.298, with df=1 and p=0.016), and between School II and School III (χ^2=7.728, with df=1 and p=0.005), which indicates that more teachers in School I and II think that professional activities and exchanges influenced their teachings. One reason could be that teachers in School I and II are provided with more chance to expose to various activities, where they did benefit for their teachings. Another reasons could be related to school facilities that even though all teachers attend roughly the same amount of tech-related professional activities, teachers in School I by using adequate school facilities and resources, can apply what they learned from the activities to their daily teaching works, so that they are more likely to feel the usefulness of various professional activities.

In summary, teachers' self-evaluations on different factors show that except for the factor of curriculum materials, and the factor of students, all factors are influential to their use of technology. Further chi-square tests reveal that there are significant differences in the teachers' evaluation of influential factors among different school categories on the factor of Facilities and resources, and Professional activities.

5.4.2 Model construction and analysis

As I mentioned in the previous chapter, multilevel modelling will be adopted in analysing how different factors influence teachers' use of technology, with MCMC Bayesian estimate as the algorithm in modelling (5000 iteration times). I will use MLwiN version 2.36 to construct the multilevel modelling with the teachers making up for the first level and the schools the second level.

Independent factors including knowledge, skill, pedagogical belief, school facility and resources, teaching materials, students, professional activities and training are examined. Besides, demographic information such as age and sex will also be examined in the model. All independent factors are examined if they have influences on the school level, i.e. the second level. For each factor, a mean score is calculated based on the corresponding items on the questionnaire. For example, item 27 and 28 are used to depict teachers' knowledge on technology, so mean score of the two items is calculated for each teacher and will be included in the model for the regression equation.

According to Hermans, van Braak and Van Keer (2008) and Vanderlinde, Aesaert and Van Braak (2014), the use of stepwise multilevel approach in model building was helpful in not only examining the change of deviance when new subset of variables were added, as well as examining the proportion of explained variance by each subset of variables, but also keeping the model relatively simple and easy to be interpreted. So I will follow the researchers' guide, and build my models in a stepwise way. In total, 5 models are built and tested, and the construction of the models are as follows: Firstly, an unconditional null model was established to test if a multilevel analysis was preferred to a single level ordinary regression model, then demographic variables of teachers including age and sex were added to form model 2. The third model included all the potential factors that could influence teachers' use of technology and these factors were tested in the model, and finally, complex variance at school-level was allowed for all remaining variables. Before the estimation of a new subset of variables in each model, the non-significant factors in the previous model were firstly removed in order to keep the model simple.

(1) Null Model (Model 0)

In this part, no predictors were added in the model, and the null model was constructed to see if multilevel model approach was preferred to an ordinary single-level regression model. The result showed that the intercept of this null model was 3.857, which was the average mean score on 'teacher' use of technology' scale of all participants, and the standard error for the intercept was 0.083. By dividing 3.857 over its standard error, we can obtain z=3.857/0.083=46.47, and $p<0.01$, indicating that the intercept is significant different from 0. Furthermore, assuming a normal distribution the mean score of 3.857 and a variance of 0.076 at school level, the 95% coverage bounds reveal that in the 2.5% schools where teachers frequently use technology in teaching, the average score on the 'teachers' use of technology' scale is 4.397 ($3.857+1.96\times\sqrt{0.076}=4.397$); In the 2.5% schools where teachers less-frequently use technology, the average score on the scale is 3.317 ($3.857-1.96\times\sqrt{0.076}=3.317$). Figure 5-17 illustrates the school level residuals on the mean score of part C of the questionnaire. The schools are ordered increasingly by the residual of its mean scores over the intercept value, and the school 17 has the lowest mean score on the scale and the school 2 has the highest mean score.

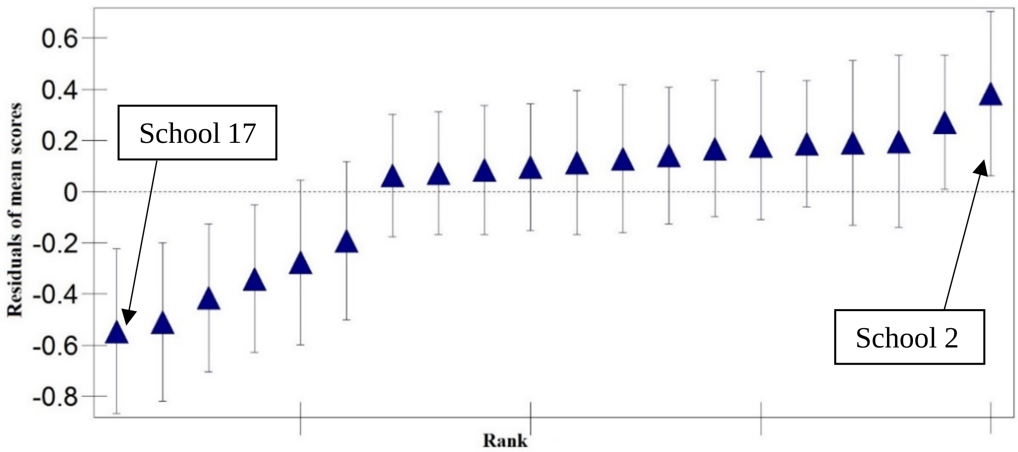

Figure 5-17. School level residuals on the mean score of 'teachers' use of technology' with 95% confidence bands

The results also support the use of multilevel analysis for the data. The calculation of the variance partitioning coefficient (VPC) delivers the proportion of the variance that is attributed to differences between schools. This is done by dividing the between-school variance by the total variance (0.076/(0.076+0.248)). The result indicated that 23.46% of the variance is due to between-school differences and 76.54% of the variance is attributed to differences at the teacher level. The fitness of the model when MCMC Bayesian estimate is adopted, according to Brown (2015), should be examined by Bayesian Deviance Information Criterion (DIC) where a drop in the value of DIC generally means a better fitness of the data. By checking the DIC of the level 2 model and level 1 model, it can be found that the drop of DIC value is 45.33, indicating that this two-level null model is a significant improvement over the single level model.

(2) Model 1

In this part, level 1(teacher) demographic variables were integrated in the 2-level random intercept model. There are in total six demographic variables: sex, age group, teaching years, grade of teaching, the highest degree obtained, and the highest professional title obtained. Here only teaching years is a continuous variable, and others are all categorical variables. In the variable of 'the highest degree obtained', due to the small number of participants obtaining 3-year diplomas, and no doctor was found in my sample, I combined the '3-year diploma' and 'bachelor' together, making it 'non-Master degree' as a reference category in the model construction. For variable of 'professional title', there are only 18 participants without any title, so I combined them with the 'junior' holders as 'below intermediate' and set it as reference category. For variables of sex, age group, and grade of teaching, 'female', 'age group 20 to 29', and 'grade 7' were chosen as reference categories respectively. By using the same method in the null model, we can determine if one coefficient is significantly different from 0, which means if one variable makes a significant contribution to the dependent variable. Model 1a contained all the above mentioned demographic variables, and from the data analysis results on MLwiN, only the coefficient for 'grade 9' was significantly different from zero, so only variables for 'grade of teaching' were kept in model 1b. Finally, the change of DIC shows that model 1b fits the data better than null model (Drop of DIC value=2.62).

(3) Model 2

In this step, all the potential influential factors collected in part D of the teacher questionnaire were added into the model 1b. Table 5-40 shows the estimations and standard errors of the coefficients for all these variables. The analysis result revealed that coefficients for 'belief' (z=-0.682, p=0.248), 'materials' (z=0.729, p=0.233), and 'students' (z=-0.269, p=0.606) were insignificantly different from 0, so these variables were deleted, while others were remained. Further analysis showed that all the remaining variables made significant contributions to the dependent variable so they were kept to form the model 2b. The change of the DIC of model 2b from model 1b was checked, and the result showed that model 2b significantly fitted the data better than model 1b. (Drop of DIC value=123.55)

(4) Model 3

Model 2b revealed which factors were influential and in this part, a further exploration will be conducted: complex variance for all variables of the model 2b was allowed at school-level to see if each factor influence different schools differently. In order to keep the final model simple and interpret-friendly, the complex variance for the variables was checked one by one rather than simultaneously. For one certain variable, the variance (u_j) and its standard error (ε_j) were checked, and the hypothesis: $u_j \neq 0$ was tested. If and only if the hypothesis cannot be rejected, the complex variance for such variable at school level would be kept. The result showed that only random variation of 'activity' at school level was significantly different from 0 (between-school variation of this slope was 0.072, with its standard error being 0.035, and therefore z=2.06, and $p<0.05$) (model 3a). However, at this time, the negative slope associated with 'grade 9' was not significant (coefficient=-0.079, standard error=0.055, and $p>0.05$). So the variable 'Grade' was removed, and the random variance of 'Activity' at school level was kept and then the model was run again. The results showed that such school-level variance was still significantly unequal to zero (z=2.08, $p<0.05$), and all the remaining variables were with coefficients significantly unequal to zero, then model 3b was constructed. Table 5-40 showed the coefficients and standard errors for all remaining variables, and it can be seen that all the remaining variables made significant contributions in predicting the dependent variables. For model 3b, the drop of DIC value from model 2b is 12.36, indicating that model 3b significantly fitted the data better than the previous ones, and is retained as the final model.

The inclusion of random variance of 'activity' at school-level added two parametres: σ_{u6}^2 and σ_{u06}. The former one stands for the between-school variance in this slope, and the latter one stands for the covariance between intercepts and coefficients of the slope. In model 3b, $\sigma_{u6}^2 = 0.073$, and $\sigma_{u06} = -0.115$. In general, the negative σ_{u06} means that schools with a high intercept (above-average mean score in 'teacher's use of technology' scale) tend to have a flatter-than-average slope, while schools with a low intercept (below-average mean score in 'teacher's use of technology' scale) tend to have a steeper slope. This means that at schools where the mean score of 'teacher's use of technology scale' is lower, the influence of 'activity' is stronger than their counterparts, which indicates that training for schools whose teachers are less often use technology could be more influential. One reason for this phenomenon could be that teachers in some schools are provided relatively fewer chances in various professional activities, so once these teachers attend tech-related activities, the influence could be seen more obviously. Another reason could attribute to the lack of enough facilities in some schools. Teachers in these schools normally don't have the chance to use various technology unless they attend certain activities. An example comes from the interview with TC5 who was provided the chance to use the IWB when he was nominated as the representative for his school to attend a city-level teaching competition. There was only one IWB in his school so normally the IWB was less-often used by teachers as a daily teaching tool. In the interview, TC2 provided me with a concrete example that by attending courseware-design competition in his school, he not only learned practical skills in using technology, but also accumulated many courseware which he directly used in his teaching. This example might indicate that technology-related professional activities not only encourage teachers to integrate technology into daily teachings, but also push them to create a number of courseware and design more tech-integrated lessons. This might also explain why teachers in school I in general use computers more often than teachers in other types of school. Of course, further studies are needed to examine these hypotheses and dig more valuable information to explain such phenomena.

Finally, the calculation of the squared multiple correction coefficient (R^2) provides us with the proportion of variance explained. In multilevel models, R^2 is divided into two parts: one at the individual level (teacher); one at the group level (school). The calculation of R^2 at both levels is based on Snijder and Bosker's (2012) work where $R^2 = R_1^2 + R_2^2$, and R_1^2 refers to the proportional reduction of error for predicting an individual outcome, and R_2^2 refers to the proportional reduction of error for predicting a group mean. $R_1^2 = 1 - \frac{(\sigma_{e0}^2 + \sigma_{u0}^2)_{comparison}}{(\sigma_{e0}^2 + \sigma_{u0}^2)_{null\,model}}$; $R_2^2 = 1 - \frac{(\sigma_{e0}^2/\tilde{n} + \sigma_{u0}^2)_{comparison}}{(\sigma_{e0}^2/\tilde{n} + \sigma_{u0}^2)_{null\,model}}$, where $\tilde{n}$ means the harmonic mean of teachers in all schools ($\tilde{n}$=10.052 in my sample). Table 5-41 presents the proportion of explained variance at both levels for models that were accepted according to the discussions above, and ΔR_1^2 and ΔR_2^2 allow us to identify the change of proportion explained at both levels between two models.

Table 5-40. Estimation and standard errors from the random intercept model of Chinese data (dependent variable: mean score on 'teacher's use of technology' scale)

	Model 0	Model 1a	Model 1b	Model 2a	Model 2b	Model 3a	Model 3b
Fixed							
Intercept (cons)	3.857 (0.083)*	3.920 (0.192)*	3.909 (0.086)*	1.783 (0.220)*	1.679 (0.187)*	1.784 (0.205)*	1.727 (0.201)*
Sex (Male)		-0.053 (0.072)					
Age group 2/3/4		-0.172/-0.319/-0.364 (0.174)/(0.241)/(0.340)					
Teaching years		0.004 (0.011)					
Grade 8/9		0.021/-0.176 (0.080)/(0.079)*	0.013/-0.163 (0.078)/(0.077)*	0.011/-0.114 (0.059)/(0.059)*	0.013/-0.115 (0.059)/(0.058)*	0.026/-0.079 (0.055)/(0.055)	
Degree (Master)[27]		0.037 (0.123)					
Professional title[28] (intermediate/senior)		0.206/0.300 (0.193)/(0.211)					
Knowledge				0.113(0.048)*	0.114(0.048)*	0.136(0.045)*	0.146(0.044)*
Skill				0.068(0.033)*	0.066(0.032)*	0.065(0.033)*	0.086(0.036)*
Belief				-0.045(0.066)			
Facility				0.308(0.065)*	0.315(0.062)*	0.347(0.059)*	0.358(0.059)*
Support				0.235(0.056)*	0.240(0.054)*	0.201(0.052)*	0.188(0.053)*
Materials				0.035(0.048)			
Student				-0.014(0.052)			
Training				0.187(0.057)*	0.192 (0.056)*	0.136(0.056)*	0.140(0.055)*
Activity				0.089(0.045)*	0.086(0.035)*	0.090(0.041)*	0.098(0.041)*
Random							
School level σ_{u0}^2 (between)	0.076 (0.050)*	0.077 (0.033)*	0.075 (0.049)*	0.070 (0.032)*	0.075 (0.033)*	0.066 (0.023)*	0.070 (0.025)*
Teacher level σ_{e0}^2 (within)	0.248 (0.023)*	0.211 (0.021)*	0.228 (0.023)*	0.141 (0.013)*	0.189 (0.013)*	0.140 (0.012)*	0.146 (0.012)*
Model Fit							
DIC	331.90	335.17	329.28	211.47	205.73	179.67	193.37
Drop of DIC value	45.33		2.62		123.55		12.36

[27] Due to the small number of 3-year diploma holders, I combine the 3-year diploma and bachelor degree together.

[28] Due to the small number of teacher without any professional title (18), I combine junior holders with those without any titles as 'below intermediate' and set it as the reference category.

Table 5-41. Proportion of variance explained at teacher and school level (Chinese data)

	Model 1b	Model 2b	Model 3b
R_1^2 (proportion of variance explained at teacher level)	0.0648	0.1852	0.3333
R_2^2 (proportion of variance explained at school level)	0.0297	0.0682	0.1604

According to table 5-41, only 6.48% and 2.97% of variance have been explained by ‘Grade’ at teacher level and school level respectively. However, when more independent variables were added and model 2b was constructed, 18.52% of the variance at teacher level and 6.82% of the variance at school level have been explained. Compare to model 1b, the proportion of explained variance at teacher level in model 2b rises by 12.04%. Besides, in model 3b, the inclusion of ‘activity’ as school-level variable resulted in an extra 14.81% and 9.22% explained variance at teacher level and school level respectively.

In conclusion, according to table 5-40 and 5-41, model 3b has been accepted as the final model for Chinese data. The demographic variables have not made contributions in explaining the variance at both levels, while variables ‘Knowledge’, ‘Skill’, ‘Facility’, ‘Support’, ‘Training’ and ‘Activity’ accounted for 33.33% of the variance at teacher level and 16.04% at school level. Besides, ‘activity’ at school level is a significant factor, indicating that tech-related activities at schools exert different impacts on teachers’ use of technology.

5.5 Qualitative Data Analysis

There are 6 teachers participating in my qualitative data collection. For each teacher, one classroom teaching is observed, followed by an interview. This section reports the findings from the qualitative data and is comprised of two subsections, which correspond to the two research questions.

The table below presents basic information of the six teachers as well as the topics of the observed lessons. It should be mentioned that TC1 has been awarded as a Master teacher[29] in 2014, and TC4 and TC6 are head of mathematics department in their schools.

[29] See section 4.3.2 for the professional title system of Chinese teachers.

Table 5-42. Information of Chinese teachers for classroom observation and interview

	School category	sex	Age group	Year of teaching	Topic of the lesson[30]
TC1*	I	male	40-49	22	Mutually Inverse Propositions[31]
TC2	I	male	20-29	2	Frequency and Probability
TC3	II	female	20-29	5	Graphs and Properties of Reciprocal Function.
TC4	II	male	30-39	17	Pythagorean Theorem
TC5	III	male	20-29	5	Equations with Algebraic Fractions
TC6	III	female	40-49	19	Multiplication of Monomials

*Hereinafter TC*n* refers to the *n*th Chinese Teacher.

5.5.1 The use of technology in teaching practices

For all observed lessons, in-site notes were taken, which recorded the used technologies. Later on during the interviews, teachers were firstly asked to reflect their teachings, which confirmed the observation records I made, and then more general questions were raised such as if they used certain technology for other topics, or if they used other technology for their daily teachings. By answering these questions, information on what technologies and how they were used was obtained. Below, I'll briefly introduce the observed lessons and interviews, and the information on the use of technology is presented.

Lesson and interview of TC1

The topic of TC1's lesson came from Grade 7, lesson 12.4 *mutually inverse propositions*. According to TC1, this lesson served for two aims: (1) students should be able to understand the concept of mutually inverse propositions, and to know how to construct the inverse proposition of a given proposition; (2) students should be able to examine the previously learned propositions to see if there were mutually inverse propositions and to prove the correctness or incorrectness of some propositions.

[30] All secondary schools in Nanjing use the same set of textbook, and thus all these topics come from the Secondary School Mathematics textbook of *Jiangsu Science and Technology Press.*

[31] For two propositions, if their conditions and conclusions are interchanged, the propositions are called mutually inverse propositions. For example, for two propositions: Proposition A: if p then q; Proposition B: if q then p. Then A and B are mutually inverse propositions.

TC1 used a computer with PowerPoint in the lesson to present a list of propositions for students to reflect. Also, examples of strict geometrical proof has been demonstrated through the PowerPoint. In the interview, TC1 explained his way of pedagogy:

> … I used PowerPoint in the teaching because it is a good tool to present a large quantity of information and contents. Besides, I can use it to make the propositions a logic network so that students can remember and understand those propositions more easily. I also presented complete proofs of certain propositions via slides so that students could model when they did their classroom exercises.

Besides, GSP was also used to visualise geometrical propositions and theorems through dynamical demonstration. GSP was used combine with IWB, which was touched by the teacher to drag or change figures. For example, there is a proposition that if a, b, c represents the lengths of three sides of a triangle, then a+b>c. TC1 asked students to phrase its reciprocal proposition and to think about its correctness. After students' thinking and discussion, TC1 used GSP to draw three line segments whose lengths satisfying the above condition and moved those segments directly on the IWB screen to see if they could form a triangle.

In the interview, TC1 was asked, based on the observed lesson, if this was his usual way of using IWB, and he answered:

> Basically yes. I think the most powerful function that GSP provides is assisting dynamic demonstration. I mean I can directly draw graphs, or change graphs in front of students so they can observe the changing process... IWB also saves lots of time. Previously I need to draw on the blackboard with charts, and sometimes it is not that accurate, which influenced students' learning and it was not good. Unlike adults, it is very important to let teenagers 'see' and 'observe' concrete objects based on which they can think and reason, so accurate and precise figures are vital in mathematics and from this aspect I regard GSP and IWB good and effective teaching tools. Sometimes I also ask students to come to the IWB to do manipulations, but that was not quite often.

For TC1, computer and IWB are useful tools for whole-class presenting and demonstrating. Besides, dynamic geometric software is frequently used for students' better understanding of relevant knowledge.

In addition to the computer and IWB, TC1 also mentioned that he often used projectors when he delivered exercises-based lessons such as review of certain chapters or commenting exam papers. During such lessons, TC1 could easily demonstrate any student's work by projectors to the whole class for students' in-depth discussions.

<u>Lesson and interview of TC2</u>

The topic of TC2's lesson came from Grade 8, lesson 10.2 *frequency and probability*. According to TC2, the aim of this lesson was to enable students to understand the concept of probability and to know the connection and difference between frequency and probability. A computer and a projector were adopted in the lesson with slides and Excel being used via the computer.

During the lesson, TC2 grouped students and asked each group to do two experiments: (1) flipping coins 20 times and making notes of how many times head/tail appeared; (2) throwing dices, and writing down of how many times each face appeared. Later, the teacher used Excel to draw segment lines based on both each group's data and excel-generated data to reveal the fact that with the time of experiment increasing, the frequency became more and more stable. When asked why he used Excel, the teacher answered:

> …by doing experiments in a limited time, it is hard to get large data. So I used computer here, actually Excel, to do simulation and to get large data quickly and then drew frequency graphs. With the change of time of simulation, the frequency graphs changed as well, so students could understand that the concept of probability is related to a changing process called limitation. The focus of this lesson was discussing frequency graphs rather than drawing, so I chose to use Excel to get the graph quickly, and by discussing the graphs, students learned the concept of probability.

TC2 knew the key objective of this lesson clearly so used the Excel for data and graph generation, based on which topic-related discussions were implemented.

TC2 also used slides, which was just for presenting concepts, examples, and exercises, and he explained: ''it saves me lots of time, and make them [concepts, examples, and exercises] clearer for all students to view, so I basically use it [slides] every day''.

During the lesson, I found that TC2 asked students to go to the projector and presents their work of drawing ''frequency segments'' and classroom exercises. So I asked him whether he always used projectors and if yes, how. He answered:

> Yes, I always use it. The projector is mainly for presenting students' works like today. I asked students to do experiments and make records in their exercise book, and draw lines to discover the stability of frequency. I asked students to come to the projector to show their works and explain their graph and what can be concluded and so on. Students can make guesses and argue with others based on their own works. They love it, and it's like their shows.

It can be seen that, computer and projector were commonly used in TC2's lessons. Computer was a good presenting tool with the help of slides, and the computer helped students reflect on and discuss certain topics when other software was adopted, such as the Excel. The projector was good for showing students' classroom works, and by doing so, according to TC2, students seemed more involved in having discussions and arguments with each other.

<u>Lesson and interview of TC3</u>

The topic of TC3's lesson came from Grade 8, lesson 7.2 *Graphs and properties of reciprocal* *function*. During this lesson, TC3 asked students to explore new functions ($y = \frac{6}{x+1}$ and $y = \frac{6}{x} + 1$) by using the methods of translating graph of an already learned reciprocal function ($y = \frac{6}{x}$). A computer and a projector were adopted in the lesson.

This lesson, as TC3 said, was based on an inquiry of exploring features of function $y = \frac{6}{x+1}$ and $y = \frac{6}{x} + 1$, and the questions and classroom exercises were presented on slides. In the interview, TC3 said that she often used slides for presenting learning information and content to the whole class.

In terms of exploring the features of the functions, GSP was used, and in the interview, TC3 explained her choice of GSP and highlighted the GSP's function of dynamic demonstration for showing the translation of function graphs.

> I used GSP as well in the lesson. I asked students to discuss two functions: y=6/(x+1), and y=6/x+1. They had difficulties in sketching the graphs of these functions, because they cannot remember the range of x and y of the functions. Without clear and right graphs, it is impossible for students to explore the translation of the graphs. So I used GSP to demonstrate how the graph of y=6/x+1 could be obtained from the graph of y=6/x. I showed the translation process dynamically. Similarly, I used GSP to show dynamically that translating the graph of y=6/x leftwards one unit, we can obtain the graph of y=6/(x+1). So they [students] can understand it better.

Besides, a projector was used for showing students' exercises based on which, a summary of key concepts and mathematical methods were made by the end of the lesson. TC3 herself summarised the common way of using the projector:

> I use the projector mainly for showing students themselves' works so that they could actively involve in the classroom instruction. They can discuss their own works instead of mine, which pushes them to deeply reflect their thinking process, and also that was more interesting for them.

Lesson and interview with TC4

The topic of TC4's lesson came from Grade 8, lesson 3.1 *Pythagorean Theorem*. TC4 didn't include many exercises and applications in the lesson, because he wanted to focus on students' understanding of how the theorem came and how to prove it in different ways. This lesson was more mathematics thinking and reasoning-based. TC4 used a range of hardware in this lesson including a mobile phone, a computer, and tablets. Actually, there are only a small number of schools adopting tablets, making them a relatively 'new technology' for mathematics classroom in Nanjing.

The lesson was started by TC4 playing a short video through his mobile phone from a video application called '*Onion video*'. In order to make the video being watched by the whole class, a projector was used. Later on in the interview, TC4 explained that the video was topic-related, so that students can be quickly brought into the learning environment, and also the video caught students' attention and got students prepared for learning.

PowerPoint was adopted for presenting various information and learning materials including Chinese and Egyptian ancient stories on Pythagorean Theorem and different ways of proving the theorem. Slides were used when TC4 spoke to the whole class, and at that time, students just looked at the teacher and cautiously followed what the teachers said and presented.

During the lesson, each student was provided with a tablet which was connected to the teacher's, and it was the teacher who controlled the learning process and changed the content displayed on tablets. According to TC4, the tablets were used as ‘‘a replacement of traditional paper-based learning materials’’: before the lesson, TC4 combined different resources into a learning package in the tablets, so that students could have access to learning resources of different natures and forms; During the lesson, together with the teacher's teaching, the corresponding content on the tablets changed, and students could freely make notes or write down problem-solving processes directly on the tablets. The teacher, in contrast, could view any student's written work through his own tablet without disturbing students. When the teacher found good problem-solving strategies, he just pressed certain bottom on his tablet and showed the student's work onto the screen in the front of the classroom for all students to analyse and discuss.

In the interview, TC4 explained more about how he used the tablets for teaching, and he stated that student directly made notes on the tablets because they could take the tablets home and do revision anytime they want. In addition to the resources in classroom teaching, TC4 also uploaded materials for pre-viewing before lessons and for homework after lessons.

> I asked students to do preview using tablet yesterday and bring them to today's class… students can watch mini-cartoon video on the tablet, make notes on the tablet, and also do exercises on the tablet in or out-classroom teaching. I just control what was shown on their tablet in the classroom teaching, and check anyone's work with my tablet. Basically, I designed and put different forms of materials into the tablet to guide students' learning process. They can make notes on the tablet and take it home and do revisions anytime they want… After the classroom teaching, I upload homework to the tablet as well, and once students finish the homework and submit it, I can directly mark it and make comments. Both of us don't need to wait until tomorrow or later, so that gives us lots of time to check our works, based on which I can further reflect my teaching.

I then asked TC4 to introduce the most commonly used functions of tablets for his teaching, and he claimed two points: multimedia-based preview and provision of feedbacks in the teaching:

> I think the way of using tablets is related to teachers' expectations. I value pre-view very much so I spent a lot of time in making tablets a good tool for preview. I searched a lot of videos online, and uploaded them into the system, so that students could watch the videos before learning and that gives them a preliminary idea of what would be discussed in the lesson. After

> such videos, some simple questions are followed so that students could know what they should understand after the preview.
>
> … Feedbacks, and this is the most powerful function [of tablet] in classroom teaching. In today's lesson, you have seen that during the final several minutes, I have provided students with around 10 short questions. I won't go through it one by one in every lesson, but students can always know what the correct answer is through the tablet feedback system. I can know the proportion of students correctly answering the question, or the proportion that gives wrong answers so I can quickly decide which one should be explained in the whole class. Students' performances on classroom exercises are stored as well in the system, so I can know if anyone badly performed for several lessons and he/she may need extra help. This is a very special function that cannot be replaced by other devices I suppose.

During the lesson, IWB was not used, but in the interview, TC4 provided some information on how he used IWB for teaching. From his words, the IWB was not equipped in every classroom of his school, and he could only use the IWB in the IWB-equipped classroom. He used to link the tablet with the IWB, so that when students wrote on his/her tablet, the works could also be shown on the IWB screen, which was quite good to those who were shy and didn't really want to stand in front of the classroom. Because with such technology, students could sit in their seats and at the same time doing and explaining problem-solving processes.

TC4 emphasised the value of preview in the learning process as well as immediate feedbacks of the homework. By using tablets, he provided relevant materials of different natures to students for the whole learning process, and he can also follow every individual learners' learning progress. TC4's explanations imply that he tries to make full use of the tablet rather than restrict its use just in the classroom teaching.

<u>Lesson and interview with TC5</u>

The topic of TC5's lesson came from Grade 8, lesson 6.5 *equations with algebraic fractions*. The aim of this lesson was to introduce the concept of equations with algebraic fractions—equations with unknowns in the denominators, as well as some methods to solve the equations.

In this lesson, a computer and a projector were adopted with the former one for showing slides, and the latter one for showing students' works and classroom exercises. During the interview, TC5 said that basically he used these two devices every day, and what he showed for the observed lesson were the usual ways that he taught and used in daily teaching work.

> I use computers mainly for presenting slides to students. The slides are useful in managing the whole lesson procedure, connecting different sections of a lesson with fewer mistakes, because I prepared the slides before classroom teaching. The slides are also good for appropriately increase the content of a lesson. Basically I use slides for every lesson that introduces new concepts. I just used PowerPoint in this lesson, because this was an algebra topic which doesn't necessarily need to adopt many technologies, I believe. I just used very common technology and in a simple way.

> The projector is good for demonstrating students' work as I showed today. I also asked students themselves to come to the teaching desk to demonstrate their solutions of certain exercises and encourage students to discuss based on what they 'see'. From their demonstration, I also know if most of the students understand the knowledge in the similar pace. Generally, if I see a student making typical mistakes on an exercise, I can directly project his/her exercise book to the whole class to demonstrate and make comments on, and also ask others to analyse. I also use this device for reviewing and commenting on test papers. Students usually want to know how their peers solve problems and what the differences are between his/her solving strategies and others. So the projector is a good facility to use in classroom teaching.

Lesson and interview with TC6

The topic of TC6's lesson came from Grade 7, lesson 9.1 *multiplication of monomials*, and the aim of this lesson was to introduce and familiarise students to a new computational rule.

In this lesson, a computer and an IWB were adopted for presenting learning resources. In the interview, TC6 explained her choice of technology in this lesson and talked about the usual ways that she used these technologies.

> I used computers in this lesson, and it was for demonstrating examples and exercises on the whiteboard, so that I didn't have to write them myself, and basically this is how I use the slides every day. The main purpose of using slides was just demonstrating, because I was demonstrating rules, questions and other key content of this topic here. I didn't use other software here in this lesson.
>
> In term of IWB, honestly speaking I am not quite familiar with the IWB because normally we don't have IWB for daily teaching. We only got whiteboards in regular classrooms, which we can just write on. IWB is specially equipped in the demonstrating classroom, so usually we just write on the whiteboard, although we can apply for using the demonstrating classroom… In this lesson, I just use very basic and simple function of IWB and I used it together with computers to present slides.

I also asked TC6 if she knew other functions of IWB for mathematics instruction. She thought for a while and mentioned that IWB could be used for highlighting if the teacher wanted to emphasis certain contents. Besides, each page of the materials showed on IWB could be saved and re-used for later reviewing. However, she said that although she knew these functions, she rarely used them.

The following table summarises the six observed lessons on the use of technologies, as well as how the technologies were used.

Table 5-43. A Summary on the use of technology in observed Chinese lessons

Teacher	Technology being used		Ways of using certain technology
	Hardware	Software/Online resource	
TC1	Computer	PowerPoint	Presenting learning materials
		GSP	Drawing figures and dynamic demonstration
	IWB		Presenting learning materials
TC2	Computer	PowerPoint	Presenting learning materials
		Excel	Generating data and drawing graphs
	Projector		showing students works
TC3	Computer	PowerPoint	Presenting learning materials
		GSP	Dynamic demonstrating the translation of function graphs
	Projector		showing students works
TC4	Computer	PowerPoint	Presenting learning materials
	Mobile Phone	Onion video	Playing topic-related video
	Tablet		Presenting learning materials and collecting students' works;
TC5	Computer	PowerPoint	Presenting learning materials
	Projector		showing students works
TC6	Computer	PowerPoint	Presenting learning materials
	IWB		showing students works

In addition to the technologies observed in lessons, questions on other technologies were also raised in the interview, and teachers' answers were rather similar.

Calculators were used by most teachers (except for TC2 who got only 2 years experiences in teaching), but they were trying to use them as less often as possible, because of the ban of calculators on examinations. However, according to most teachers, when calculators were used, they were used under two circumstances: (1) there was a lesson in the textbook specially introduce the use of calculators for a specific purpose. For example, TC5 and TC6 described that in grade 9, students were asked to learn to calculate trigonometrical function of any acute angles by calculators; (2) teachers wanted to design an inquiry-based lesson/activity where complex calculation might be involved. For example, TC4 said that he sometimes proposed real-life problems for students to solve via cooperating, and in this solving process, calculators were used as a tool to find approximate value answers. Such example also confirms the finding that teachers in School I and

II use calculator more for Inquiry and exploring than teachers in School III.

Mobile phones were banned in schools according to all teachers in the interviews, so teachers didn't have much chance to use it in classroom teachings. However they still sometimes used mobile phones to take pictures of students' exercises and works for materials collections. TC4 said: ''I sometimes use mobile-phones to take picture of students' homework, and regard the pictures as resources to put in the slides for helping students review. However I never use it in classroom teaching. Students are not allowed to use phones in the school either. There is no strict restriction for teachers' use of phone in the school, but we rarely use it in classroom teaching.'' Similarly, TC1 also stated: ''I rarely use it. Sometimes when I check and mark students' homework and find unique or special problem-solving strategies, or typical errors that many of them make, I may take pictures of that''. Instead of for teaching mathematics, mobile phones were mentioned by TC3 for general educational purposes. She said: ''I don't think any teachers in my school would use mobile phones in classroom teaching. In terms of out of school time, I know an application called 'Xuewendao', which is used between teachers and parents to share information about the children, like what homework I give, or what is the score of the child in a test, and something like that. I have set up a group there to send information to all parents when needed''.

In addition to the above findings, some other information was also revealed in the interviews. For example, all teachers were asked to point out commonly used software and online resources which had not been observed in the lessons. Their answers were similar to each other. Below I just pick up some answers provided with details.

R: Do you use Micro-office package in your teachings?

TC1: I use slides a lot, for demonstration. But for Word and Excel, not often, just very occasionally. For example, after examinations, I may just use Word to analyse the test in the class, and Word makes it simple and convenient because I don't have to prepare slides. In terms of Excel, I normally just use it for analysing students' scores, and it is for my own work rather than classroom teaching. In the textbook, especially in the topic of statistics, it is suggested that students should use Excel to analyse large data, and I may think of using it in classroom teaching, but really rare, really. Emm… Oh Word, yes I also use it for doing lesson plans and for creating test papers, and this is the main way that I use Word.

R: Do you use any online resources for teachings?

TC6: I don't use the internet in the classroom teachings. (…) But I use it in the office for lesson plans. I search for exercise, examples, and relevant materials, such as pictures, online. For example, when I teach the topic of golden section and golden ratio, I search relevant materials and potential applications of such knowledge from the Baidu[32]. I also like using the internet to search for typical problems, or the problems that students easily solve in a wrong way. There are many websites that serve such purposes, especially those specific maths-teaching website

[32] a search engine in China

> such as Jingyou website (菁优网), Xueke website (学科网). I have downloaded lots of well-designed lesson plans, courseware, and slices, for my teachings. (…) I also used QQ group to share teaching materials with my colleagues, such as lesson plans, courseware, videos of public observed lessons, and so on.

In addition to the information above, TC5 also added:

> TC5: (…) I did use some mobile phone apps such as Xuexibao and Souti. But just use them after class, and never use them in classroom teaching. Sometimes when I feel unsure about the solutions I have, I use these apps to have a check.

It can be seen that Chinese mathematics teachers use slides a lot and the main purpose is for presenting curriculum contents; Word and Excel are just occasionally used by teachers in classroom teaching. The Word is mainly for doing lesson plans and create test papers, and Excel mainly for analysing students' test scores. For online resources, Chinese teachers use a wide range of online resources for their teachings. However, the main use of such resources is not for classroom knowledge delivery either, but for accumulating teaching materials and doing lesson plans.

In summary, from both quantitative and qualitative data, it can be concluded that:

(1) Although most teachers have used calculators, which are just occasionally used in classroom teachings. This can be seen from the fact that the mean score of calculators is just 0.689, and the mean score on each pedagogical strategy is less than 1.0. According to the interviews, all participants mentioned that calculators were banned in any tests, which could be one reason that Chinese teachers rarely used calculators in teaching mathematics. Besides, it seems that most teachers' use of calculators is based on the requirement of the textbook. On the one hand, for some topics, the textbook suggests that students should use calculators to learn; one the other hand, the content of some lessons[33] are manipulations of the calculator. Besides, calculators are rarely used as a tool merely for calculation, and some Chinese teachers would design inquiry-based lessons to integrate calculators, and during those lessons, calculators serve to assist students' exploration. This echoes what Heid and Edwards (2001) found, as they affirmed that calculators were capable to provide immediate results for various calculations including even transcendental numbers, which made them good tools for problem-solving. However, it should be pointed out that the graphical calculator was just used by 34 teachers, and it seems that the affordance of 'visualisaion' mentioned by many researchers (such as Goo, Stillman & Vale, 2007; Sead & Nihad, 2013) is not adopted by Chinese teachers in their teaching practice.

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[33] In Chinese mathematics textbook, content is organised in topics, and each topic contains several lessons.

(2) Computers are the most frequently used technology in classroom teaching, and this has also been reflected in both the questionnaire data and the observed lessons, where all teachers used computers. TC4 has even used both desk-computer and tablets. The words from interviews are consistent with the findings from the questionnaire data. The computer is used as a tool for presenting learning materials such as questions, examples and exercises via slides (the mean score of ID is the highest). Actually, researchers in different countries found similar facts (e.g., Thomas, 2006; Hu, 2011; Zhang, 2015; Rešic & Bešic, 2013), which might indicate that the use of computers as a representational tool is quite common. What's more, computers are also used for dynamic demonstration, such as the change of frequency graphs and the construction of triangles (there are 86.9% of the participants used GSP in their teaching practices). Such dynamic demonstrations have been described by many researchers (e.g., Hadas, Hershkowitz & Schwarz, 2000; Jones, 2000; Mariotti, 2000) as an important approach in preparing students to grasp deductive proof and in assisting students in interpreting complex concepts. The words from the interviews also confirmed the above statement, and teachers claimed that their use of dynamic demonstration was mainly for students' deep understanding of certain concepts, proposition or theorem; besides, in terms of the use of software, most teachers described how they used GSP to teach geometrical topics, which indicates that GSP is a very commonly used software for geometry.

(3) IWB is a less-frequently used hardware, and the questionnaire data shows that only 37.1% of the participants used IWBs. According to the interviews, the IWBs are normally used for presenting theorems, examples and exercises to the whole class, which saves teachers' time. This can be reflected by its mean score of ID (0.778), which is the highest one. Although the interactive function of IWBs is mentioned and highly valued by some teachers, due to the inadequacy of facilities in some schools, teachers lack chances to develop various pedagogical strategies of teaching with IWBs. This finding also confirms what has been found by Hammond *et al.* (2009) that the inadequacy of facilities might be a main reason for the low utilisation rate of technology in schools.

(4) Mobile phones are rarely used by teachers in their classroom teaching, and the mean score of it is the lowest one over all technologies. A very important reason is that students (and teachers in some schools) are not allowed to use mobile phones in the classroom. However, teachers still viewed mobile phones as a good tool for accumulating teaching resources, such as students' homework and videos from certain applications, and they normally use phones at off-lesson times. This finding is consistent with what Galligan *et al*. (2010) discovered as they found that the mobile device-instruction was good for instructors to analyse their teachings, and this study further provides Chinese teachers' way of using mobile phones in reflecting their instructions. Besides, mobile phones are also used as a connecting tool between teachers and parents for sharing

information of the children, although this is not particularly for mathematics education. It is also worth mentioning that there are some educational applications which can be used for mathematics teaching and learning, but only a few teachers realised that and made use of the applications. In my opinion, teachers and students should be encouraged and be given more opportunity to explore the educational functions of mobile phones so that they can be exposed to a variety of teaching and learning resources.

(5) Projector is a commonly used technology in Chinese mathematics classrooms. However, the projector is used mainly for presenting, but in a relatively interactive way so that students' work is presented to the whole class for making comments and for giving rise to discussions. The interviews from six teachers also confirmed the findings from the questionnaire that although the mean score of projector is just 0.591, the score for the strategy of RD is 1.012 which is significantly higher than those of other strategies. This finding corresponds Zheng's (2006) and Zhang's (2015) studies who found that Chinese teachers' use of technology was mainly for whole-classroom instruction. The interviews from six teachers also confirmed the findings from the questionnaire that the mean score of projector ('other' technology) for item 20 is 2.079, which is much higher than all other items. The findings show that although projectors are often used, the device is employed in a limited way—reflecting and discussing through students' work.

5.5.2 Influencing factors

In the interview, teachers were also asked how different factors influenced their tech-related pedagogical behaviours, and by answering the questions, all teachers provided me with concrete examples which revealed more specific and contextualized evidence of the influencing factors on teachers' uptake of technology in instructions.

School facility and resources

Quantitative analysis of the questionnaire data revealed that school facility and resource was a very important factor, which was also confirmed by the interview. By providing different examples, all teachers expressed the direct impact of school facilities and resources on their tech-related behaviours. For example, TC1 compared his pedagogy in the observed lesson with other pedagogies he used several years ago in teaching the same topic, and stated that:

> [the method I used today] is totally different from how I used to teach several years ago. At that time, classrooms were not equipped with computers, IWBs, and other technology, so I had to write all things on the blackboard. It was so inefficient, and it was impossible for me to cover as much content in one lesson as I do now. I also find that students can understand the knowledge better with the help of technology like GSP and IWB, because they can 'see' things before 'think'. I would definitely use technology if I was provided such technology at the early time.

Similar ideas have been mentioned by TC3, TC5 and TC6 in whose schools there were only one or two classrooms equipped with IWBs. These teachers expressed their desires of using IWBs to have more interactions with students in the teaching of certain topics. However, due to the lack of sufficient facilities, they have to give up such ideas.

Another example came from TC2 who described in detail how his plan for the lesson 'frequency and probability' had formed. TC2 said that he was thinking about providing each student with an iPad for graphing, so that the chance of self-inquiry could be given to students. However, due to the lack of devices in his school, he finally changed his pedagogy and used Excel for demonstrating statistical results.

In addition to hardware, the quality of the internet in school has also been complained by teachers. During the interview, all teachers talked about the slow speed and instability of the internet in classrooms, which stopped them from using online resources in their teaching. A typical example was given by TC3:

> When I taught the topic of *relations between a circle and a straight line*, I asked students to think and give me examples based on their real-life experience. One student gave me the example of the sun coming out from the horizon. This process can exactly reflect the three relations [between a circle and a straight line], so I was thinking about playing a video to visually present it. But I couldn't access the internet and search it online so I quitted. This example was raised by a student, so I feel especially regretful.

Teachers mentioned that usually if they wanted to use videos or other online resources, they would download the materials beforehand in their office, and then use them in classrooms. However, ideas and requirements which are raised by students in the process of classroom teaching can hardly be prepared beforehand (as the above example), and under such condition, the lack of sufficient technological and resources supports greatly influence the effect of classroom teaching. Similarly, when those online materials cannot be downloaded, the difficulty of getting such materials increases. As TC1 said:

> … Some videos cannot be downloaded, so I would say the ideal situation is that I can directly play the videos via the website in the classroom. By doing so, I have to assure that the quality of the internet in the school is pretty good, which is sometimes hardly guaranteed. So now I normally play the video before the lesson in my own computer, and at the same time use another video-maker software to make a cope, and then play the cope in classroom teaching. Of course, then I have to learn to manipulate that software, which takes time…

The lack of sufficient technology not only restricts teacher's chances of using different technologies, but also further limits the development of teachers' knowledge, skills and familiarity with technologies, and this fact was mentioned by TC3, TC5 and TC6. According to the interview, these teachers stated that having not being exposed enough to IWB resulted in their unfamiliar with the devices, so they might tend to not use IWB even though they had the chance. Like TC5 said:

> …Another problem is that there is only one IWB in our school, and not each classroom is equipped with the IWB, so we don't have many chances to practice using the device. I personally lack sufficient knowledge and skill to use IWB, so I may not really want to use it sometimes.

The words from teachers show that hardware in schools indeed affected their tech-integrated teaching practices. In the interview, both TC5 and TC6 pointed out the lack of IWBs in their schools, which might be the reason that teachers in school III use IWBs less often than their counterparts in School I.

<u>Knowledge and Skills</u>

The above TC5's words not only indicate the importance of school facility and resource, but also imply that with enough knowledge and skills, he would be more likely to use IWB to teach. The idea that knowledge and skills matter in teachers' adoption of technologies have been mentioned by other teachers as well. For example, TC6 claimed that the lack of IWBs in ordinary classrooms in her school impacted her knowledge and skills of using the devices. If she wanted to use IWB, she had to apply for the IWB-equipped classroom and had to practice with the IWB in advance. TC1 provided me with a case in detail about teaching the topic of *nets of a cub*, where he lacked enough knowledge and skill on GSP:

> I think the best situation in using technology is that you do whatever you want, but this is hard to achieve due to lack of knowledge and skills. … For example, when I taught the topic of the net of a cube, I really wanted to use GSP or flash to show students that there are many ways to unfold a cube. However, I didn't know how to design the animation, the dynamic demonstration, so I had to give up this idea and used a real cubic box to demonstrate. I asked students to bring paper-made boxes to the classroom and try to unfold them. There are 11 different ways, so it is really hard for students to discover all possibilities, so I asked them to communicate, cooperate and discuss. If I can create the courseware myself by GSP or flash, it would be much easier for me to show students the nets of the cube.

TC1's words indicate that teachers' knowledge and skills of technologies includes both how to manipulate certain devices, and how to design and create materials (i.e. courseware) for lesson demonstration.

It should be mentioned that although teachers considered knowledge and skills important, they value the convenience of using technology more and considered that knowledge and skills should be easily learned. For instance, TC2 valued 'practice' a lot and stated that

> ''…Regards to knowledge and skill, I think, …,yes important, I mean you can always learn [them] by yourself, right? But practice is more important. I just learn those that I think they are useful, so I guess you don't have to specially learn some knowledge, but simply grasp some skills when you need to use.''

For TC2, convenience is important when he thought of using technology. According to TC2, practice is a way to get himself familiar with certain technology, and systematic and special learning should not be required. By recalling her observations on other mathematics teachers, TC6 also thought that mathematics teachers normally just used basic functions of technologies, and no special knowledge and skills were needed. Similarly, such idea is explicitly expressed by TC4, who used tablets in teaching *Pythagorean Theorem*. During the interview, he explained his criteria for choosing technologies:

> I just choose something that they [teachers and students] should already familiar with. In terms of tablets, the system is very easy to operate, and all you need to do is just pressing appropriate buttons without needing special training. You take it and use it very quickly, and this is the principle for any technology in education I think.

These words confirmed TC2's idea, and also expressed teachers' opinions on educational technologies in general that the technologies should be easy to manipulate and special training should be less.

School supports and Professional Activities

Another important issue mentioned in the interviews was communications and support from colleagues. Professional communications in schools, including lesson observations, informal experiences exchanges and discussions, are quite common among Chinese mathematics teachers. In such communications, teachers are provided chances to learn mutually, which could possibly change the ways how they teach. Just like TC5 stated:

> ''I would say practice and communication with colleagues are really important, and I can always learn new things from my colleagues and sometimes copy what they do in terms of using technology in the classroom teaching''.

Another very typical example came from TC3, who were asked if professional communications between colleagues shaped her tech-related instructions, and TC3 responded positively and described in detailed how she formed her lesson design for the observed lesson:

> I have observed my Master's[34] lessons a lot, and also discussed with my colleagues, and they inspired me a lot. I wanted to change the way that I taught, so I expressed my idea to my Master. She is quite experienced, and she suggested me that I could try to re-design this lesson into an activity-based lesson. She also taught me how to create the courseware by GSP. After several discussions, I finally end up with the pedagogy you observed today.

Later on, she added more information, which further confirmed the influence of colleague

[34] In some schools in China, a young teacher is paired with a mature teacher who has much more teaching experience so that the mature teacher (Master/mentor) is in charge of helping the novice teacher (or apprentice) with their professional skills including class management and subject teachings.

exchanges:

> I communicated and exchanged a lot with my colleagues and my Master. I always observe others' lessons and learn from them. I sometimes use their already made courseware and they are happy to share as well. Without their help, I can never grow so fast, and definitely I won't use GSP so often now… The head of our department is actually my Master, who is a mature teacher and very good at using GSP. When I go and observe her lessons, I can always find her using GSP. She's really nice and always welcomes me and other young teachers to her lessons.

Besides the informal professional exchanges among teachers, formal professional activities were also influential to teachers' use of technology. When asked if the school provided technology-based activities, most teachers expressed that few technology-specific activities were organized, however technology-related topics had always been an important part in most of the professional activities. For example, TC1 talked about teaching and researching activities in his school, where a teacher was publicly observed of the classroom teaching, and then followed by a group discussion with all mathematics teachers (or mathematics teachers who were teaching the same grade). The discussion covers a variety of aspects of the lesson from how the lesson is designed, and how the key knowledge is decided to what tools and technologies are used and how about students' reactions. According to TC1, he would regularly observe how other teachers use technologies in different ways, and he would then asked the teachers questions in detail to learn more about technology. TC2 talked about a mini-lecture competition in her school. The competition required participants to produce courseware using computers for given topics, and then uploaded the completed courseware to the school. According to TC2, by attending such competition, he learned a lot by doing the courseware, and ''now I can use them [the courseware] in my instructions.''

More often, teachers were asked to participate in different activities organised by educational bureaus of different levels. Teachers therefore, in most of the cases, would inevitably join in various formal professional activities which exerted influences on their tech-integration instructions. For example, during the interview, TC1 talked about an activity organized by the educational bureau:

> Recently years, the educational bureau is working at building micro-lesson videos pool. These videos are specifically for knowledge and topic which students feel difficult to learn. Teachers in every school are asked to make a short video around 10 minutes to explain one topic to make it easier for students to understand. The pool is also a resource-library for teachers to obtain videos for teachings, and they are encouraged to do so as well. I used to download some videos from the pool and played in the classroom teaching to replace my explanation. For some students, I also encourage them to log in to the pool to frequently watch videos for a better understanding.

TC5 described a city-level teaching competition, in which all participants were asked to use IWB in their teachings and the lessons were public observed and marked. As the representative of his school, TC5 was provided more chances to use IWB in classroom teachings and therefore he got more knowledge and skill about the IWB.

Professional training

In addition to the above activities, teachers also talked about trainings that they attended, in which tech-related content was covered. According them, there are various types of professional training held by different organisations from school or district-authorities to provincial or national educational administrations. The form of training is also multiple from mini-lecture or short-term regular lectures to web-based learnings. During the interviews, all teachers admitted that they had attended different professional training either in-school or out-school, and the main content about technology could be classified into three categories: (1) the introduction of new technology, what it works for and how to operate it; (2) how to creatively use common (old) technologies; and (3) how to use technology in teaching mathematics. The previous two usually deliver only general knowledge and skills, and they are for teachers of all subjects, although in most cases, teachers of different subjects are trained separately; while the third one was subject-based, and more detailed information upon teaching mathematics could be delivered. Teachers stated that in general they could learn new things from all training, which benefited them. However, when talking about teaching mathematics, training on specific topics with adequate examples and cases were more welcomed. For example, TC2 described the training he attended and said that he learned a lot of practical strategies and skills of tech-integration through the type 3 training and ‘‘those in-service training which are more practical, and practice-based training with lots of concrete cases are exactly what I need’’. More examples were provided by TC2, TC3, and TC6, all of whom said that they had attended GSP training organized by their departments, and learned many practical skills for course teaching, and therefore they used GSP more often. The example of more general, subject-mixed training was given by TC4 and TC6 as well, who said that training about IWB were always organized for a large number of teachers in spite of their subjects. Such training, according to TC4, ‘‘are good but sometimes not as good as what we expected’’.

Pre-service training was also discussed by teachers. By using the term ‘pre-service training’, I mean the university learning experiences. From the participants’ words, tech-related courses were covered in the universities and teachers did get acquainted with different technologies through these course. Nevertheless, teachers’ familiarities with the technology was obtained when they entered schools with enough practices. Like TC3 mentioned:

> I learned about slides in the university, so I can use it since then … I mean I didn’t have many chances to use it then. So in terms of practices, in terms of becoming skillful, I learned from my work.

To me, this also explained why teachers valued practice more when they talked about knowledge and skills.

Students

Questions about the classroom size and students were especially proposed. According to teachers' opinion, classroom size indeed influenced teaching effect, because ''less students means more efficient management'' (words from TC1), but when asked if the classroom size influenced their use of technology, teachers either responded that ''I don't think so'' (TC5), ''I don't see a difference. The number of students…I think there is no influence'' (TC2) or expressed that they had not thought much about it. Similar answers were also given when asked if students' skills on different technology influenced teachers' technology-adoption. Teachers generally believe that nowadays, students are what Prensky (2001) called 'digital-natives' and therefore teachers would not consider too much about students' knowledge and skills upon technology. Like TC3 said: ''they [students] are quite good at technology now and much better than we do… I don't think I'll consider students' attitudes or knowledge of technology too much when doing lesson plans. I just start from the content and the knowledge itself.''

Actually, in discussing the relationship between students and using technology, all teachers held a very clear view that they occasionally considered using technologies to attract students' attention and to make students more involved in classroom learning, but more importantly, their decisions of whether or not adopting technology were based on the content to be taught. Like TC6 stated:

> I would think more from the content itself, from what I need to teach. (…) I don't care much about the number of students, I will always use if I think necessary.

A more typical answer was provided by TC5 whose attitude on students' influence on his tech-use changed, from the beginning that he wanted to use technology to attract students' interests and attention, to now he concerned more about the content and knowledge.

> To be honest, I personally don't believe that technology changes the way students learn. They have to face the tests anyway, right? (…) So I did use different technologies to make them happy and enjoying at the very beginning of my career, but now I think more from the content and topic, while thinking less from students.

Pedagogical attitudes and beliefs

It is worthy to be mentioned that compared to other factors, teachers provided much less information about their pedagogical attitudes and beliefs towards educational technology in the interviews, so I specifically asked them how they viewed technology in education, and if such viewpoints had impacts on their uptake of technology.

Answers from teachers implied that in general they had a dialectic view towards educational technology. On the one hand, teachers thought that using technology was an inevitable trend, and students should be given chances to be exposed to various technologies through which information could be searched and knowledge could be learned, and thus teachers didn't refuse to use technology; one the other hand, technology itself didn’t guarantee the acquisition of knowledge, especially when learners were teenagers whose attention and interests were easily occupied by technology, and therefore teachers tried not to use technology too often. For example, when asked why he embedded tablets into classroom teaching and learning, TC4 answered:

> I believe this is a tendency. Our children will inevitably face various technology of different natures, then why we as teachers should reject the technology? Why can’t we provide students with chances to use the technology now, as a preparation for their future lives? This was what I thought at the very beginning.

I then further asked several questions in detail:

> *R: Do you believe that technology really helps to learn?*
>
> TC4: It depends. Some children have a strong self-control ability, then technology is a good helper; while some are not interested in studying and pay much attention in games, and then any technology cannot become learning-assistant.
>
> *R: Does technology help in explaining difficulty knowledge and concepts?*
>
> TC4: To some extent, yes. I am pretty sure that I am teaching mathematics rather than technology, so I am pretty clear that I use technology for teaching mathematics knowledge. So I don’t always think of technology in teaching …if technology helps, I use, or I don’t use.

TC4 expressed his belief about students’ future challenges, based on which he claimed the importance of technology in education. However, when discussing using technology to teach, his emphasis had been put back to mathematics, which suggested that whether or not use technology depended on the knowledge to be taught and learned. Similar points can be found from TC1’s words:

> TC1: I believe that teachers should always update to the new ages, because it is an inevitable trend that increasing technologies are created and adopted... teachers should always update their perceptions and ideas and brace new ideas. Only in this way, can the students walk in the frontier of the age. If we teach in a very old and obsolete way, our students can never be in the front of the age.

But when asked if such idea influence his actual use of technology for teaching, TC1 answered:

> TC1: That [Attitude and belief] doesn’t mean you have to use technology. I will try to use technology if possible, but I will consider my own teaching needs, and content to be taught to decide if technology should be adopted.

In addition to the previous attitudes, there are also some negative beliefs on the usefulness of technology in mathematics learning. For example, TC6 said: ‘‘I don’t really believe software helps students a lot… In some cases, I play videos as a part of my teaching, and they [students] may feel it attractive. But as I said, that is not my aim, and I rarely do so, rarely.’’

It shows that teachers have different attitudes and beliefs on educational technology. Even though there were teachers believed the importance of technology in today's world and students' lives, such attitudes and beliefs played a limited role in teachers' decision-making process on tech-integrations. What really mattered was that how could certain knowledge easily and solidly mastered by students. Just like TC3 stated:

> I believe that the focus of learning is not technology, which is just tool or aid. If students just focus on the technology, rather than mathematics knowledge, then the technology is a disadvantage. I am a mathematics teacher, so I will focus more on mathematics, you know, the subject matters, skills, content, etc.

The interviews imply that teachers have various views on educational technology, and some teachers do believe that they should more often employ technologies and provide students with more opportunities in learning with technologies. However, in practices, all teachers consider using technology based on whether the employment of technologies enhances knowledge delivering and learning, and therefore their beliefs and attitudes exerted less direct influence in teaching practices.

Assessment and Curriculum materials

During the interview, when teachers explained why they rarely used calculators, all of them mentioned the assessment requirement, so I specifically asked questions about the influence of assessment on their uptake of technology in instructions. Information on this issue was mainly obtained from teachers' answers to either the question about calculators or the questions about curriculum materials.

As can be seen from section 5.5.1, all teachers tried ''to use calculators as less often as possible'' (TC3), due to the reason that calculator of any forms are excluded from the Senior High School Entrance Examination (SHSEE). For example, TC5 said: ''I use calculators very occasionally, and so do students. Because SHSEE is not allowed them to use calculators''. TC2 said: ''[I] never [use calculator]. Because students are not allowed to use it in any tests. Besides, I don't think using calculator is necessary, because normally the exercises are not complex in calculation, and they could easily be worked out by paper-and-pen, so I don't use calculations''.

As regards teaching materials, all interviewed teachers use the same textbook—*Secondary School Mathematics textbook of Jiangsu Science and Technology Press*, which is actually used by all schools in Jiangsu province. Besides, teachers have access to quite a wide range of curriculum materials including textbook-corresponding teachers' guidebook, national curriculum standard, a collection of excellent lesson plans, previously used resources, and other paper-formed materials and courseware collected from the internet or shared by colleagues.

According to teachers' words in the interviews, technology-related content was found in both textbook and curriculum materials of different natures. In the textbook, tech-related content could be found in the form of either independent lessons whose aims were introducing students to use technology to solve certain mathematical problems, or attachment information such as suggestions of tech-based activities for certain topics. For example, ''in grade 9, there is one lesson especially introducing how to use calculator to find the values of trigonometric functions for any angles'' (TC5); or ''after learning the concept of variance, there is a small piece of note [in the textbook] to suggest they [students] use Excel to do some explorations'' (TC3). While in other curriculum materials, tech-related contents were more likely to be presented as instructional advice for teachers. For example, before giving the lesson of 'frequency and probability', TC2 searched others' lesson plans and found that Excel was used by other teachers. I then specially asked if teachers followed what textbook presented and took the tech-related suggestions in their teachings. All of them provided me with rather a similar answer that ''it depends, it depends on the topics and content'' (TC3), or ''I rarely follow what has been written in the guide'' (TC6). When further asked the reason why she didn't follow such suggestions, TC6 answered:

> …[M]ost of us just ignore the suggestion, because this has nothing to do with examinations. In addition, I don't think calculator helps students develop their thinking skills, so we just skip it.

TC3 also said that much tech-related content was ignored, but interestingly she proposed a remedy method:

> Yes theoretically [we should teach those content], but you know the test doesn't cover this part, so we just ignore it. Sometimes we will discuss with technology teacher, and ask for their help—ask them to try to cover the content in their lessons, so that students could try to manipulate. The technology teachers would normally help us to complete these tasks.

It should be noted here that TC2 used Excel in his lesson, and in the interview when asked how the lesson plan was formed, the teacher explained that he searched many materials online before the lesson, and there was one lesson plan in which the designer described how to use Excel to gain a better learning effect, so TC2 adopted such idea and utilised Excel in his classroom teaching. Based on this example, I specially asked TC2 whether his teaching practices were usually influenced by different suggestions in teaching materials. TC2 highlighted the content in answering my questions, and stated that he put his emphasis on the content rather than technology itself, so he would cautiously think about such suggestions before making decisions.

Similarly, TC1 shared his experience of professional growth, and his words pointed out that young teachers were more likely to be influenced by instructional suggestions:

> …I think that suggestions in textbooks and other teaching materials will probably influence young teachers because I remember 20 years ago when I was a new teacher, I did what textbook and teachers' guidebook said. With my experiences accumulated, I gradually learned to reflect on the textbook and teachers' guidebook and learn to plan lessons based on my own thoughts and didn't always follow what textbook says.

Overall, the interview data suggests that teachers have different views and reactions to tech-relevant suggestions and content. In general, such suggestions and content in curriculum materials will be considered by teachers, but more importantly, the following two reasons are vital in their final decisions: (1) if the use of technology or relevant content was associated with assessment requirement; (2) if the use of technology indeed enhanced students' learning and understanding.

According to the interviews with six Chinese mathematics teachers, some conclusions can be drawn: firstly there are various factors which influence teachers' use of technology; secondly, different teachers held different views on the usefulness of technology in educations; for example, compared with TC6, TC4 was subject to believe the usefulness of technology in helping students learn difficult knowledge and concepts. Thirdly, for a certain teacher, different factors influence his/her use of technology differently as well.

Besides, what has been found in the interviews, to a large extent, is consistent with the quantitative findings, and the interview data provides more detail information. Teachers' knowledge and skills of technology are influential not only in classroom teaching when teachers need to manipulate different hardware and software, but also in designing and creating learning materials (i.e. courseware). There are many training and professional activities in China for teachers to attend, and in the training and activities, practical information on tech-integration is provided. Teachers welcome practice-based training with concrete cases so that they can directly apply what they learned into their teaching practices. Chinese teachers get a great amount of help and support from schools and especially their colleagues who often share teaching experiences and discuss lesson designs together, so that teachers are more likely to influence each other pedagogically including how different technologies are integrated. The provision of school facility varied in different schools, and in all interviewees' schools of category II and III, IWBs are equipped in only a few of classrooms which doesn't meet teachers' needs, and this supports what I explained in 5.4.1, and seems explain that fact that teachers in School I and II use IWBs differently than teachers in School III. The interviews also reveal that assessment requirements are of great importance in teachers' uptake of technology, which has not been discussed by many studies. Besides, although various instructional materials contain suggestions on the use of technologies, teachers don't usually follow the suggestions, and the utilisation of technologies is mainly decided based on teachers' analysis of content as well as the assessment requirements. Similarly, students' non-cognitive needs (such as being attractive) are considered, but in practices, how the knowledge could be better delivered and understood are always considered first. Teachers' beliefs and attitudes on educational technology vary, and some teachers do consider students' long-term development in a tech-surrounded world. However, their beliefs and attitudes seem to exert less-direct influences on their instructional practices, where students' mastery of concrete knowledge and skills are valued.

Finally, some other factors are also discovered from the interviews. For example, teacher's view on certain influencing factors may be dynamic and changing with his/her teaching years increasing; Another example is that teachers mentioned that they would decide whether or not to use technology based on the content to be taught, which proved the idea that teachers' use of technology should be researched by different discipline rather than in a mixed way, and such idea also supports my intention of doing this subject-specific study.

5.6 Summary

This chapter analyses Chinese teachers' data, based on which questions of how technology is used, and what factors influence teachers' use of technology are answered. The following findings can be revealed:

(1) In general, Chinese teachers used a wide range of technology in their teaching of mathematics, and for different teachers, the adoption of technology is different.

(2) Among all investigated hardware, projector, desk-computer and scientific calculator are used by the most majority of teachers.

(3) Among all investigated software, Microsoft office packages (i.e. Word, Excel and PowerPoint) are most frequently used, followed by Geometer's Sketchpad (GSP) adopted as a dynamic geometry software for dynamic demonstration. However, symbolic manipulation and graphing packages are not embraced by many mathematics teachers in their instructions, and data analysis software is used by only about 5% of teachers.

(4) Chinese teachers use a wide range of online resources for their teachings, including search engines (mainly Baidu), subject-based websites, local instant information exchange packages (either QQ or Wechat), subject-based educational mobile applications, and other downloadable resources.

Besides, information on how different hardware are used by Chinese teachers for teaching is also obtained:

(5) Calculators are not often used in Chinese mathematics classrooms. However, for teachers who use calculators, they are used mainly via the strategy of Inquiring and Exploring (IE), and least used via the strategies of Illustrating and Demonstrating (ID) and Explaining and Justifying (EJ); there is no significant difference in the use of calculators for instructional purposes.

(6) Computers are used by Chinese teachers in a relatively similar way for teaching. Specifically, Computers are mainly used via the strategy of Illustrating and Demonstrating (ID), and Explaining and Justifying (EJ), followed by the strategy of Reflecting and Discussing (RD),

and Calculating and Checking (CC), and least used via the strategy of Inquiring and Exploring (IE); there is no significant difference in the use of calculators for instructional purposes.

(7) Interactive Whiteboards (IWBs) are used mainly via the strategy of Illustrating and Demonstrating (ID), and Explaining and Justifying (EJ), and least used via the strategy of Calculating and Checking (CC), Reflecting and Discussing (RD) and Inquiring and Exploring (IE); IWB is more used for the cultivation of Positive Disposition towards Mathematics (PDM), rather than for other purposes.

(8) Mobile phones are rarely used and there are significant differences in neither various pedagogical strategies nor various instructional purposes of the adoption.

(9) Projector is used mainly via the strategy of Reflecting and Discussing (RD), and less used via other strategies, and the projector is more used for the teaching of Mathematics Thinking and Reasoning (MTR), rather than other goals.

Table 5-44 summaries the above findings:

Table 5-44. A summary of how Chinese teachers use different hardware in their teachings

Hardware	Pedagogical strategy	Instructional Purposes
Calculator	IE > CC, RD > ID, EJ [a]	No significant difference
Computer	ID, EJ > RD > CC > IE	No significant difference
IWB	ID, EJ > CC, RD, IE	PDM > MKS, MTR
Mobile phone	No significant difference	No significant difference
Projector	RD > ID, EJ, CC, IE	MTR > MKS, PDM

a. This means, for calculator, teachers' use for IE is significantly more frequency than that of CC and RD (no significant difference is found between CC and RD), and the use of calculator for CC and RD is significant higher than that for ID and EJ.

(10) As regards the software and online resources, GSP is frequently used to teach geometrical topics for students' deep understandings of concepts, propositions or theorems; and slides are mainly adopted for presenting curriculum content. Although Chinese teachers use a wide range of online resources, the main use of such resources is not for classroom teaching, but for accumulating and preparing curriculum materials.

In addition to the general information of Chinese teachers' use of different hardware, comparisons between different school types have also been conducted and findings are also revealed:

(11) In general, Teachers in School I and II use computers and IWBs more often than their counterparts in school III, while no statistic differences has been found between different types of schools in the mean scores of teachers' use of other hardware.

(12) As regards the pedagogical strategies, the data revealed that for calculators, teachers in School I use them for Reflecting and discussing more often than teachers in other types of schools

and teachers in School I and II use them for Inquiring and Exploring more often than teachers in School III. For computers, teachers in School I and II use them for Explaining and Justifying, and Inquiring and Exploring more often than teachers in School III; teachers in School I use them for Reflecting and Discussing more often than teachers in School II, and for the same strategy, teachers in school II use the computers more often than teachers in School III. For IWBs, teachers in school I and II use them more often for both Illustrating and Demonstrating and Explaining and Justifying than their counterparts in School III. No significant difference has been found in mobile phone and projector in terms of teachers from different school types of their use in various pedagogical strategies.

(13) In terms of instructional goals, the data revealed that significant differences have been found in teachers' use of computer for teaching Mathematics Thinking and Reasoning among the three schools, and teachers in School I and II use IWB more often for cultivating Positive Disposition towards Mathematics.

Finally, findings on the influencing factors are also obtained:

(14) School facility and resources is the most important factor which influences teachers' use of technology in teaching mathematics, followed by school support; other influencing factors contain knowledge, skills, training and professional activities that teachers attend. Besides, the interviews also reveal the influence of assessment on teachers' uptake of technology in instructions.

(15) Beliefs, Instructional materials and students are found to be uninfluential based on the multilevel model constructed in the chapter.

(16) 'Professional activity' is found to be a school-level influential factor. Specifically, at schools where the mean score of 'teacher's use of technology scale' is lower, the influence of 'activity' is stronger.

Chapter 6 English Teachers' Use of Technology in the Instruction

In this chapter, research questions will be answered to describe English teachers' use of technology in instructions. This chapter adopts the same structure as the previous chapter and contains 6 sections. The data analysing methods for each question keep the same as previous chapter, therefore for the convenience in reading, only findings are presented.

6.1 Demographic Information of the English Respondents

In England, the head of mathematics department of each school could choose to fill in either online questionnaires or paper-based questionnaires, and there were three schools whose teachers filling in paper-based questionnaires. In total, 147 questionnaires (including paper-based and online forms) are provided to 17 secondary schools in South part of England, and 119 valid returned, making the response rate being 80.9%. The table below presents the response rate at each category of schools in the population.

Table 6-1. Valid response rate by school categories in England

	No. of questionnaire sent	No. of questionnaire back	Response rate
Category I Schools (5 schools)	49	44	89.8%
Category II Schools (6 schools)	52	37	71.2%
Category III Schools (6 schools)	46	38	82.6%
Total	147	119	80.9%

According to respondents' answers to the part A of the questionnaire. 76 out of 119 are females (63.9%), and 43 are males (36.1%). The largest age group in which the participants dropped is between 30 and 39 (51.3%), and the average teaching year of all teachers is 9.2. There are 105 teachers (88.2%) holding the Postgraduate Certificate in Education (PGCE), and only 3 teachers (2.5%) hold The Postgraduate Diploma in Education (PGDE). As regards the topics taught in the academic year when the study was conducted, there were 109 teachers (92.4%) indicated that they had taught all topics listed in the questionnaire (including Number, Algebra, Probability, Statistics, Geometry and measurement, and Ratio proportion and rate of change). More detailed information on the profile of all participants is presented in Appendix G.

6.2 Technology Being Used

6.2.1 Hardware and devices

In question 5, five categories of hardware are listed. The Tables below depict teachers' responses to this question.

Table 6-2. Number of English teachers using calculator to teach

Type	None [a]	Simple	Scientific	Graphical	Symbolic
Number of user	0	85 (71.4%)	104 (87.4%)	21 (17.7%)	3 (2.5%)

[a] Hereinafter numbers of teachers in 'None' refers to those didn't choose any option in this sub-question.

Table 6-3. Number of English teachers using computers to teach

Type	None	Desk-computer	Laptop	Tablet
Number of user	5 (4.2%)	85 (71.4%)	70 (58.8%)	37 (31.1%)

Table 6-4. Number of English teachers using other hardware to teach

Type	None	IWB	Projector	Mobile phone	Other
Number of user	5 (4.2%)	102 (85.7%)	46 (38.6%)	13 (10.9%)	3 (2.5%)

Similar to Chinese teachers, English teachers adopted a variety of hardware and devices in teaching mathematics, and for different teachers, the adoptions of technologies are different. Besides, in each category, there is one device used by the majority of teachers. For example, calculators have been used by all participants although the types of calculator used varied, and the most frequently used one is scientific calculators (87.4%), while only less than 20% of teachers used graphical or symbolic calculators. Desk-computer and laptop are the most frequently used computer, and only 37 teachers (31.3%) used tablets in teaching mathematics. As regards other technologies, IWB is ticked by 102 teachers, and this number is the closest one to the number of scientific calculators, and these two are the most frequently used hardware over all technologies. Besides, the proportion of respondents who used mobile phones is only 10.9%, making it the least used device. Although there are 3 teachers indicated that they used other devices in their teaching of mathematics, but only one teacher specified that he/she had used pupil response unit.

These 17 schools are classified based on their students' performance on GCSEs into three categories: I (schools with performance above the average of the whole England), II (schools with average performance of the whole England), and III (schools with performance below the average of the whole England). Now I will use chi-squares test to see if there exists a significant difference of choice of technology among teachers from different categories of schools.

Table 6-5. Distribution of the numbers of English teachers among three school categories ticking different hardware and devices

Technology: Simple Calculator

	Category I School	Category II School	Category III School	Total
No	16	9	9	34
Yes	28	28	29	85
Total	44	37	38	119

Chi-square test: χ^2=2.081 df=2 p=0.353

Technology: Scientific Calculator

	Category I School	Category II School	Category III School	Total
No	4	4	7	15
Yes	40	33	31	104
Total	44	37	38	119

Fisher-Freeman-Halton exact test: p=0.475

Technology: Graphical Calculator

	Category I School	Category II School	Category III School	Total
No	34	31	33	98
Yes	10	6	5	21
Total	44	37	38	119

Chi-square test: χ^2=1.360 df=2 p=0.507

Technology: Graphical & Symbolic Calculator

	Category I School	Category II School	Category III School	Total
No	33	30	33	96
Yes	11	7	5	23
Total	44	37	38	119

Chi-square test: χ^2=1.840 df=2 p=0.399

Technology: Desk-computer

	Category I School	Category II School	Category III School	Total
No	21	4	9	34
Yes	23	33	29	85
Total	44	37	38	119

Chi-square test*: χ^2=14.075 df=2 p=0.001

Technology: Laptop

	Category I School	Category II School	Category III School	Total
No	8	24	17	49
Yes	36	13	21	70
Total	44	37	38	119

Chi-square test*: χ^2=18.376 df=2 p=0.000

Technology: Tablet

	Category I School	Category II School	Category III School	Total
No	25	27	30	82
Yes	19	10	8	37
Total	44	37	38	119

Chi-square test: χ^2=5.075 df=2 p=0.079

Technology: Interactive Whiteboard (IWB)

	Category I School	Category II School	Category III School	Total
No	4	6	7	17
Yes	40	31	31	102
Total	44	37	38	119

Chi-square test: χ^2=1.613 df=2 p=0.446

Technology: Projector

	Category I School	Category II School	Category III School	Total
No	24	28	21	73
Yes	20	9	17	46
Total	44	37	38	119

Chi-square test: χ^2=4.655 df=2 p=0.098

Technology: Mobile Phone

	Category I School	Category II School	Category III School	Total
No	39	33	34	106
Yes	5	4	4	13
Total	44	37	38	119

Fisher-Freeman-Halton exact test: p=0.475

According to the statistical results above, teachers from the three categories of schools are rather close in using all hardware except for desk-computer and laptops where significant differences have been found. By employing chi-square test again to conduct one to one comparison between School I and School II, School I and School III, and School II and School III, we can see that for using desk-computer, there exist significant differences between School I and School II (χ^2=12.837, with df=1 and p=0.000), and between School I and School III (χ^2=5.080, with df=1 and p=0.024), while no significant differences have been found between School II and School III (χ^2=2.168, with df=1 and p=0.141). For using laptop, there exist significant differences between School I and School II (χ^2=18.328, with df=1 and p=0.000), and between School I and School III (χ^2=6.785, with df=1 and p=0.009), while the difference between School II and School III has just slightly missed the significance level (χ^2=3.065, with df=1 and p=0.080). By checking the proportion of teachers in the three categories of schools using desk-computers and laptops, we can say that significantly fewer teachers in School I use desk-computers; while significantly more teachers in School I use laptops in instructions than their counterparts in Schools II and III.

If we treat 'desk-computer' and 'laptop' as ordinary computers (compare with tablets), it is worthy to see if teachers in different types of school use 'ordinary computers' to the same extent in spite of their differences in using specific ordinary computers. So I combine the data of desk-computer and laptop together and use chi-square test again. The test result shows that no significant difference has been found among the three types of schools (χ^2=0.435, with df=2 and p=0.804), indicating that roughly same proportion of teachers in the three types of schools use 'ordinary computers' in instructions.

In summary, it can be seen that scientific calculator and IWB are two most frequently used hardware and devices. Over half of the participants indicated that they used either desk-computer or laptop in teaching mathematics, and statistically higher proportion of teachers in School II and School III used desk-computer and higher proportion of teachers in School I used laptops than their counterparts.

6.2.2 Software

Questions 6 asks teachers to tick what software and programs they have used for teaching, and the tables below depict teachers' responses to this question.

Table 6-6. Number of English teachers using Micro-office tools to teach 1

Type	Microsoft Word	Microsoft Excel	Microsoft Power Point
Number of user	89 (74.8%)	82 (68.9%)	64 (53.8%)

Table 6-7. Number of English teachers using symbolic manipulation and graphing package to teach

Type	Autograph	DERIVE	Mathematica	Other [a]	None
Number of user	45 (37.8%)	0	0	1	31 (26.0%)

[a] Here, there are seven teachers selecting 'other', but when asked to specify the software adopted, six of them wrote 'demos', which is included in the online resources, and one didn't provided any information.

Table 6-8. Number of English teachers using dynamic geometry software to teach 1

Type	GSP	GeoGebra	Calibri	Other	None
Number of user	31 (26.0%)	56 (47.0%)	1 (0.8%)	0	23 (19.3%)

Table 6-9. Number of English teachers using data analysis software to teach 1

Type	Fathom	General statistical software	Other	None
Number of user	0	0	0	119 (100%)

The figures indicate that English teachers seem not use quite a wide range of software in teaching mathematics. In all software, teachers more frequently use Microsoft office packages than others. Besides, Autograph and GeoGebra are adopted by some teachers as well, following by GSP. While data analysis software is not adopted by mathematics teachers in their instruction. Now let us use chi-square to see how the teachers' school categories are related to their use of different software.

Table 6-10. Distribution of the numbers of English teachers among three school categories ticking different software

Technology: Word

	Category I School	Category II School	Category III School	Total
No	11	8	11	30
Yes	33	29	27	89
Total	44	37	38	119

Chi-square test: χ^2=0.535 df=2 p=0.765

Technology: Excel

	Category I School	Category II School	Category III School	Total
No	11	14	12	37
Yes	33	23	26	82
Total	44	37	38	119

Chi-square test: χ^2=1.552 df=2 p=0.460

Technology: PowerPoint

	Category I School	Category II School	Category III School	Total
No	15	16	24	55
Yes	29	21	14	64
Total	44	37	38	119

Chi-square test*: χ^2=7.122 df=2 p=0.028

Technology: Autograph				
	Category I School	Category II School	Category III School	Total
No	21	23	30	74
Yes	23	14	8	45
Total	44	37	38	119
Chi-square test*:	χ^2=8.452	df=2	p=0.015	

Technology: GSP

	Category I School	Category II School	Category III School	Total
No	33	25	30	88
Yes	11	12	8	31
Total	44	37	38	119
Chi-square test:	χ^2=1.300	df=2	p=0.522	

Technology: GeoGebra

	Category I School	Category II School	Category III School	Total
No	18	20	25	63
Yes	26	17	13	56
Total	44	37	38	119
Chi-square test:	χ^2=5.093	df=2	p=0.078	

The tables above show that teachers' uses of all software, except for the PowerPoint and Autograph, are not associated with the school categories where they work. A further analysis shows that there is significantly higher proportion of teacher in School I used PowerPoint and Autograph than their counterparts in School III (for PowerPoint: χ^2=6.907, with df=1 and p=0.008; for Autograph: χ^2=8.453, with df=1 and p=0.003). While no difference has been found between school I and II, and between II and III in using either software. (Between school I and II for PowerPoint: χ^2=0.713, with df=1 and p=0.269, for Autograph: χ^2=1.688, with df=1 and p=0.141; between school II and III for PowerPoint: χ^2=2.987, with df=1 and p=0.067, for Autograph: χ^2=2.548, with df=1 and p=0.089)

6.2.3 Online resources

Questions 7 asks teachers to tick what online resources (including mobile apps) they have used for teaching during the current academic year. The tables below depict teachers' responses to this question.

Table 6-11. Number of English teachers using general online resources to teach

Type of resources	Search engine				Downloaded Pictures and videos	Other
	Google	Yahoo	Bing	Other		
Number of users	94 (79.0%)	2 (1.7%)	5 (4.2%)	0	68 (57.1%)	5 (4.2%)

Table 6-12. Number of English teachers using mathematics-related online resources to teach

Type of resources	Subject-based Websites, such as MyMaths, NRICH Maths	Maths-online applications, such as Logos, Desmos	Other
Number of users	104 (87.4%)	46 (38.7%)	4[a] (3.4%)

[a] Only one teacher here specified that s/he used school local area network where resources can be obtained.

The figures show that the majority of teachers used search engine (of which Google is the most popular one adopted by 79% participants) and 57.1% of teachers had downloaded pictures and videos from the Internet for their instructions. Besides, maths-related websites are widely used by teachers (87.4%), and 38.7% of the teachers had used online applications. When answering these questions, teachers provided specific examples. For example, *Maths Watch* or *Hegarty maths* contain demonstrative videos covering all topics, exercises, homework and assessment and all students can be recorded in terms of their performance of these practices; interactive web-based software *Board works* contains videos covering all KS3 &4 maths topics, and can be played in classroom teachings; *Mr. Corbett Maths* contains videos and practices resources. It should be mentioned that there were four teachers selecting 'other subject-based online resources' in this question, and only one teacher gave a specific example of *TES Resources*, which is a website containing a variety of teaching resources designed and uploaded by teachers over a range of subjects.

According to the data collected, I just apply chi-square tests (or Fisher-Freeman-Halton exact tests, more detail can be seen in Appendix H) to see if teachers' school categories are related to their use of Google search engine, downloaded resources, subject-based websites, and maths-online applications. The test results show that there is no significant difference among different groups of teachers of their use of any online resources, except for Maths-related Websites, whose test result shows $p=0.028$ (Fisher-Freeman-Halton exact test). A further Fisher exact tests show that there is significantly higher proportion of teacher in School I used Maths-related Websites than their counterparts in School III ($p=0.020$), and no significant differences are found between School I and II ($p=0.404$) and between School II and III ($p=0.222$).

6.3 The Way of Using Technology

Figure 6-1 presents the mean score of all respondents on each technology based on part C of the questionnaire, and Table 6-6 shows the statistical test of the average scores. Hereinafter, before conducting statistical tests, all the data is checked and the result shows that they are approximately normal distributed.

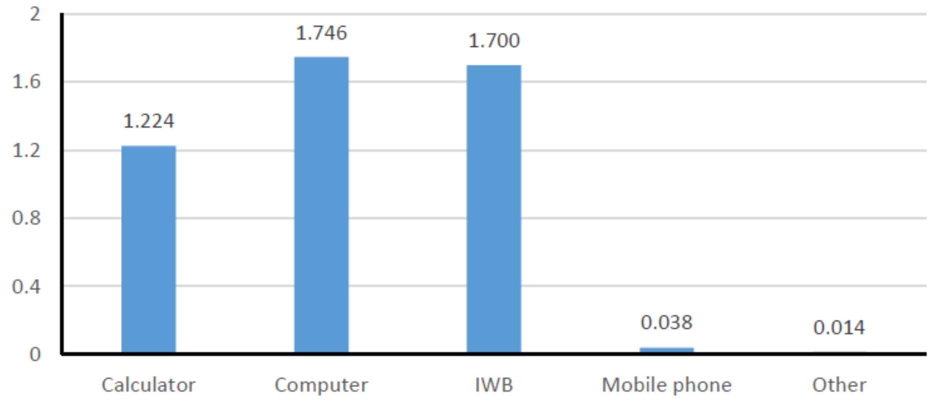

Figure 6-1. Mean scores of English respondents on each technology

Table 6-13. Repeated measures ANOVA test of English teachers' mean scores of different technology

Within Subject Effects	Mauchly's W	Approx. Chi-square	df	Sig.
Mean scores	0.019	461.948	9	0.000

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Greenhouse-Geisser	354.643	1.854	191.268	541.013	.000
Huynh-Feldt	354.643	1.883	188.388	541.013	.000

Mean differences (A-B) B \ A	Calculator	Computer	IWB	Mobile phone	Other
Calculator		0.522*	0.476*	-1.186*	-1.210*
Computer			-0.046	-1.708*	-1.732*
IWB				-1.662*	-1.686*
Mobile phone					-0.024*
Other					

The first two tables indicate that there are significant differences in the mean score among the five different technologies. The final table presents the result of pairwise comparison based on LSD test, which gives information on how each score statistically differs from other scores. The figure provided above, to a great extent, reflects teachers' answers in question 5, in which I found that calculators, computers and IWBs are widely adopted by teachers, and here the mean scores for these three technologies are much higher than others. The above tables also reveal that the difference of mean scores between other different technologies are statistically significant, indicating that in general, teachers use different technologies differently.

Just as the previous chapter, in the following section, how teachers use each device in their instructions is analysed in detail. The comparison on the mean score of each technology between three categories of schools is conducted, before analysing how the technology is used in different pedagogical strategies and goals respectively.

6.3.1 Calculator

The table below presents mean score of technology for each category of school and the analysis of variance, and the figures show that the mean scores of calculators of the three school categories are rather similar and there is no significant difference on the scores.

Table 6-14. Mean scores of calculators of three English school categories

School Category	Category I School	Category II School	Category III School
Mean Score	1.194	1.282	1.204

ANOVA test: F=0.179, p=0.446

Now, whether teachers use calculators in different pedagogical strategies in their teachings is analysed. The mean score for each strategy (ID, CC, EJ, RD and IE) is calculated and compare, then comparisons on the mean scores for each strategy is conducted among different categories of schools. The similar method is employed to the analysis of other four technology as well.

Below, the figure 6-2 presents and compares mean scores of all English respondents' mean score of calculators on different pedagogical strategies, and table 6-15 presents statistical tests of the mean scores.

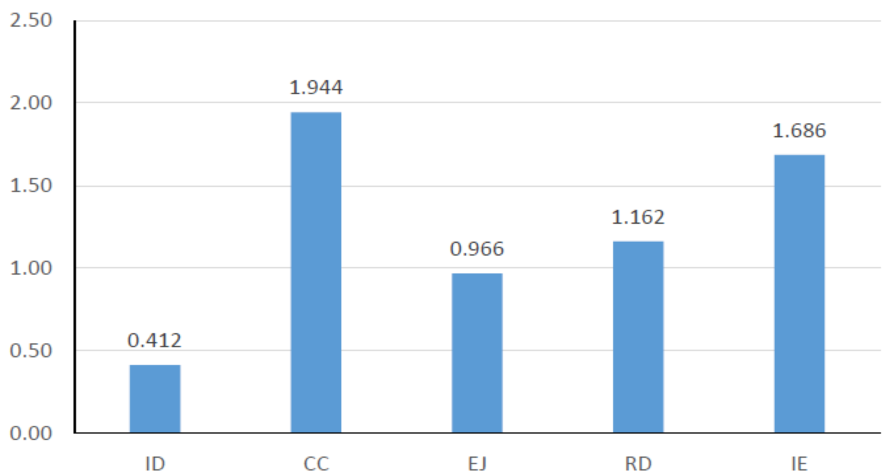

Figure 6-2. English teachers' mean scores of calculators on different pedagogical strategies

Table 6-15. Repeated measures ANOVA test on English mean scores of calculators on different strategies

Within Subject Effects	Mauchly's W	Approx. Chi-square	df	Sig.
Mean scores	0.765	31.191	9	0.000

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Greenhouse-Geisser	173.849	3.485	49.879	321.638	0.000
Huynh-Feldt	173.849	3.604	48.232	321.638	0.000

Overall, the mean scores of calculators on different pedagogical strategies are significantly different. By further using LSD tests of conducting pairwise comparisons reveal that, English teachers' mean scores on different strategies are significantly different from each other's, with the decreasing order of average scores on strategies being Calculating and Checking (CC), Inquiring and Exploring (IE), Reflecting and Discussing (RD), Explaining and Justifying (EJ), and Illustrating and Demonstrating (ID).

Table 6-16 presents the mean scores of calculators in each strategy of the three categories of schools. Based on the figures, a radar chart is formed as showed in figure 6-2.

Table 6-16. Comparison of three English school categories in the use of calculators in different strategies

Strategy / Mean score / School category	Illustrating and demonstrating	Calculating and checking	Explaining and justifying	Reflecting and discussing	Inquiring and exploring
School Category I	0.415	1.864	0.756	1.136	1.800
School Category II	0.459	2.099	1.054	1.252	1.649
School Category III	0.362	1.886	1.125	1.105	1.589
Analysis of Variance	F=0.519, p=0.596	F=1.982, p=0.142	F=7.011, p=0.001*	F=1.444, p=0.240	F=2.661, p=0.074

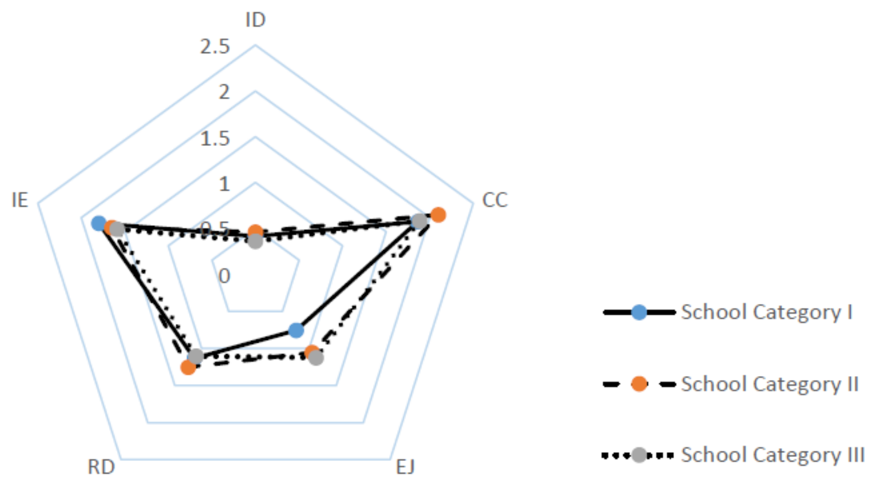

Figure 6-3. Radar chart of English teachers' use of calculators

Both the table and the figure imply that there is no significant difference in the mean scores of ID, CC, RD and IE of using calculators among three school categories, but the mean scores on EJ are significantly different among the three school categories. By looking at LSD test on one to one comparisons in the scores of EJ between the school categories, we can find that the mean score of School I is significantly lower than that of School III (MD=0.298, p=0.006), and that of School II (MD=0.369, p=0.001), but there is no statistical difference between School II and School III (MD=0.071, p=0.521). This shows that in general, teachers in School I use calculator less for explaining and justifying compared to their counterparts in school II and school III.

Finally, let us analyse teachers' use of calculators for different instructional goals— Mathematics Knowledge and Skills (MKS), Mathematical Thinking and Reasoning (MTR), and the cultivation of Positive Disposition towards Mathematics (PDM). Figure 6-4 presents mean score of English respondents of calculators on different goals, and table 6-17 presents statistical analysis on the mean scores.

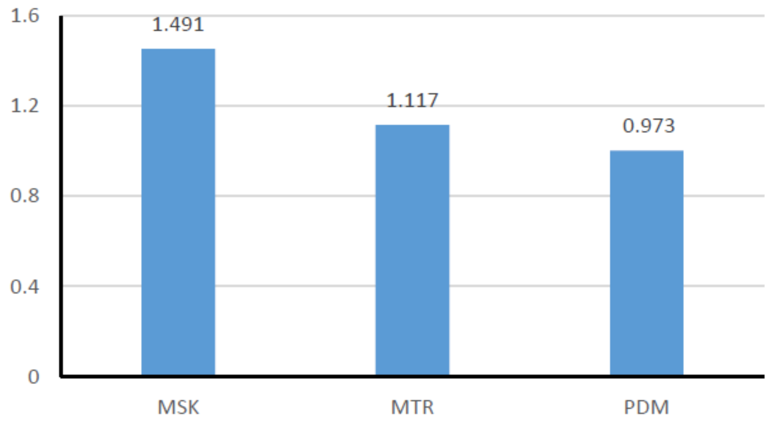

Figure 6-4. Mean scores of English teachers of calculators on different goals

Table 6-17. Repeated measures ANOVA test on English mean scores of calculators on different goals 1

Within Subject Effects	Mauchly's W		Approx. Chi-square	df	Sig.
Mean scores	0.842		20.134	2	0.000
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Greenhouse-Geisser	17.038	1.727	9.886	76.073	0.000
Huynh-Feldt	17.038	1.750	9.734	76.073	0.000

Overall speaking, there are significant differences between English teachers' mean scores of calculators on different goals. By further using LSD test on one to one comparisons, we can find that the mean score of MSK is significantly higher than that of MTR (MD=0.374, p=0.000), and that of PDM (MD=0.518, p=0.000), but there is no statistical difference between the score of MTR and that of PDM (MD=0.144, p=0.059).

Table 6-18. Comparison of mean scores of calculators of three Chinese school categories in different gaols

Goals / Mean score / School category	MKS	MTR	PDM
School Category I	1.428	1.020	1.131
School Category II	1.625	1.179	0.885
School Category III	1.432	1.168	0.875
Analysis of Variance	F=2.635, p=0.076	F=1.922, p=0.151	F=6.048, p=0.003*

According to table 6-18, there is no difference among the three school categories in their use of calculators for MKS and MTR, while significant difference has been found in the score of calculator for PDM. LSD tests reveal that the average score for teachers in School I is higher than that of teachers in School II (MD=0.246, p=0.004), and in School III (MD=0.256, p=0.003); while no significant differences are found in the score of calculators for PDM between School II and III, indicating that statistically teachers in School I more often used calculator to cultivate students' positive dispositions than their counterparts in School II and III.

6.3.2 Computer

According to figure 6-1, computers have been frequently used by teachers, which reflects the findings reported in the previous section. The table below shows mean scores of computers for each category of school.

Table 6-19. Mean scores of computers of three English school categories

School Category	Category I School	Category II School	Category III School
Mean Score	1.816	1.714	1.697

ANOVA test: F=0.411, p=0.664

There is no significant difference on the mean score of computer across the three categories of schools, indicating that in general, teachers of different school categories use computers to the similar extent. Now, let me turn to more detailed investigations on how English teachers use computers in different pedagogical strategies and instructional goals.

Figure 6-5 and table 6-20 show the mean scores and the statistical analysis of all English respondents on computers on each pedagogical strategy.

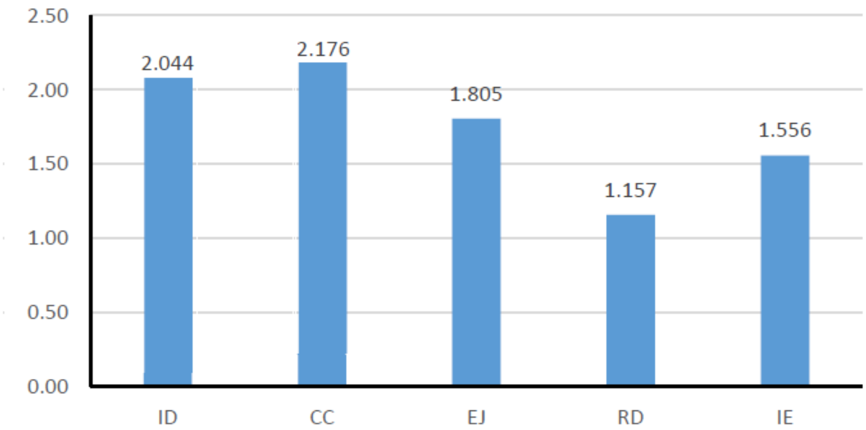

Figure 6-5. English teachers' mean scores of computers on different pedagogical strategies

Table 6-20. Repeated measures ANOVA test on English mean scores of computers on different strategies

Within Subject Effects	Mauchly's W	Approx. Chi-square	df	Sig.
Mean scores	0.650	50.096	9	0.000

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Greenhouse-Geisser	78.620	3.428	22.933	65.492	0.000
Huynh-Feldt	78.620	3.543	22.189	65.492	0.000

It shows that the highest score belongs to CC, followed by ID, and EJ, whose scores are higher than those of IE and RD. Table 6-20 reveals that overall the mean scores of English teachers' use of computers on different pedagogical strategies significantly differ from each other. Further LSD tests of conducting pairwise comparisons reveal that English teachers' mean score on ID is not significantly different from that of CC, but they are significantly higher than scores of other three strategies. Besides, the mean score of EJ is significantly higher than those of RD and IE, and the mean score of IE is significantly different from RD. By looking at the mean scores of each school category on different pedagogical strategies, we can find that there is no statistical difference in the mean scores of all strategies except for Illustrating and demonstrating across the three school categories. Table 6-21 presents the mean scores and the analysis of variance, and figure 6-6 shows a general picture of how English teachers in each school category use computers in different strategies.

Table 6-21. Comparison of three English school categories in the use of computers in indifferent pedagogical strategies

Strategy / Mean score / School category	Illustrating and demonstrating	Calculating and checking	Explaining and justifying	Reflecting and discussing	Inquiring and exploring
School Category I	2.403	2.121	1.943	1.280	1.382
School Category II	1.824	2.207	1.703	1.207	1.643
School Category III	1.842	2.210	1.743	0.965	1.674
Analysis of Variance	F=7.978, p=0.001*	F=0.139, p=0.871	F=1.157, p=0.318	F=1.578, p=0.211	F=1.840, p=0.100

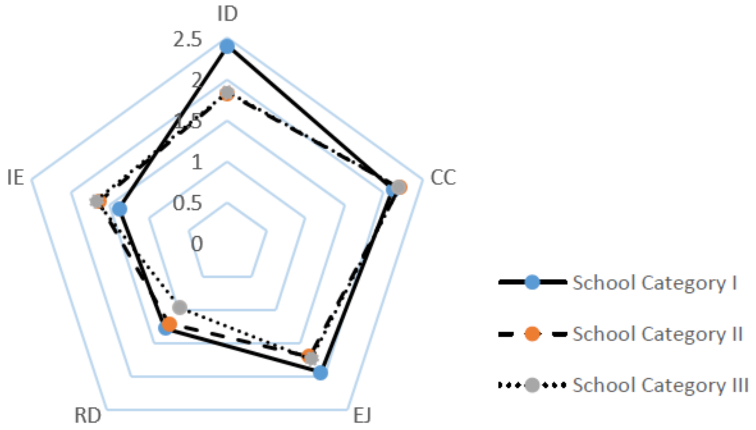

Figure 6-6. Radar chart of English teachers' use of computers

According to the shapes of the radar charts, teachers in different school categories use computers in a rather similar way: generally, computers are used for Illustrating and demonstrating, and Calculating and Checking more often, followed by Explaining and justifying. However, computers are not usually used for either Reflecting and discussing, or Inquiring and exploring. The statistical analysis shows that the only significant difference in the mean scores across three school categories is found in the strategy of Illustrating and demonstrating. A further checking on LSD test shows that the mean score of School I is significantly higher than that of School II (MD=0.579, p=0.001) and School III (MD=0.561, p=0.001), while no significant difference has been found in the mean scores between School II and School III (MD=0.018, p=0.754).

With respect to the use of computers for various goals, I again use the questionnaire data to calculate the mean scores of three goals for all participants as well as for teachers of each category of school and then compare the mean scores, and the results are presented below.

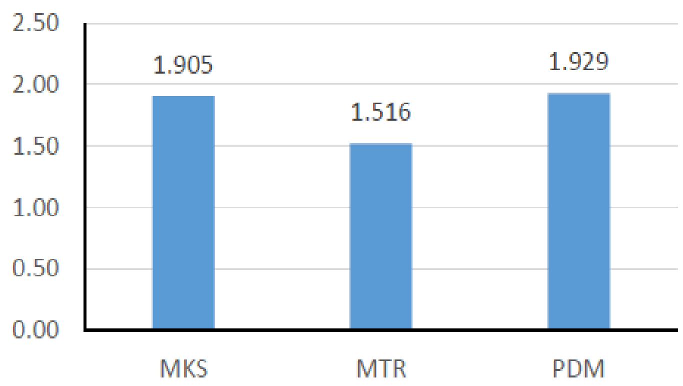

Figure 6-7. Mean scores of English teachers of computers on different goals

Table 6-22. Repeated measures ANOVA test on English mean scores of computers on different goals

Within Subject Effects	Mauchly's W	Approx. Chi-square	df	Sig.
Mean scores	0.767	30.981	2	0.000

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Greenhouse-Geisser	12.797	1.623	7.887	32.100	0.000
Huynh-Feldt	12.797	1.642	7.794	32.100	0.000

The table shows that there are significant differences in the mean scores of computers on three instructional goals. Figure 6-7 shows that the mean score on PDM is slightly higher than that of MKS, which is much higher than that of MTR. Further LSD tests of conducting pairwise comparisons reveal that the mean score of MKS is not different from that of PDM, whose scores are significantly higher than that of MTR. This fact indicates that in general, English teachers use computer more for teaching mathematics knowledge and skills and the cultivation of positive dispositions, while less for teaching mathematics thinking and reasoning. Now, let us compare the scores between different school categories to see if there are differences among the three school categories.

Table 6-23. Comparison of mean scores of computers of three English school categories in different gaols

Goals / Mean score / School category	MKS	MTR	PDM
School Category I	1.919	1.435	2.398
School Category II	1.954	1.416	1.892
School Category III	1.842	1.707	1.928
Analysis of Variance	F=0.220, p=0.803	F=2.342, p=0.101	F=19.608, p=0.000*

Table 6-23 reveals that no significant difference has been found in the mean scores of the goal of MKS and MTR across the school categories, while the mean score of cultivating Positive

Disposition of Mathematics significantly varies across the school categories. The further LSD tests show that the mean scores of PDM in school I is significantly higher than that of school II (MD=0.506, p=0.000) and school III (MD=0.47, p=0.000); no significant difference has been found between School II and School III (MD=0.036, p=0.065).

Considering the figures and statistical results above, we can generally conclude that English teachers use computers in a relatively similar way in terms of instructional goals. However, teachers in school I more often use computers to cultivate students' positive dispositions towards mathematics. Besides, teachers of School I use computers as a tool for Illustrating and demonstrating more often than teachers of School II and School III.

6.3.3 Interactive whiteboard (IWB)

Table 6-24 presents the mean score of IWB for each category of school, and an analysis of variance has been conducted as well.

Table 6-24. Mean scores of IWBs of three English school categories

School Category	Category I School	Category II School	Category III School
Mean Score	1.891	1.694	1.484

ANOVA test: F=3.046, p=0.051

According to the p-value, there is no significant difference in the mean scores of IWBs across three school categories at the 95% level. However, since p=0.051, which approaches the borderline of significance, so I still check further in detail. The LSD results show that the mean score of IWBs of school I is significantly higher than that of school III (MD=0.407, P=0.015), while no significant difference has been found between other pairs of school types. This result indicates that in general, teachers in school I use IWBs more often than teachers in school III.

Figure 6-8 and table 6-25 show the mean scores and the statistical analysis of all English respondents on IWB on each pedagogical strategy.

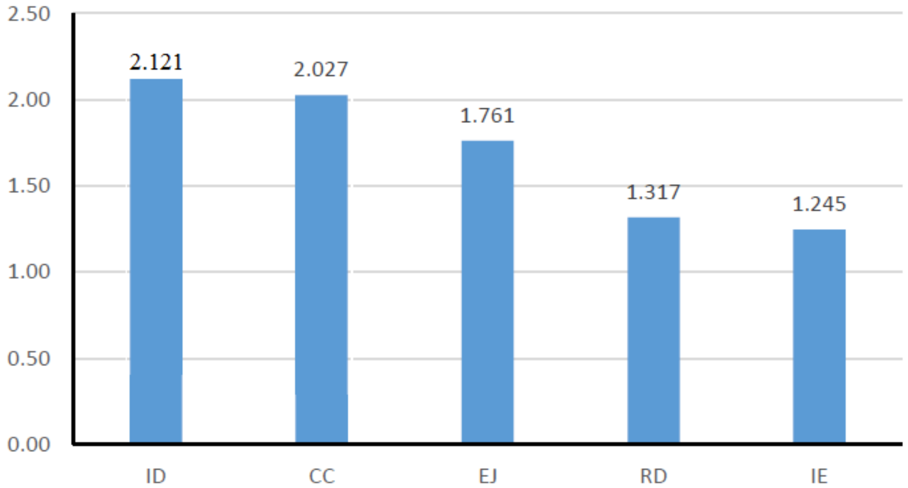

Figure 6-8. English teachers' mean scores of IWB on different pedagogical strategies

Table 6-25. Repeated measures ANOVA test on English mean scores of IWBs on different strategies

Within Subject Effects	Mauchly's W	Approx. Chi-square	df	Sig.
Mean scores	0.675	45.838	9	0.000

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Greenhouse-Geisser	87.496	3.432	25.491	68.867	0.000
Huynh-Feldt	87.496	3.548	24.663	68.867	0.000

The highest score belongs to ID, followed by CC, and EJ, whose scores are much higher than those of RD and IE. Table 6-25 shows that overall speaking, there are significant differences between the mean scores of English teachers' use of IWB on different pedagogical strategies. Further LSD tests of conducting pairwise comparisons reveal that English teachers' mean score on RD is not significantly different from that of IE, but they are significantly lower than scores of other three strategies. In addition to that, the mean scores of ID is not significantly different from that of CC, but they are significantly higher than that of EJ.

Table 6-26. Comparison of three English school categories in the use of IWBs in different strategies

Strategy / Mean score / School category	Illustrating and demonstrating	Calculating and checking	Explaining and justifying	Reflecting and discussing	Inquiring and exploring
School Category I	2.338	2.088	1.954	1.561	1.364
School Category II	2.180	2.007	1.878	1.135	1.306
School Category III	1.799	2.018	1.421	1.210	1.215
Analysis of Variance	F=9.638, p=0.000*	F=0.173, p=0.841	F=4.146, p=0.018*	F=2.487, p=0.088	F=2.127, p=0.113

By looking at the mean scores of each school category on different pedagogical strategies, we can find that there is no statistical difference in the mean scores of all strategies except for Illustrating and demonstrating (ID), and Explaining and justifying (EJ). Table 6-26 presents the mean scores and the analysis of variance, and figure 6-9 shows a general picture of how teachers in each school category use IWB in different strategies.

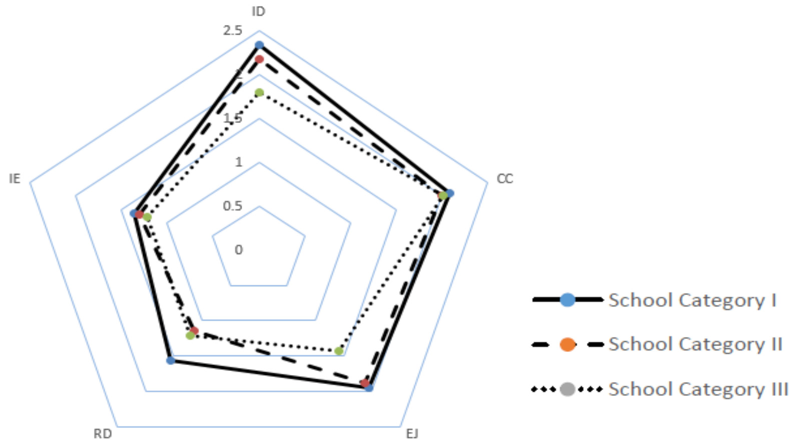

Figure 6-9. Radar chart of English teachers' use of IWBs

According to figure 6-9, teachers seemed to use IWBs less for IE and RD compared to other strategies. Table 6-26 shows that teachers in different school types use IWBs for ID and EJ significantly different from each other. Further analysis shows that for Illustrating and demonstrating, the mean score of School I is significantly higher than that of School III (MD=0.539, p=0.014), and the score of School II is higher than that of School III (MD=0.381, p=0.048) with the p-value at the margin of statistical significance. For Explaining and justifying, the mean score of School III is significantly lower than that of School I (MD=0.533, p=0.042), and School II (MD=0.457, p=0.050), while no significant difference has been found between school I and II either in ID or in EJ.

With respect to the use of IWB for various goals, the results are presented below.

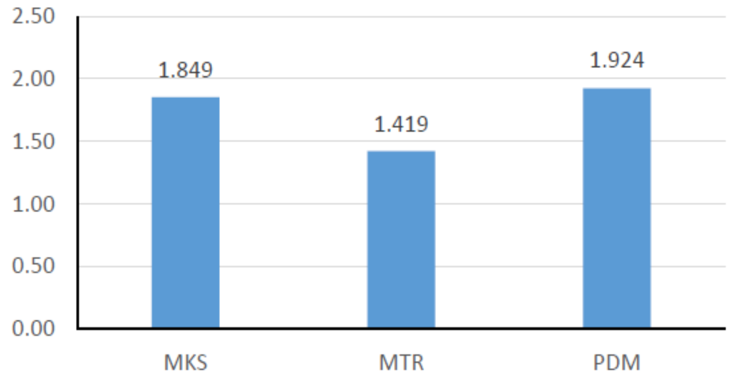

Figure 6-10. Mean scores of English teachers of IWB on different goals

Table 6-27. Repeated measures ANOVA test on English mean scores of IWBs on different goals

Within Subject Effects	Mauchly's W	Approx. Chi-square	df	Sig.
Mean scores	0.801	25.982	2	0.000

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Greenhouse-Geisser	17.674	1.668	10.597	47.890	0.000
Huynh-Feldt	17.674	1.789	10.465	47.890	0.000

The table shows that overall speaking, there are significant differences in the mean scores of IWB of English respondents on the three instructional goals. According to figure 6-10, the mean score on PDM is higher than that of MKS, which is much higher than that of MTR, and further LSD tests reveal that the mean score of MKS is not different from that of PDM, whose scores are significantly higher than that of MTR (both p=0.000). This fact indicates that in general, English teachers use IWB less for teaching MTR, but more for teaching MSK and cultivating PDM. Now, let me compare the scores between different school categories to see if there are differences among the three school categories.

Table 6-28. Comparison of mean scores of IWBs of three English school categories in different gaols

Goals / Mean score / School category	MKS	MTR	PDM
School Category I	1.964	1.543	2.460
School Category II	1.903	1.436	1.844
School Category III	1.662	1.260	1.382
Analysis of Variance	F=1.626, p=0.201	F=1.322, p=0.271	F=16.493, p=0.000*

The mean scores of Positive Disposition towards Mathematics are significantly different across school categories. Further LSD tests reveal that the mean scores of PMD are significant different from each other (For school I and II: MD=0.616, p=0.002; for school I and III: MD=1.078, p=0.000; for school II and III: MD=0.462, p=0.021).

In summary, IWBs were widely adopted by teachers in their instruction, while the data indicated that teachers in school I were more likely to use IWB than their counterparts in school III. As regards the use of IWBs via different pedagogical strategies, the analysis revealed that teachers used IWB more as a tool in ID, CC and EJ than RD and IE. Besides, teachers in school I and II used IWB more through ID and EJ than teachers in schools III. For different instructional goals, the analysis showed that English mathematics teachers use IWB less for teaching MTR, but more for teaching MSK and cultivating PDM. Teachers in school with better GCSEs results used IWB more for cultivating students' positive disposition than those working in schools with less-good GCSEs results.

6.3.4 Mobile phone

Now let us analyse the use of mobile phone in English mathematics classrooms. In the previous discussion, we can see that the mean score of all English teachers on 'mobile phone' is just 0.038, indicating that 'mobile phone' is rarely used in classroom teaching compare.

The following tables and figures present how English teacher use mobile phones in their instructions.

Table 6-29. Mean scores of mobile phone of three English school categories

School Category	Category I School	Category II School	Category III School
Mean Score	0.046	0.037	0.023

Kruskal-Wallis test[35]: $p=0.101$

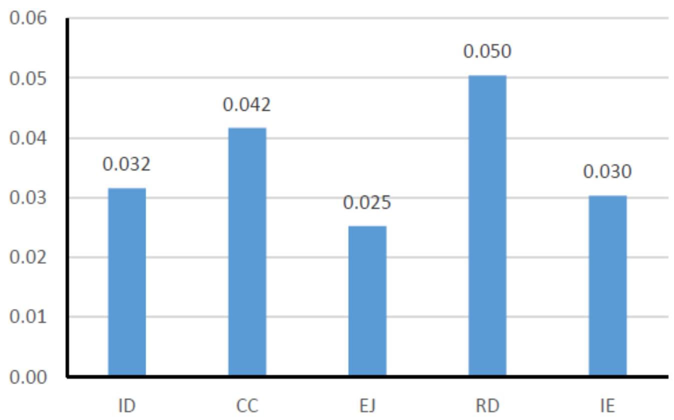

Figure 6-11. English teachers' mean scores of mobile phones on different pedagogical strategies

Similarly, by conducting the Shapiro-Wilk normality tests, it can be seen that the p-value for all pedagogical strategies are less than 0.05, indicating that the data of these mean scores are not normal distributed. Therefore, Non-parametric (related-samples Friedman's Two-way analysis of variance by ranks[36]) is adopted to check if the average mean score of the five strategies are significantly different from each other. The related-samples Friedman' test shows that $p=0.135$, indicating that there is no difference between the scores of the five different strategies.

[35] The Shapiro-Wilk tests of the normality of these data shows that none of them is normal distributed, so non-parametric test (independent-samples Kruskal-Wallis test) is used here, and $p<0.05$ indicates the existence of statistical difference one the mean scores between different school categories.

[36] Hereinafter, this test is abbreviated as related-samples Friedman' test.

Table 6-30. Comparison of three English school categories in the use of mobile phones in different strategies

Strategy / Mean score / School category	Illustrating and demonstrating	Calculating and checking	Explaining and justifying	Reflecting and discussing	Inquiring and exploring
School Category I	0.058	0.068	0.035	0.078	0.036
School Category II	0.020	0.036	0.027	0.027	0.043
School Category III	0.000	0.048	0.000	0.018	0.010
Kruskal-Wallis test	p=0.063	p=0.091	p=0.103	p=0.110	p=0.111

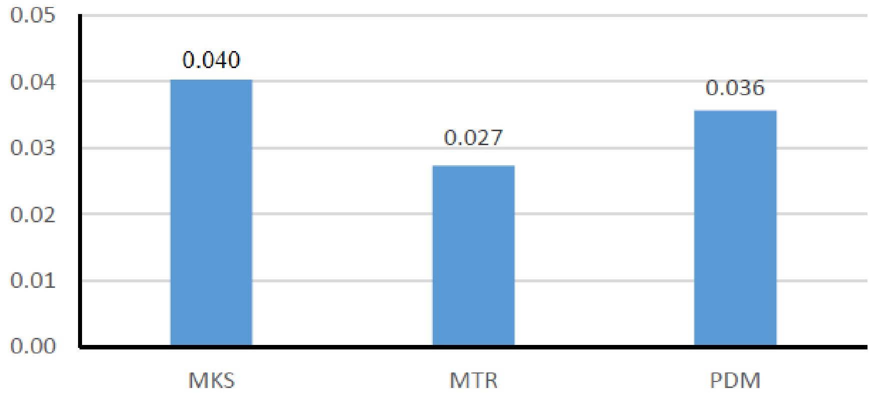

Figure 6-12. Mean scores of English teachers of mobile phones on different goals

Related-samples Friedman's test is used here to check if there is a statistical difference on the mean score of the three goals. The test shows that p=0.162, indicating that there is no significant difference between English teachers' mean scores of mobile phones in different instructional goals.

Table 6-31. Comparison of mean scores of mobile phones of three English school categories in different gaols

Goals / Mean score / School category	MKS	MTR	PDM
School Category I	0.046	0.042	0.052
School Category II	0.027	0.030	0.040
School Category III	0.026	0.010	0.000
Kruskal-Wallis test	p=0.070	p=0.064	p=0.117

As can be seen, there is no significant difference on the mean score of the mobile phones across the three school categories. In addition, on neither pedagogical strategies nor instructional goals, differences are found in the mean scores of mobile phones, indicating that teachers from the three categories of schools used mobile phones in a similar way.

6.3.5 Other technology

Finally, I will turn to 'other' technology. Table 6-34 below shows the mean scores of three categories of schools on 'other' option, and there is no significant difference on the mean scores across the three categories of schools.

Table 6-32. Mean scores of other technology of three school categories

School Category	Category I School	Category II School	Category III School
Mean Score	0.010	0.018	0.013

Kruskal-Wallis test: p=0.324

The figure indicates that 'other' technology is rarely used in teaching mathematics, and this is consistent with the data in section 6.2 where I found that only three participants indicated that they used 'other technology', and only 46 teachers claimed that they used projectors.

Figure 6-13 shows English respondents' mean scores of 'other technology' on each pedagogical strategy.

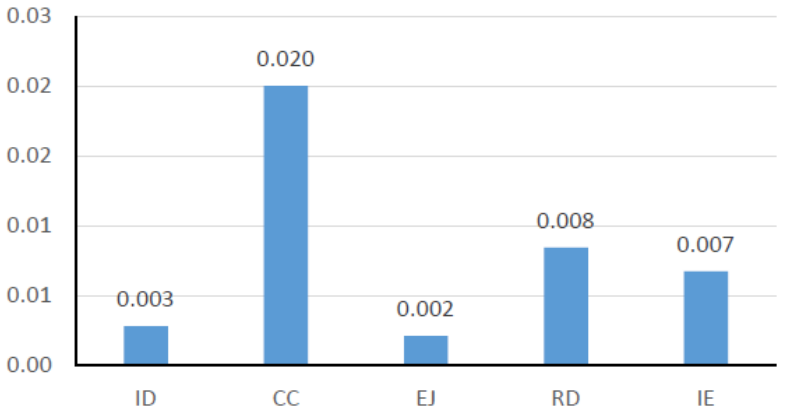

Figure 6-13. English teachers' mean scores of other technology on different pedagogical strategies

From figure 6-13, it seems that the highest score belongs to CC, while the related-samples Friedman' test shows that p>0.1, indicating that overall speaking, there is no significant difference between the mean scores of English teachers' use of 'other technology' via different pedagogical strategies.

By looking at the mean scores of each school category on different pedagogical strategies, we can find that there is no statistical difference in the mean scores of any strategy, which indicates that statistically all teachers use projectors in a similar way, and they followed the pattern that has been discovered and explain before.

Table 6-33. Comparison of three English school categories in the use of projectors in different strategies

Strategy / Mean score / School category	Illustrating and demonstrating	Calculating and checking	Explaining and justifying	Reflecting and discussing	Inquiring and exploring
School Category I	0.000	0.022	0.000	0.000	0.004
School Category II	0.009	0.027	0.000	0.016	0.009
School Category III	0.000	0.009	0.006	0.000	0.000
Kruskal-Wallis test	p=0.330	p=0.581	p=0.344	p=0.084	p=0.134

With respect to the use of IWB for various goals, figure 6-14 and table 6-37 to table 6-38 below present the analysis of the mean scores of other technology in the three instructional goals.

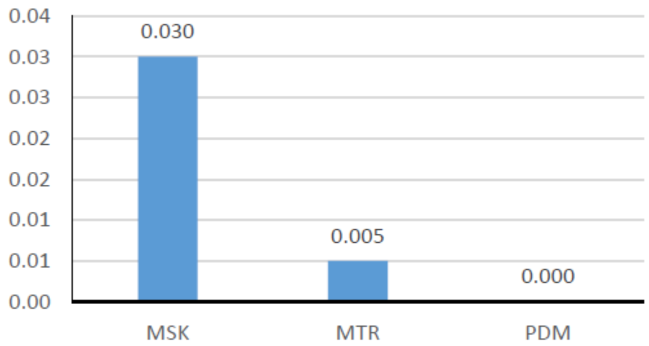

Figure 6-14. Mean scores of English teachers of other technology on different goals

Related-samples Friedman's test is again used here to check if there is a statistical difference on the mean score of the three goals. The test shows that p<0.01, indicating that there is a significant difference between teachers' mean scores of other technology on different goals. Further homogeneous subsets show that the mean scores of MKS, MTR and PDM are significantly different from each other. (For MKS and MTR: p=0.000; for MKS and PDM: p=0.000; for MTR and PDM: p=0.025).

Table 6-34. Comparison of mean scores of projectors of three English school categories in different gaols

Goals / Mean score / School category	MKS	MTR	PDM
School Category I	0.022	0.002	0
School Category II	0.038	0.010	0
School Category III	0.030	0.003	0
Kruskal-Wallis test	p=0.770	p=0.363	/

The table above shows that no significant difference has been found in the mean scores of any pedagogical strategy between teachers of different school categories.

Although the figure reveals that the mean score on different instructional goals are significantly different, the actual scores are much lower than that of previous technologies, and the scores of ‘other technology’ are close to zero, which indicated that, compared to the previously discussed technologies, ‘other technology’ is rarely adopted by English teachers in their teachings.

6.4 Influencing Factors

Part D of the questionnaire describes different factors which may influence teachers’ use of technology, and teachers are asked to indicate the degree of agreement on each statement.

6.4.1 Teachers’ self-evaluations

The figure below shows how English teachers self-evaluated the influences of nine factors on their daily technology integration.

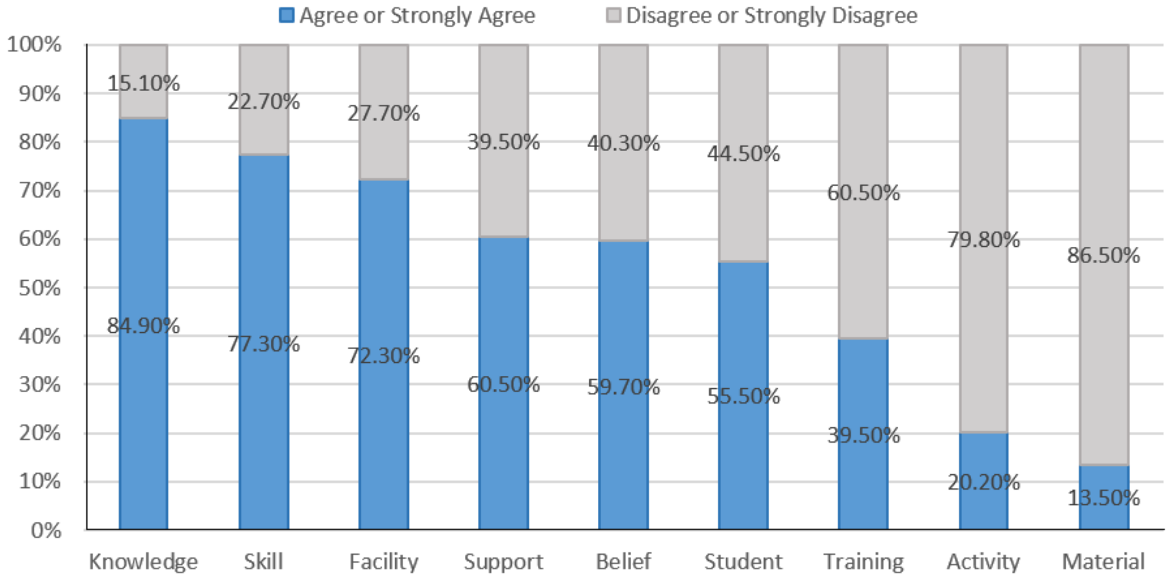

Figure 6-15. Percentages of English teachers’ self-evaluations on each factor

The result showed that there are six factors regarded by the majority of teachers (over 50%) as influential in their use of technology in instructions, and these factors are Knowledge (84.9%); Skill (77.3%); School facility and resources (72.3%); School support (60.5%); Beliefs (59.7%) and Students (55.5%). While Training, Professional activities and Curriculum materials (including textbook) are considered less influential by most teachers.

Similar to the analysis of different technology used by teachers, we are interested in seeing how school categories shape teachers’ view on different influential factors, which will be answered by chi-square tests as follows.

Table 6-35. Distribution of the numbers of teachers in three English school categories giving different evaluation of influential factors

Factor: Knowledge

	Category I School	Category II School	Category III School	Total
No [a]	6	5	7	18
Yes	38	32	31	101
Total	44	37	38	119

Chi-square test: χ^2=0.472 df=2 p=0.790

Factor: Skill

	Category I School	Category II School	Category III School	Total
No	10	5	12	27
Yes	34	32	26	92
Total	44	37	38	119

Chi-square test: χ^2=3.488 df=2 p=0.175

Factor: Pedagogical beliefs and attitudes

	Category I School	Category II School	Category III School	Total
No	13	13	22	48
Yes	31	24	16	71
Total	44	37	38	119

Chi-square test*: χ^2=7.413 df=2 p=0.025

Factor: Facility and resources

	Category I School	Category II School	Category III School	Total
No	15	10	8	33
Yes	29	27	30	86
Total	44	37	38	119

Chi-square test: χ^2=1.743 df=2 p=0.418

Factor: School support

	Category I School	Category II School	Category III School	Total
No	12	14	21	47
Yes	32	23	17	72
Total	44	37	38	119

Chi-square test*: χ^2=6.747 df=2 p=0.034

Factor: Instructional materials

	Category I School	Category II School	Category III School	Total
No	38	32	33	103
Yes	6	5	5	16
Total	44	37	38	119

Chi-square test: χ^2=0.004 df=2 p=0.998

Factor: Students

	Category I School	Category II School	Category III School	Total
No	20	19	14	53
Yes	24	18	24	66
Total	44	37	38	119
Chi-square test:	χ^2=1.621	df=2	p=0.445	

Factor: Training

	Category I School	Category II School	Category III School	Total
No	25	25	22	72
Yes	19	12	16	47
Total	44	37	38	119
Chi-square test:	χ^2=1.131	df=2	p=0.568	

Factor: Professional activities and exchanges

	Category I School	Category II School	Category III School	Total
No	33	31	31	95
Yes	11	6	7	24
Total	44	37	38	119
Chi-square test:	χ^2=1.069	df=2	p=0.586	

[a] 'Strongly disagree' and 'Disagree' are combined to the row of 'No'; 'Strong agree' and 'Agree' are combined to the row of 'Yes'.

From the above table, it is clear that teachers' evaluations of most factors on their use of technology are not associated with the school categories where they work. Significant differences are only found in the following two factors: Pedagogical beliefs and School support. By further conducting one to one comparison, it can be found that for factor of pedagogical belief, no significant difference is found between School I and II (χ^2=0.288, with df=1 and p=0.382), while significant differences have been found between School I and III (χ^2=6.698, with df=1 and p=0.009), and between School II and III (χ^2=3.902, with df=1 and p=0.040), although the p-value is close to the marginal point; For the factor of School support, no significant difference is found either between School I and II (χ^2=1.029, with df=1 and p=0.219), or between School II and III (χ^2=2.287, with df=1 and p=0.100), while a significant difference has been found between School I and III (χ^2=6.643, with df=1 and p=0.009). These figures indicate that in general a higher proportion of teachers in school I believe that their pedagogical beliefs and attitudes, and the support in their schools influence their uptake of technology.

In summary, teachers' self-evaluations on different factors show that except for the factor of instructional materials (including textbook), the factor of activity and the factor of training, all factors are believed to be influential to their use of technology. Further chi-square tests reveal that there are significant differences in teachers' evaluation of influential factors among different school categories on the factor of pedagogical beliefs and the factor of tech-related school support.

6.4.2 Model construction and analysis

As in the previous chapter, in this section, a multilevel model by a stepwise approach with MCMC Bayesian estimate (5000 iteration times) will be constructed for analysing how different factors influence English teachers' use of technology in teaching mathematics.

(1) Null Model (Model 0)

In this part, no predictors of any level were added in the two-level random intercepts model. The result showed that the intercept of this null model was 4.231, which was the average mean score on 'teacher' use of technology' scale of all participants, and the standard error for the intercept was 0.153. By dividing 4.231 over its standard error, we can obtain z=4.231/0.153=27.654, and $p<0.01$, indicating that the intercept is significantly different from 0. Furthermore, assuming a normal distribution the mean score of 4.231 and a variance of 0.249 at school level, the 95% coverage bounds reveal that in the 2.5% schools where teachers frequently use technology in teaching, the average score on the 'teachers' use of technology' scale is 5.209 ($4.231+1.96\times\sqrt{0.249}=5.209$); In the 2.5% schools where teachers less-frequently use technology, the average score on the 'teachers' use of technology' scale is 3.253 ($4.231-1.96\times\sqrt{0.249}=3.253$). Figure 6-17 illustrates the school level residuals on the mean score of 'teachers' use of technology' scale, and from the figure, it can be seen that schools are ordered increasingly by the residual of its mean scores over the intercept value, and the school 13 has the lowest mean score on the scale and the school 4 has the highest mean score.

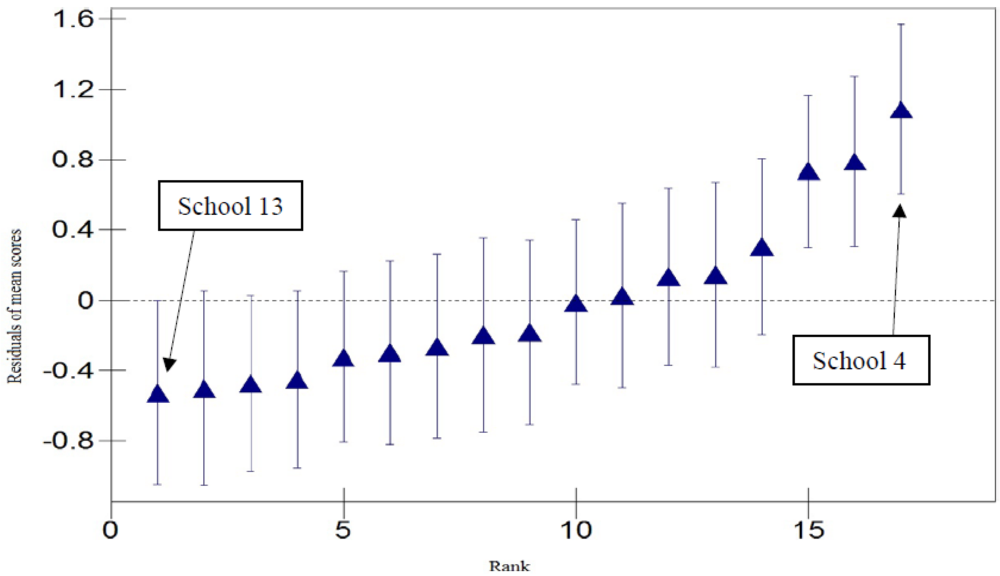

Figure 6-17. School level residuals on the mean score of 'teachers' use of technology' with 95% confidence bands (English)

The calculation of the variance partitioning coefficient (VPC) delivers the proportion of the variance that is attributed to differences between schools. By dividing the between-school variance over the total variance of ‘teachers’ use of technology’ among teachers (0.249/(0.249+0.536)), we can find that 31.72% of the variance is due to between-school differences and 68.28% of the variance is attributed to differences at the teachers level. The change of Deviance Information Criterion (DIC) of the 2-level model compared to single-level model is -60.493, indicating that this two-level null model is a significant improvement over the single-level model.

(1) Model 1

In this part, level 1 (teacher) demographic variables were integrated in the 2-level random intercept model. There are in total seven demographic variables collected in the questionnaire: sex, age group, teaching qualification, the highest degree obtained, teaching years, topics taught and the professional titles. However, only ‘sex’, ‘age group’ and ‘teaching years’ can be added into the model to analyse. Because for teaching qualifications, only 14 teachers are non-PGCE holders; for topics taught, 109 teachers have taught all topics listed on the questionnaire; for highest degree obtained, only 29 participants hold above-bachelor degrees; and for professional titles, only 9 teachers holding titles such as ‘subject leader’, and the rest 110 are just ordinary teachers without any title.

It should be mentioned here that only teaching years is a continuous variable, and others are all categorical variables. In the variable of ‘age group’, due to the small number of participants over 40 (only 18 teachers), so I combine ’30-39’, ’40-49’, and the group ’50-59’ together as the group of ‘over 30’, and set it as the reference category. For the variable of ‘sex’, female is chosen as reference category. Model 1 contained the above described three demographic variables, and from the data analysis results on MLwiN, no coefficient of these variables was significantly different from zero, so all these demographic variables were deleted, and the null model is kept.

(2) Model 2

In this step, all the potential influential factors were added into the null model, and form the model 2a. Table 6-40 shows the estimations and standard errors of the coefficients for all these variables. The analysis result revealed that coefficients for ‘materials’ (z=0.184/0.109=1.688, p=0.094), training (z=0.079/0.116=0.681, p=0.494) and ‘activity’ (z=0.186/0.135=1.378, p=0.168) were insignificantly different from 0, so these variables were deleted, while others were remained. Further analysis showed that all the remaining variables made significant contributions to the dependent variable so they were kept to form the model 2b. The change of the DIC of model 2b from the null model was checked, and the result showed that model 2b significantly fitted the data better than the previous one. (Drop of DIC is 38.848)

(3) Model 3

In this part, random slope exploration was conducted to see if each pre-found factors influence different schools differently: variance for all variables of the model 2b was allowed at school-level, and the variance was checked one by one as did in modelling Chinese data. The result showed that only random variation of 'belief' at school level was significant different from 0 (between-school variation of this slope was 0.226, with its standard error being 0.114, and therefore z=1.982, p=0.047<0.05) (model 3a), and the drop of DIC from model 2b is 12.902, indicating that model 3a significantly fitted the data better than the previous ones, and is retained as the final model.

The inclusion of random variance of 'belief' at school-level added two parametres: σ_{u3}^2 and σ_{u03}. The former one stands for the between-school variance in this slope, and the latter one stands for the covariance between intercepts and coefficients of the slope. In model 3a, $\sigma_{u03} = 0.508$, meaning that schools with a high intercept (above-average mean score in 'teacher's use of technology' scale) tend to have a steeper-than-average slope, while schools with a low intercept (below-average mean score in 'teacher's use of technology' scale) tend to have a flatter slope. This means that at schools whose mean score of 'teacher's use of technology scale' is higher, the influence of 'belief' is stronger than their counterparts, or 'beliefs' for schools whose teachers are more often use technology could be more influential. From my interview, one explanation might be extracted: some schools are easier to attract and recruit ambitious teachers, who may be more self-motivated in pursuing effective teaching, so they might are more likely to think deeply on pedagogical issues, and put their ideas into practices. The interview with TE5 (shown in the next section) could be a good example. One year ago, TE5 noticed that another school was recruiting a lead-practitioner, so she applied for the position and later on attended the job interview in which she demonstrated her professional experiences and ambitious, and finally joined in the school which is where she works in currently. TE5 is a very professional motivated person. She usually utilised summer vacations to train herself different educational software and programs, which she might use in her daily teaching works. Similarly, in the interview, TE3 told me that he was offered a higher position by a better school, and soon he would go to that school to continue his career. Of course, these are just two cases from my interviews. To examine this hypothesis and dig more valuable information to explain such phenomena, future studies are needed.

Finally, the calculation of the squared multiple correction coefficient (R^2) provides us with the proportion of variance explained. The calculation of R^2 at both levels is based on Snijder and Bosker's (2012) work where R^2=$R_1^2 + R_2^2$, and R_1^2 refers to the proportional reduction of error for predicting an individual outcome, and R_2^2 refers to the proportional reduction of error for predicting a group mean. $R_1^2 = 1 - \frac{(\sigma_{e0}^2+\sigma_{u0}^2)_{comparison}}{(\sigma_{e0}^2+\sigma_{u0}^2)_{null\ model}}$; $R_2^2 = 1 - \frac{(\sigma_{e0}^2/\tilde{n}+\sigma_{u0}^2)_{comparison}}{(\sigma_{e0}^2/\tilde{n}+\sigma_{u0}^2)_{null\ model}}$, where $\tilde{n}$ means the harmonic mean of teachers in all schools ($\tilde{n}$=6.69). Table 6-41 presents the proportion of explained variance at both levels for models that were accepted according to the discussions above.

Table 6-36. Estimation and standard errors from the random intercept model of English data (dependent variable: mean score on 'teacher's use of technology' scale)

	Model 0	Model 1	Model 2a	Model 2b	Model 3a
Fixed					
Intercept (cons)	4.231 (0.153)*	4.389 (0.212)*	1.602 (0.646)*	1.491 (0.430)*	1.146 (0.501)*
Sex (Male)		-0.178 (0.137)			
Age group (over 30)		-0.097 (0.145)			
Teaching years		-0.005 (0.013)			
Knowledge			0.304 (0.110)*	0.258(0.100)*	0.237 (0.095)*
Skill			0.328 (0.098)*	0.213(0.083)*	0.241 (0.081)*
Belief			0.336 (0.139)*	0.449(0.133)*	0.393 (0.168)*
Facility			0.302 (0.136)*	0.327(0.131)*	0.349 (0.130)*
Support			0.232 (0.111)*	0.222(0.110)*	0.214 (0.105)*
Materials			0.184 (0.109)		
Student			0.235 (0.106)*	0.222(0.108)*	0.247 (0.104)*
Training			0.079 (0.116)		
Activity			-0.186 (0.135)		
Random					
School level σ_{u0}^2	0.249	0.325	0.247	0.219	0.214
(between)	(0.165)*	(0.157)*	(0.018)*	(0.071)*	(0.052)*
Teacher level σ_{e0}^2	0.536	0.471	0.361	0.346	0.332
(within)	(0.067)*	(0.069)*	(0.044)*	(0.046)*	(0.039)*
Model Fit					
DIC	245.526	247.059	189.098	206.678	193.776
Drop of DIC	60.493			38.848	12.902

Table 6-37. Proportion of variance explained at teacher and school level (English data)

	Model 2b	Model 3a
R_1^2 (proportion of variance explained at teacher level)	0.2802	0.3044
R_2^2 (proportion of variance explained at school level)	0.0856	0.1990

According to table 6-37, when independent variables were added and model 2b was constructed, 28.02% of the variance at teacher-level and 8.56% of the variance at school-level have been explained. In model 3a, the inclusion of 'belief' as school-level variable resulted in an extra 2.42% and 11.34% explained variance at teacher-level and school-level respectively.

In conclusion, according to table 6-36 and table 6-37, model 3a has been accepted as the final model for data of English teachers. The demographic variables have not made contributions in explaining the variance at both levels, while variables 'Knowledge', 'Skill', 'Facility', 'Belief', 'Support' and 'Student' accounted for 30.44% of variance at teacher level and 19.90% at school-level. Among all contributing independents, 'Belief' has been found as a school-level factor.

6.5 Qualitative Data Analysis

In England, there are 5 volunteer teachers for the collection of qualitative data which contains the observation of one classroom teaching and a follow-up interview, and this section reports the findings from the qualitative data.

The table below presents basic information of the five teachers as well as the topic of the observed lessons. It should be mentioned that the TE5 is a Lead Practitioner teacher, and TE1, TE2 and TE4 are heads of the mathematics department in their schools.

Table 6-38. Information of English teachers for classroom observation and interview

	School category	sex	Age group	Year of teaching	Topic of the lesson
TE1*	II	male	30-39	14	Construction of Triangles
TE2	III	male	30-39	10	Reverse Percentages
TE3	II	male	30-39	6	Sine and Cosine Rules
TE4	III	male	30-39	5	Boxplots
TE5	I	female	30-39	8	Inquiry based on Real-life Data

*Hereinafter TE*n* refers to the *n*th English Teacher.

6.5.1 The use of technology in teaching practices

Below, I'll briefly introduce lessons observed and interviews by participants, from which information on the use of technology is obtained.

<u>Lesson and interview of TE1</u>

The topic of TE1's lesson was related to the congruence of triangles, and it was delivered to students of age 13. According to TE1, the aim of this lesson was to try to get students actively practising the skill of constructing triangles under a series of given conditions. For example, given two angles and the length of the common side, students were asked to draw the triangle out.

TE1 used an IWB and a visualiser in delivering the lesson. The IWB was used for presenting learning materials such as warming-up questions and exercises. During the interview, TE1 stated that he normally used IWB just for showing learning materials although there were some maths tool within the IWB package, and the maths-tools "are not user-friendly enough":

> There is an on-screen protractor and other on-screen tools related to maths, but they're not user-friendly enough. They make modelling construction, for today's lesson, at least, um- they- they don't make the explanation easy… And so, as a maths specific teaching piece of software, I don't find it particularly useful, but for general presentations and a whiteboard to write on when you're recording answers, and when you're modelling an algebra topic, for example, just to have that clear whiteboard, the ability to change colours, to highlight key points, move things around the screen if you need to, you can use it for that, but it's not a great software package for maths.

The visualiser was for modelling how to construct triangles with a compass and a ruler. After presenting questions of constructing triangles on the IWB screen, TE1 sat on his chair and drew the triangle under the camera lens of the visualizer and at the same time explained the drawing steps and process. In the interview, when asked how the use of visualiser fitted his instruction, TE1 explained as follows:

> I always try and model best practice with construction. Previously, I'd be trying to model it, stood with the white board, with my back to the students, trying to model it in an unrealistic way, because I wasn't able to use a compass on the white board and show them how to hold the compass and how to manipulate it, whereas the visualizer allows me to model exactly what they got to do with opening up to the set lengths they need for the sides, and how to position the protractor accurately, so it's able to give me much more, um- it makes my explanation much clearer for them and much more useful. They can follow exactly what I'm doing, and they can get a good level of success right from the beginning, rather than having to struggle through.

According to TE1, visualiser was particularly good for modelling practice-based topics where the teacher could easily demonstrate certain skill and at the same time clearly explain to enable students to get much more accurate information.

When asked other ways that he used the visualiser, TE1 mentioned that he also presented good practice of students' own work:

> I've also used it increasing now where there's example of good work from students. Previously, I just take a book and hold it at the front of a classroom, but not everyone can see. If you have the visualizer there, you can place it under the camera. Everyone can see straight away what good work is looking like… it's a fantastic tool for modelling best practice and modelling good maths practices in my opinion.

Lesson and interview of TE2

The topic of TE2's lesson was Reverse percentages, and the aim was to enable students to solve word problems with proportions such as 'Lee bought a shirt with 15% off discount, and he spent £16. What is the original price of the shirt?' This lesson was delivered to students of age 11 and it belonged to the topic 'ratio and proportion'.

During this class, an iPad-connected projector and calculators were used. The projector used together with the iPad for projecting questions and exercises answers for all students, while calculators were used by the teacher and students doing calculations when doing exercises.

According to TE2, he stored a great number of files of questions on all different topics in mathematics, and in order to save time and make full use of the files, he often connected the iPad to the projector and present questions into the whiteboard.

> Sometimes, rather than writing them, I know where it is there. Two seconds. It connects. It's there quicker, because one thing you find in teaching is if you're doing things that take a lot amount of time, you can lose the concentration of the class. Everything has to be quick, quick, quick.

TE2 said that normally he just used the projector in a simple way by presenting questions and answers, and by explaining the reason, he talked about his opinions on mathematics learning. TE2 highlighted the importance of practices in grasping knowledge, and therefore he wanted to provide students with as much time as possible and get them actively doing exercises rather than 'staring at the technology'.

TE2 doesn't often use technology for teaching and he prefers more traditional ways with just a mark pen writing on the whiteboard. According to the lesson observation and the interview, the most common way that he uses technology is that using projectors to project exercises and answers through his iPad where he has accumulated a great number of files for various topics.

Lesson and interview of TE3

This lesson was delivered to students of age 15, and aimed at enabling students to solve problems of non-right angled-triangles with sine and cosine rules.

Calculators were the only technology in the lesson, and it is mainly used by students for exercises. In the lesson, the teacher wrote down and explained the formula structures of sine and cosine rules on the whiteboard with mark pens, before giving two examples on how to use these rules to solve problems. After that, he distributed worksheets to students. On the worksheet, there were 10 questions relevant to the topic, and these questions were mixed with both sine and cosine rules. Students were asked to finish as many exercises as possible and calculators were allowed to be used. During this time, teachers walked around in the classroom to check each student's work and to provide help when asked.

During the interview, TE3 explained his way of teaching and why calculators were used:

> I found that the most effective way in learning is to get students actively practicing, and you got to give them challenge questions. I used to teach sine rule and cosine rule separately in different lessons, but I found students were easily distracted because questions were easy and without challenge, so I mixed the two rule together. Students have to think carefully which rule should I use and how, what conditions are for which rule, etc., so the questions are more challenging, and they need more time in solving the questions.

> …Solving triangular problem involved trigonometrical functions, and without calculators, students could not get the values of trigonometrical functions for giving angles, nor were they told to remember such values, so they need calculators to do such calculations.

When asked if he often asked students to use calculators in this way, and if the calculators were used every lesson, TE3 responded that calculators were just used for doing calculation and students were trained to use calculators by different exercises. In terms of the percentage of lessons with calculators, he said that in general, around 50% of the lessons were with calculators, and normally the higher students' year was, the more frequently calculators were used.

Due to the fact that only calculators were used in the lesson, so I deliberately asked the teacher, for regular lesson teaching, if he used other technologies. TE3 answered that he was actually aware of different technologies and used to use computers and IWBs. However, now he rarely use these devices, and he provided two reasons: on the one hand, he believed that practicing was key to students' grasp of mathematics knowledge, so he was trying to provide as much time as possible for students to do exercises rather than looking at screens and just listening to the teacher; one the other hand, he believed that one of the most important features of mathematics is the logical process of thought and the presentation of that logical argument, and such process was hardly presented by technologies, and actually in most of the cases, technology hid such logical process and ''made them as easier than they really are''. However, he always encourages students to raise questions and solve inter-disciplinary problems (physics problems), so he would use the computer in his classroom to search for information to questions that are unknown to him.

Lesson and interview with TE4

This lesson was delivered to students of age 14 and it was the second lesson of this topic. By the first lesson, students were taught how to read a boxplot to get the mean and the range of a set of data, and in this lesson, the aims were to enable students to (1) read out basic information from a boxplot based on different real-life situations, and (2) draw boxplots based on a set of data.

In this lesson, a laptop and an IWB were used by the teacher. Calculators were adopted by students when they did their classroom exercises.

All the topic-based content was presented through the slides including key knowledge recapping, which was a brief-revision of the knowledge from the previous lesson; examples, through which the teacher explained (on a separate whiteboard) how to read a boxplot based on real-life problems, or how to extract key information from word problems, mathematize the information, and then draw a boxplot to visualise the information; and classroom exercises, for which students were provided around half an hour to work independently.

According to TE4, he uses laptops and IWBs almost for every lesson, and in most of the cases, these technologies are used for demonstrative purposes. Examples are normally presented to show students the problem-solving process, but TE4 usually uses a whiteboard with pens to write down the solving process.

Calculators were used for solving the examples and classroom exercises. The teacher asked students to do calculation work when explaining examples and after that, students were provided a list of exercises showing on the screen and the rest of the time of the lesson was given for students to finish the exercise.

When asked if there were other hardware and software used for teaching mathematics, TE4 pointed out that he also use GeoGebra in teaching geometrical content such as transformation and rotation of figures, while when teaching non-geometrical topics, GeoGera was hardly used. Besides, he also used iPad (together with an online system called *Kahoot!*) for revision lessons when the instructions of certain topics had been finished. However, the use of iPad was not as frequent as others, because according to TE4's explanation:

> We use *Kahoot!*, a free online system and it is like an iPad-based competition, where loads of questions are asked, and you can choose the answer that you think is right, and you compete with others to see who can get the highest mark finally. I do find children feel exciting when using *Kahoot!*, but often they just concern the time, they often just want to press the keys as quickly as possible rather than thinking thoroughly, so I just used this for low-ability students in their lower-year's study, where only easy questions are asked.

It should be mentioned that besides the *Kahoot!*, other online systems are also used by TE4 for homework and GCSEs revision:

> In our department, we also pay for *MyMaths*, and we use it for homework. We ask students to do homework on it… We also use something called *Method Maths*. It's another online tool, and it's for year ten and eleven really, so the higher end of the school…It [*Method Maths*] is mainly for GCSE revision. You see here they'll do the questions on the topic. They're real GCSE papers, and they have to answer the questions to get the marks. It saves a lot of money on printing, it saves us a lot of time on marking. They get instant feedback, it's just a lot easier.

TE4 used quite a wide range of technologies including different hardware, software and various online resources. Besides, rather for a unique purpose, TE4 used such technologies with different aims including classroom instruction, homework, and examination revision.

Lesson and interview with TE5

This lesson was delivered to students of age 14 and was inquiry-based. In this lesson, the teacher introduced *gapminder world* (www.gapminder.org/world) to students, and asked students to do exploration based on the data on the website. The whole 1 hour-lesson was divided into two parts: the first 23 minutes were provided to students for their self-exploring of the website with brief introductions on basic operation of the website, as well as how data could be interpreted. During this introduction, some questions about it were answered by the teacher; secondly, students were asked to compare two countries (a developed one and an undeveloped one) over a two-century time range on the relationship between income per person and life expectancy, and try to explain the traces of the countries in the graph. For example, the following picture shows the traces of the UK and China from 1800 to 2015. Students could observe the relations between income per person and the life expectations in the two countries over the 215 years, so they were asked to try to explain the general tendency as well as why in certain years the relations didn't follow general rules.

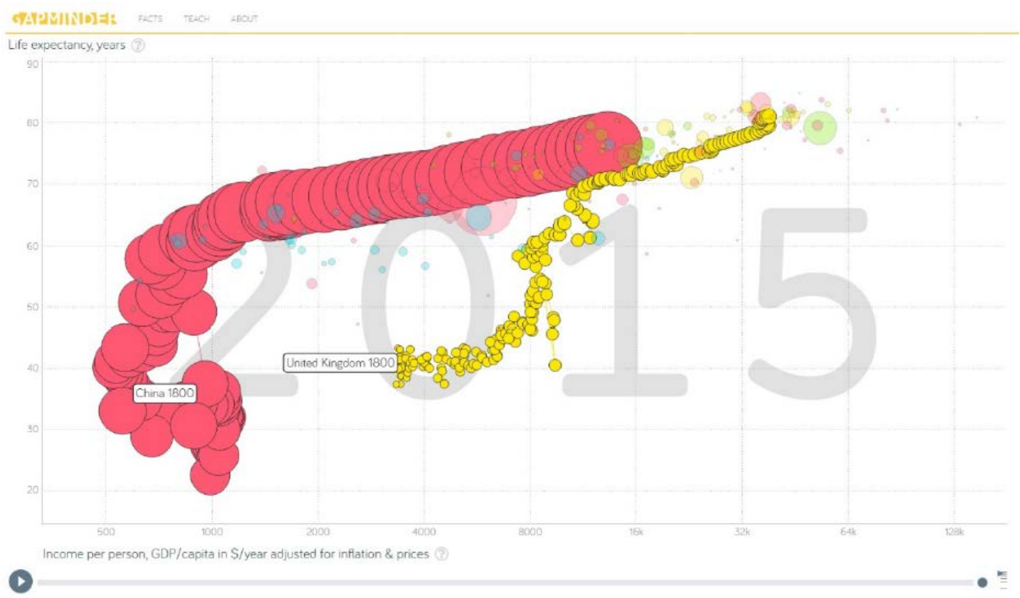

Figure 6-18. An example of *gapminder world* in TE5's observed lesson

According to the teacher, this lesson was designed to make students aware of the importance of mathematics in understanding the real world, rather than applying rules and formulas to do exercises. Besides, by involving in this inquiry, students were introduced to the real-data website which they could have access to and self-explore any topic they were interested in.

In this lesson, a computer and an IWB were used by the teacher. Besides, every two students formed a group with a provided laptop, so that the group could accomplish inquiring tasks.

The teacher used the desk-computer to search the *gapminder world* through Google, and clicked the corresponding link to open the website. Then she gave all students 10 minutes to self-explore the *gapminder world* website before she briefly introduced essential information about the website. When the teacher demonstrated how different graphs could be viewed or how specific countries or regions could be selected, she directly touched the screen of the IWB, and at the same time, asked students to manipulate on their laptops to confirm her descriptions.

After the introduction, TE5 asked all students to observe the life expectancy graph and posed a series of questions such as ‘what is the independent variable and what is the dependent variable?’ and ‘what is the general tendency reflected on the graph?’ By dynamically showing the change of the graph over different years, it had been seen that in general, the dots (one dot represent one country/region) moved along the diameter of the graph from left to right. However, in year 1917 and year 1940, almost all dots on the graph dropped dramatically, so the teacher asked students to explain the reasons behind. According to TE5, ‘such bigger and open questions are helpful and they lead students to apply maths but think beyond mathematics’. Later on, TE5 asked students to work in groups to compare a developed country/region with an undeveloped country/region of the people’s life expectancy over years, try to describe the tendencies and explain the tendencies from various aspects. Students are suggested to use Google and Wikipedia to search for relative information for the exploration.

In the interview, TE5 was asked about the reason of providing students with laptops, and she pointed out that laptops allowed students to go on their own speed and focused on areas which they found interesting:

> The laptops allow students to be completely independent. It allows them to work in different paces, to have different focuses, and allow them to explore – which is what I wanted. If I could have done the lesson with just my graph on the board, that would have only allowed them one view, one option… Because they have access themselves, they could get the excitement going… Some of them had – I was talking to a student who was going to the Maldives this summer, so I looked at Maldives. Some of them have family in different countries, so he wants to look at different countries. They got to explore their interest which made the subject, way more interesting to them.

When asked if she had used other technology for classroom teaching, the teacher explained that she had previously used iPads in the classroom. She connected her iPad with the screen to explain certain content, and it was more for demonstration. But more often, she went around and took pictures of students’ works, marked the works in front of the whole class, showed where they had done correctly, where they had room to improve.

In terms of software, TE5 provided some examples of her previous teaching practices. She used autograph a lot for graphing, and according to her description, she always used autograph to show students graphs of different functions, besides she used autograph to introduce differentiation and to visually demonstration maximums and minimums of various functions when she teaches A-level courses. She also used GeoGebra for geometrical topics although not as often as autograph. With slices, TE5 likes making rolling slides for the recap.

> So basically, you have really simple questions up there. Usually from the previous lesson … I will have up [to] twenty questions, really simple like what’s 15 percent of this, 10 percent of this, one per slide and they all track in move every 3-4 seconds. It’s like a competition and all slides are on a loop so they come back round. The kids they try to write down all the answers. And it means if the kid writes down the answer and misses one, it doesn’t matter [because] it

> will come back up. So it holds their attention for the ten minute to start up. It also means that if the kid is a minute late it doesn't matter they can get straight on it. It means that they have to concentrate really well to answer "have I got that one, have I got that one."

In addition, during the interview, TE5 said that she was quite familiar with different web-resources such as *My Maths*, *Maths Watch*, *Integral MEI*, *Underground Mathematics*, and so on, and these resources covered quite a wide range of learning periods. By using these resources, TE5 obtained a great number of examples and questions with various backgrounds for both classroom teaching and homework. She has also used the online resource for exams (for example, *Integral MEI* has been used as an exam board). The key purpose for which she visited these online resources, was that she searched for big ideas where maths and real-life situations mixed together.

Table 6-39 below summarised the five observed English lessons on the use of technologies, as well as how the technologies were used.

Table 6-39. A summary of technology used in English observed lessons

Teacher	Technology being used		Ways of using certain technology
	Hardware	Software/Online	
TE1	IWB		Presenting learning materials
	Visualiser		Modelling and explaining
TE2	iPad-connected projector		Presenting learning materials
	Calculator		Doing calculation for exercises
TE3	Calculator		Doing calculation for exercises
TE4	Laptop	PowerPoint	Presenting learning materials
	IWB		Presenting learning materials
	Calculator		Doing calculation for exercises
TE5	Desk-Computer	Gapminder world	Presenting learning materials;
	IWB		Introducing and explaining website; doing inquiry
	Laptop	Gapminder world	showing students works; doing inquiry
		Google	Doing inquiry

In summary, from both quantitative and qualitative data, it can be concluded that:

(1) Calculators are commonly used in classroom teaching, and this can be seen from the questionnaire data that 87.4% of participants used calculators. Although calculators were used in different topics, they were mainly for doing calculation for exercises, and the main reason was that

GCSEs embraced calculators (both TE1 and TE4 clearly mentioned that around two thirds of the GCSEs is calculator-based). The findings are consistent with what has been analysed in the section 6.3.1 that calculators were used principally as a tool for Calculating and Checking (CC).

(2) The classroom observations revealed that computers were often used with IWBs together for presenting and demonstrating, as Glover and Miller (2011) stated that teachers usually used IWBs with computers to present multi-resources. This has also confirmed the findings in section 6.3 where the radar charts showed that teachers' use of computers and IWBs are quite similar in terms of different pedagogical strategies and instructional goals. Perrotta (2013) conducted a study with 24 English secondary schools, and he also found that the majority of teachers used technology in an unambitious way, i.e. technology was adopted mainly for presenting teaching content.

(3) Mobile phones were not found in classroom observations. During the interviews, teachers explained that mobile phones were banned in most schools, so teachers didn't have much chance to use it. This fact corresponds to the result from the questionnaire data that the mean score of mobile phones is just 0.038. However, TE5 said that there were some schools where teachers might permit students' use of phones in classroom, but the mobile phones could only be used for learning rather than personal contacting. In that case, students were allowed to bring mobile phones to the school, but could only use the phones as long as they got approvals from teachers in doing certain tasks.

(4) In addition to the above findings, some other issues were also examined in the interviews. For example, during the interviews, all teachers were asked to point out commonly used software and online resources. The answers indicated that firstly, teachers used a good number of online resources of different nature from social media such as *Facebook* and *Twitter*, general search engine such as *Google*, to professional websites such as *MyMaths* and *Hegarty Maths*. Actually, the questionnaire result shows that 87.4% of participants used maths-related websites in teaching mathematics, and up to 79% of teachers used search engines. Secondly, these resources were used for multi-purposes, including materials preparation, in-class demonstration, in-class inquiry, in-class quiz, homework, and GCSEs revision.

6.5.2 Influencing factors

In addition to questions related to the observed lessons, some general questions were also asked upon factors that influence teachers' use of technology. This section analyses the data obtained from such questions.

School facility and resources

Similar to Chinese teachers' interviews, most English teachers mentioned the importance of school facilities and resources in their use of technology. Three teachers compared their working experiences with different schools conditions and all of them said that the lack of certain devices restricted their practices. For example, TE1 mentioned that his department just bought visualisers, which according to him, although did not change the way he delivered the knowledge, but greatly ‘‘changed the impact of the way’’ he delivers it on the student.

> I always try and model best practice with construction. Previously, I’d be trying to model it, stood with the whiteboard, with my back to the students, trying to model it in an unrealistic way, because I wasn’t able to use a compass on the whiteboard and show them how to hold the compass and how to manipulate it. We’ve started using visualizers now in the department, for the last three or four months, and the visualizer allows me to model exactly what they got to do with opening up to the set lengths they need for the sides, and how to position the protractor accurately, so it’s able to give me much more, um- it makes my explanation much clearer for them and much more useful. They can follow exactly what I’m doing, and they can get a good level of success right from the beginning, rather than having to struggle through.

Similarly, TE5 compared her teaching in the previous school where she and her students could use iPads and she always connected the iPad to the screen in order to explain certain knowledge or mark student’s work in front of the whole class. However, her present school cannot provide iPads and has a different Wi-Fi set up, which stopped her from adopting the previous pedagogies, and she commented that ‘‘[t]he difference in technology here means that I have to find my own way to do it’’.

When reflected his observed lesson, TE4 expressed his hope that having a set of iPads in each classroom so that more interactions could happen among him and his students. Besides, he also mentioned that due to the tight budget of his school, the calculators were not enough in the school so that he tried to use them as less frequently as possible in teaching lower graders. According to his words, although basic calculator operations and practices were taught, more calculator-based inquiry lessons were less frequently planned.

Unlike the previous teachers, TE3 tended to use fewer technologies, but still, he mentioned the influence of school Internet on his teaching. During the interview, TE3 said that he liked encouraging pupils to think independently and proposing challenging questions. However, some questions were not easy to answer because they might be inter-disciplinary (often physics-related), so he would then use computers to search for relevant information to answer students’ inquiries. The unstable internet connection would then inevitably negatively influenced his instruction, so he said: ‘‘Good Internet quality is very necessary now’’.

TE2 described how web-sources are purchased in his department, and according to him, the budge of mathematics department varies in different schools, which affect the use of web-resource in the schools.

> There are different web-resources, but you have to pay. Even My Math now. There are people in my school, my team, that want to keep paying for My Math. I won’t get it because it is too

> expensive but some of them, my colleagues, say oh no I use it a lot. I say okay we can have a meeting, so finally we keep it [My Math], and stop using another one. It is not my money anyway. I would rather just forget them because it is being superseded by YouTube and other free internet sites.

Knowledge and Skills

English teachers have different views on knowledge and skills of technology. For example, both TE2 and TE3 de-emphasised the function of technology in students' learning, but highlighted that teachers should own various skills to motivate students and detect potential difficulties that students might encounter. They didn't often use technology, so they thought that the knowledge and skills of technology played a less important part in their lesson plan and classroom teaching.

TE1 expressed his idea that knowledge and skill were important for using technology, but those should not be a problem and barrier for teachers. One of his criteria for choosing new technology was user-friendliness. In other words, knowledge and skills should not be specially learned or the knowledge and skills should be very easy to grasp.

> TE1: There are a lot of technologies out there, a lot of apps and a lot of websites which, on the surface, look useful, but when you dig deeper, actually they're not as user friendly as they could be, and for me, good technology is one that you can pick up and use, which is why the visualizers have proved to be so successful, because there's no new skill involved at all. Although we haven't used it before, we know some functions. It's plug it in and go.

TE1's words delivered important information for educational technology developers that convenience for using and easy to manipulating should always be considered when new technology is developed for education settings.

TE4 held a relatively different view on the knowledge and skills of technology. According to TE4's recall of his teaching experience, he believed that with more knowledge and better skills, he might be more likely to use technology to teach.

> TE4: Yes, knowledge and skills matter. I would definitely use more technology in teaching if I know more knowledge or have better skills. Sometimes I was thinking of another way to teach, you know especially some topic students felt difficult. I think at this time technology may help, but don't really know how to do that. So it does sometimes bother me.

TE5 held similar ides as TE4, so during the interview, she stated that she was going to learn more about GeoGebra during summer vacation so that she could use this software in teaching mathematics.

> TE5: Yeah. I do use GeoGebra. I am not as hot on GeoGebra as I am on Autograph. It depends on which one you naturally use more… Because I favour Autograph, I know the autograph better. I found GeoGebra can be used for more topics than autograph, but I am unfamiliar with it [GeoGebra]. So I decide to do some training this summer on it. I mean use something like video to go through to see if I can do it, or using other resources to self-learn something about GeoGebra.

TE5's example shows that the unfamiliarity to certain technology will restrict her from using it, which indicates that the knowledge and skill of technology influence teachers' use of technology.

<u>School Support and Informal communication with colleagues</u>

Communicating with and learning from colleagues and other teachers has been seen as very important, according to the interviewees. All the five teachers said that they had learned something from various ways of communicating with other teachers, and they were always looking for more chances to continue this communication. As TE5 said: ''teaching is all about that, not keeping it to yourself. It's about sharing it around, because you get as much as you give''.

TE1's modelling has changed a lot because of the bringing of visualisers to his department, and he said that the devices were firstly adopted by the department of English where lots of teachers described how good the devices were, and therefore the department of mathematics decided to try them, and now all mathematics teachers in TE1's school use visualisers quite extensively. Another example provided by TE1 is that he frequently used social media for sharing teaching experience, and from these web-platforms, he absorbed instructional ideas and tried to put them into practices.

> TE1: I'm heavily involved in social media, and I get a lot of my teaching ideas from other experienced teachers around the country. We do sometimes have online webchats through twitter and maths chats, where we talk about teaching and pedagogy, and we talk about how technology can enhance, but also inhibit as well.

In terms of off-line communications, TE1 mentioned a conference, called *La Salle Education Math Conference*, which is a maths-teaching specific conference in Bristol. In this conference, TE1 attended different workshops including technology-related ones, where he watched other teachers' presentation of certain technologies which they found quite useful, and from the conference, TE1 ''pick[ed] lots of ideas''.

TE5 also mentioned social media where she visited blogs of other teachers and got different ideas of teaching and pedagogy. Besides, TE5 highlighted the importance of observing other teacher's teaching and regarded that ''one of the best ways to improve your teaching, in any subject, is to see other teachers teaching different topics''.

In some schools, colleague exchange and communication are encouraged and teachers are provided more freedom to visit each other's classroom to observe the teachings. Both TE3 and TE4 in the interview discussed their school cultures and stated that watching other teachers' classroom teaching was a very effective way to reflect their own instructions and to obtain new teaching strategies and resources. TE4 directly explained his choice of technology in teaching 'Boxplots' (the observed lesson) as learning from observing his colleagues' teaching. TE3 explained in detail of the culture of mutual learning in his department:

> Within this department in our school, we regularly have meetings. We mainly discuss content arrangement, but also good practice that ensures students' better learning. Once someone tried new methods with good effects, he would share with others in the meeting, and we all try it to see if it works in others' classes, and if yes we keep it. We can freely visit any classroom to observe the teachings. So we have a relatively consistent way of teaching. We try to combine different effective ways of teaching. Of course, there are some variations because each class is different, but I mean generally we teach in the same fashion.

<u>Students</u>

Drawing student's attention has been expressed by three English mathematics teachers in the interviews in which teachers said that getting students excited and involved was a very important task for maths class, and therefore teachers tried to use technology as a way to catch students' eyes. For example, TE1 compared students' reactions with and without using technology, and said that

> Yes, they reacted differently. I think we've seen with visualizers, the attention of a class and my whole team report this, when they're using it for demonstration, the class is much more attentive. They are much more focused on what they'll be doing.

TE4 also said that ''They [Students] do enjoy working with various technologies, such as having a competition using iPad in hand, so I will specially use some technology for teaching some topics''. However, he also found that sometimes technology could work negatively to distract students from the content, which pushed TE4 to think more deeply about the use of technology for non-cognitive issues. He then added that

> But sometimes you'll see a lot of them, they are all about speed and just to get it done. They don't think about it as fully as you would hope sometimes. But I found in general, technology works well for lower ability groups. I have a very lower ability of year eight class, and they liked fun maths. You know, they want to have mathematics fun rather than challenging. Their concentration is very low, and they won't last very long at all, so they'll need different work throughout the lesson, and things like using computers can keep them focusing for longer.

Similarly, TE5 adopted various technologies for her teaching, and she is always ready to try different technologies as well. She thinks that technology is good for personalised learning and enabling students to connect their own experiences to the learning content, which makes the learning process interesting and makes learners active in discovering and understanding new knowledge. While she also thinks that the use of technology should be considered by students' abilities, especially the technology is used by students themselves. TE5 explained that lower ability students were easily distracted and they were often lack of basic understanding of technologies, so ''from my experience, I found that even logging in can be sometimes problematic, not mention about the content problems, so I would less often use technology there''. However, TE5 further added that since in most English schools the bottom sets were a lot smaller in terms of classroom size with only 10-15 kids, so with careful design, teachers could still use technologies.

TE3, although didn't use technology in the observed lesson, still expressed that he always explored different online resources and tried to find good resources where students could benefit. However, he also noticed that keeping students focused on learning itself and getting them to produce learning outcome was very important, so he was very cautiously in selecting and using technology and relevant resources, and would not use those which distracted students from the learning content itself.

Pedagogical attitudes and beliefs

During the interview, teachers' pedagogical attitudes and beliefs are found to be very different from each other, and the attitudes and beliefs exerted great influence in teachers' uptake of technology. It is found that teachers who always use technologies hold positive attitudes on technology, while others suspect the positive impacts of technology. For example, TE1 believed that today, instructions should follow the development of the technology, so teachers should make use of available technologies and resources in their teachings.

> TE1: I want to use technology because it's out there, and the students use technology every day. I think we should use them. If I was using an old-fashioned blackboard with chalk, the way I was taught, lessons weren't very dynamic. They weren't always very engaging. Um, it didn't stop me learning, but I think technology is there, we need to make use of it in order to- almost to keep their attention. Um, if you're a very traditional style of teacher in the way that I described with chalkboards, with blackboards, um, I think you can lose a class quite quickly.

TE5 said that in most schools, mobile phones were banned, but she still believed that whether or not students could use phones sometimes was decided by their teachers' attitudes. During the interview, she provided me with some examples of teachers that she knew, who allowed the students to use mobile phones in the lesson to calculate or to search information, and according to her explanation, these teachers believed that to some extent, phones were like calculators, which were tools for people to solve problems. When asked why she chose to adopt laptop in the lesson observed, she directly responded that

> The way the world's going, everyone's going more technology based. So, I believe our teaching should be as well because that's what they're going to use in the future.

Unlike other teachers, TE2 and TE3 used fewer technologies in their observed lessons. During the interview, they also explained their instructional behaviours and the beliefs underpinning. Both of them believed in the importance of non-technological issues in students' learning of mathematics in schools, and therefore didn't put many efforts in thinking about adopting technologies.

> TE2: Generally speaking, I think the number one thing that gives a child a good experience in mathematics in secondary school is not technology, it is the skills of the teacher. Technology doesn't change school mathematics dramatically, and they can be distracting, so I try to use [them] as little as possible.

> TE3: I believe the core thing for students' better mastery of knowledge is repetition and challenge. You got to get their brains work. Technology may be helpful in some cases, but they are not the key component, so I don't always think of technology in my teaching.

Overall, the interviews shows that teachers' attitudes and pedagogical beliefs varies a lot and teachers who believe in the positive impact of technologies on teaching and learning are more likely to adopt technologies in teaching practices.

Assessment

Similar to Chinese teachers, all English teacher connected the use of calculators with the GCSEs, which is the national assessment for the graduation of secondary course in England. Their descriptions also confirmed the influence of GCSEs upon their teaching and the use of technology.

All teachers said that they taught students how to do various calculations with calculators based on the assessment requirement, and the higher students' ages were the more often calculators were used in order to get students familiar with the calculator for GCSEs. Just as TE3 described:

> We train students to use calculators for the test. The first year of secondary school, nothing is calculated so they don't need to have one. We don't do anything that requires a calculator then, so they should do all by hand. In year eight we start to use the calculator, maybe one-quarter of the time. It builds up. Then in year 11 the last year it is over 50 percent.

Besides, TE3 provided more information to show that the learning content in schools was also influenced by GCSEs. TE3 accumulated GCSEs questions of the past 10 years and compiled those questions by topics as an exercise booklet. According to his explanation, the booklet was perfect for 1) reviewing, and 2) guiding the instruction.

> The test dictates the topics that we need to cover. I am very familiar with such information, and the compiled material (exercises book) also showed me which topics will be tested. For example, if we have the area of a circle or a segment or sectors. If it wasn't on the GCSC test then it is unlikely that we would teach it unless it was necessary for something else.

Actually, not only the content, but also the pedagogy was influenced by the GCSEs. TE5 mentioned that the new GCSEs required students themselves to be able to do exploration for problem-solving rather than just counting and calculating based on the given conditions. So, she tried to design more inquiry-based lessons in which various information searching tools such as computers would be adopted.

> TE5: What information did you need? I need to know what coin that is, I need to know how many on a stack, I need to know what the base is, how wide it is? You say how much one coin weighs, and all this information, because the GCSE is going that way, that they would have to explore information, rather than as you'd be given it. It's really good for that problem-solving mechanism kind of mechanics. Which is one of the reasons why I more often use them (inquiry-based questions and inquiry-encouraging websites).

Instructional materials

There is no unified textbook for secondary mathematics in the UK, and students are not asked to own textbooks either. Therefore, which textbook should be used is decided by mathematics teachers themselves. Normally, a certain number of textbooks would be stored in the classroom, and the teacher occasionally asks students to take the textbook for temporary use. After the lesson, those textbooks should be put back. In all classrooms I visited, the number of books was less than the number of students and therefore a book was shared by several students when used.

During my observation, only two teachers (TE1 and TE2) used textbooks in the lesson. Textbooks were used by students when they were told to do exercises for practicing what had been learned, so students just turned to the page which contained a number of exercises. The teachers selected several exercises from that page and provided students with around 30 minutes to do the exercises. Then teachers checked students' answers to see if most students could accomplish the tasks.

During the interview, I asked all teachers how they normally used textbooks. All teachers responded that they just use the exercises on the textbooks without going through the previous content. Realising that there are different textbooks in the market, I specifically asked teachers what criteria they would follow when they chose to buy a set of textbooks for their department. Teachers' answers were similar and they all focused on the exercises in the textbook. Here I attach TE1's words as an example.

> TE1: So, it's got to have a range of questions, problem-solving questions as well. Got to cover the whole curriculum. Got to be a good value in money…We, in our department, we regularly have meetings, and anyone can say I've seen a good book, and we will ask him to bring the book and discuss. But the key thing is always good questions. Good question, good question, good question! Making sure they're varied. Making sure they give them [students] enough time to practice it and going into the harder problem-solving questions as well.

TE2 also added that, his department has not got enough budget so buying textbooks was decided by all teachers, and usually the purchase and use of textbooks (actually textbook exercises) was based on students' abilities.

> TE2: I base the textbooks use upon the abilities of the pupils. Different groups use different textbooks. Higher ability group, you need to give them more challenging questions, but for lower ability group, just simple and basic questions are enough. We don't have enough money for books so usually think very carefully and it was decided by all teachers.

In order to know if textbooks influence teacher' use of technology, I asked teachers besides the exercises, if they read other content of the textbook and use them for their lesson plan. The most common answer was ''not really''. As TE3 answered:

> TE3: Personally I never really based my lesson plan on textbooks. Maybe sometimes in some topics but mostly I haven't. I've been lucky to be good at math over the years and I know how I want to present the information and when you combine that with experience, it helps you learn and the things they get stuck on.

TE5 provided me with a little bit different answer that she would also look at the content other than exercises. However, she just used the textbook which matched her pedagogical ideas. So it still can be said that the textbook would not influence her way of teaching.

> TE5: The book won't change my teaching I think. I usually choose the textbook whose ideas match mine so that I can directly use the examples and questions there and don't have to re-design the exercise or re-arrange the questions. I did so as well but try to use textbooks with less such work.

In addition to textbooks, teachers were asked if they use other materials for lesson plans, and all of them gave me negative answers and stated that they designed their lesson based on their own understanding and experiences. For example, TE1 stated that: ''I tend to make my own. I know how I want to teach it. I know how I want to explain it. I will make my own, rather than following what is written in any books''.

It can be seen that textbooks played little role in shaping teachers' use of technology, and teachers normally don't use other instructional materials for their lesson plan.

<u>Professional training</u>

Questions on professional training were proposed in the interview. Teachers were asked whether they attended any professional training and if they benefited from such training for their instructions.

All participants answered that they have attended professional training but mainly for promotion in leadership, so the training were about administration and management. As TE3 described:

> I have only done training on middle leadership, so moving to my role of head of departments. It's not to do with maths. It is more about management. If you want to be promoted or take more leadership work and tasks, you got to proof that you have special skills or know such job, and you need to attend some training.

In terms of training focusing on teaching, only TE5 described one in York where she learned useful online resources for teaching, and indeed she used such resources in her practice. For example, the website '*gapminder world*' that she used in the observed lesson was actually from that training. According to TE5's description, she attended the training when she was just a NQT (Newly qualified teacher) and the training was designed for mathematics and science teachers and aimed to introduce the idea of 'learning is for solving real-life problems' to all participants. TE5 added that the training in York was not organised by her school, and she went there because she had seen an advertisement online. As regards training organised by her school, the foci were mainly about administration and management, so such training exert little influence on her classroom teaching.

During the interview, TE2 expressed his view on various training, which to an extent reflected TE5's situation.

> TE3: They [Excellent teachers] are good not because of standardized professional development, they're good because they're personally motivated. Training courses, you asked about the training courses. Training courses are often carried out in a very kind of uniform way that everyone is presented with the same information, the same training, but it's not necessarily applicable to that individual or necessarily that subject in the same way. There's a simple solution to this which is that we should have more time to observe other people and share best practices or good practices, but we don't have time. We don't have enough money to afford the teachers to give staff the free time on their timetable to go and observe other staff and to discuss it.

TE3 thought that most training was standardised and might not meet teachers' needs, and therefore the training was always ineffective in enhancing teachers' teachings. However, he also proposed that more mutual lesson observations and discussions among teachers could be one replacement for training.

Overall, according to the interviews with Five English mathematics teachers, it can be drawn that there are various factors which influence teachers' use of technology, which is consistent with the quantitative findings.

Firstly, the findings in this study are consistent with what has been found by many other researchers (e.g., Zhao *et al.*, 2002; Groff & Mouza, 2008; Afshari, 2009) that teachers' knowledge and skills of technology and School facility are vital in teachers' uptake of technology. During the interviews, teachers described how they taught differently in different schools (with different facility and resources provisions), and how the lack of specific knowledge and skill of technology hindered them from integrating technology into their teachings. Besides, the interview also implies that budget is a problem in some schools, which affected the purchase of various resources for mathematics education, and this might also affect teachers' use of technologies. Secondly, there are various ways through which English teachers could communicate and exchange teaching experiences with each other, and these communications to some extent impacted teachers' teaching behaviours and tech-related pedagogies. Thirdly, the data revealed that teachers' pedagogical beliefs varied a lot, and there is a positive relation between teacher's view upon the use of technology in pupils' learning and his/her uptake of technology in instructions. Fourthly, teachers often considered their use of technology based on pupils' abilities including their preparation for certain technology. Actually, the fact that pupils are grouped based on their abilities in English schools makes it easier for teachers to connect their uptake of technology with pupils' abilities. Finally, assessment requirements were also found to be influential in English teachers' teachings, and the influence reflected not only on students' frequent use of calculators but also on teachers' lesson plan and pedagogies.

However, teachers are rarely influenced by instructional materials in their teachings and when teachers select textbooks, they mainly focused on the exercises part and takes little suggestions from other parts. Teachers rarely attended subject-based professional training and activities, whose influences upon teachers' tech-integration were not detected.

6.6 Summary

The analysis on this chapter is based on English teachers' data. Research questions of how technology is used, and what factors influence teachers' use of technology are answered. The following findings are discovered:

(1) Among all investigated hardware, calculator, IWB, desk-computer and laptop are four devices used by the most majority of teachers (over 50% of the participants).

(2) Among all investigated software, Microsoft office packages (i.e. Word, Excel and PowerPoint) are most frequently used, followed by GeoGebra and Autograph adopted as dynamic demonstrative software for the instruction of geometry and function graph. GSP (Geometer's Sketchpad) has been used by fewer teachers. However, data analysis software has not been used by any teacher.

(3) English teachers use a wide range of online resources for teachings, including search engines (mainly Google), downloaded pictures and videos, subject-based websites and subject-based online applications, such as Desmos.

Besides, different technologies are used differently in teaching mathematics:

(4) Calculator is used mainly via the strategy of Calculating and Checking (CC), and least used via the strategies of Illustrating and Demonstrating (ID); and for instructional purposes, calculators are more used for the teaching of mathematics knowledge and skill (MKS), rather than mathematics thinking and reasoning (MTR), and the cultivation of positive disposition towards mathematics (PDM).

(5) Computer is used mainly via the strategy of Illustrating and Demonstrating (ID) and Calculating and Checking (CC), followed by the strategy of Explaining and justifying (EJ), Inquiring and Exploring (IE) and Reflecting and Discussing (RD); Computer is more used for the teaching of Mathematics Knowledge and Skills (MKS), and the cultivation of Positive Disposition towards Mathematics (PDM), rather than for the teaching of Mathematics Thinking and Reasoning (MTR).

(6) Interactive Whiteboard (IWB) is used mainly via the strategy of Illustrating and Demonstrating (ID), Calculating and Checking (CC), and followed by Explaining and Justifying (EJ), and least used via the strategy of Reflecting and Discussing (RD) and Inquiring and Exploring (IE); IWB is used more for the teaching of mathematics knowledge and skill (MSK), and the cultivation of Positive Disposition towards Mathematics (PDM), rather than for mathematics thinking and reasoning (MTR).

(7) Mobile phone is rarely used by teachers for teaching and there are significant differences in neither various pedagogical strategies nor various instructional purposes of the adoption.

Table 6-40 summaries the above findings:

Table 6-40. A summary of how English teachers use different hardware in teaching of mathematics

Hardware	Pedagogical strategy	Instructional Purposes
Calculator	CC > IE> RD > EJ > ID	MSK> MTR, PDM
Computer	ID, CC > EJ > IE > RD	MKS, PDM > MTR
IWB	ID, CC > EJ > RD, IE	MKS, PDM > MTR
Mobile phone	No significant difference	No significant difference
Other	No significant difference	MSK> MTR > PDM

In addition to the general information of English teachers' use of different hardware, comparisons between different school types have also been conducted and findings are also revealed:

(8) Statistical difference has been only found in the mean scores of IWBs between school I and school III.

(9) As regards the pedagogical strategies, the data revealed that for the calculator, teachers in School I use it for Explaining and justifying less often than teachers in other types of schools. For computer, teachers in School I use it for Illustrating and demonstrating more often than teachers in School II and III. For IWB, teachers in school I and II use it more often for both Illustrating and demonstrating and Explaining and justifying than their counterparts in School III. No significant difference has been found in mobile phone and other devices in terms of teachers from different school types of their use in various pedagogical strategies.

(10) In terms of instructional goals, the data revealed that teachers in school I use calculator, computer and IWB more often for the cultivation of positive disposition towards mathematics than teachers in other school types; teachers in school II use IWB more often for the cultivation of positive disposition towards mathematics than teachers in school III.

Finally, findings on the influencing factors are obtained:

(11) Teacher's pedagogical belief is an important factor which influences teachers' use of technology in teaching mathematics, and it is found as a school-level influential factor. Specifically, at schools where the mean score of 'teacher's use of technology scale' is higher, the influence of 'belief' is stronger.

(12) Besides, 'school facility', 'student', 'teacher's skill' 'teacher's knowledge', and 'school support' are also influential. Assessment is also an influential factor found through the interviews.

(13) According to the multilevel model, instructional material (including textbook), training and professional activities are found to be uninfluential on teacher' uptake of technology.

Chapter 7 Overall Comparison and Discussion

The last two chapters have presented evidence showing how Chinese and English mathematics teacher use technology in their teachings separately. In this chapter, some comparisons are made and discussed.

7.1 Comparison on the Use of Technology

In China, 23.6% of the participants did not use calculators in their teaching of mathematics, while all English participants used calculators. The main reason explained by teachers from both countries was whether calculators were allowed in the examinations. During the interview, all Chinese teachers claimed that students were not allowed to use calculators in the SHSEE, so they normally didn't use calculators. Similarly, English teachers highlighted the ratio of calculator-based content in the GCSE (around 2/3), so teaching and instructing students to use calculators was necessary. Chinese teachers admitted that there was some calculator-related content in the textbook, but not all of them would follow what the textbook presented (TC5), which further decreased the likelihood of using calculators. This might indicate that the influence of examination is stronger than that of teaching materials.

In terms of how calculators are used, differences are found between China and England. Being able to use calculators is a requirement in GCSEs so English teachers provided chances to let the students practice how to use calculators to solve different problems in order to equip them with good skills. This might explains the fact that the strategy of Calculating and Checking (CC) gains the highest score out of all other strategies. In other words, calculators are mainly used for obtaining answers for routine exercises. This is also confirmed by the result that statistically, English teachers use calculator more for teaching mathematics knowledge and skills than other goals. While in China, the highest score of using calculator is for Inquiring and exploring (IE), which might imply that Chinese teachers tried to integrate calculators into their teaching to highlight the mathematics content itself by designing inquiry problems for students to solve, although teachers didn't use calculator frequently. One example came from TC4, who in the interview recalled a lesson where he asked students to use a given rectangular paper to make a lidless cuboid by cutting four squares of the same size at each corner, and to try to make the volume of the cuboid as big as possible. In solving such question, students were encouraged to use calculators to estimate and trial and error. Another reason that Chinese students were not allowed to use calculators in routine problems, according TC5, was the fact that Chinese teachers valued the mental calculation a lot, and tried to avoid students' mental calculation ability being weakened by calculators.

In both China and England, computers have been used by a great number of teacher, and the data shows that the overall score of computer was the highest in both nations. One reason could be the wide variety of software and applications in the market which bring convenience for teachers. PowerPoint, for example, not only frees teachers from writing with chalks to some extent so more time is saved for explanation, discussion, problem-solving and other activities, but also enables teachers to include more content and information in a lesson (see TC1, TC4, and TE5's example). Besides, adopting slides also helps teachers to manage the teaching procedure and control the pace of the instruction (as TC5 stated). There are some professional software specially developed for mathematics education such as GSP, GeoGebra, Autograph and Desmos, which help teachers to visualise mathematical activities and processes. The dynamic demonstration provided by such software and applications may not only attract learners' interests, but also enhance learners' understanding of certain topics (example from TC1).

The strategies for using computers in the two countries were slightly different. In China, teachers used computers more in ways of ID and EJ. Chinese teachers explained in detail that they quite often employed slides for presenting learning materials, and GSP for explaining and dynamic demonstrating geometry problems. This can be confirmed by the figure that 95.6% and 86.9% of Chinese teachers used slides and GSP respectively. In England, teachers used computers more in ways of ID and CC. This can be seen from the data that less than 50% of participants had used professional software and applications in their teachings. A good example came from TE2, who stated that he just used tablets for ID and CC in his teaching as he stored a great number of questions and answers in his tablet, so he always connected the tablet with the projector to present questions and answers to students. Besides, the study also finds that Chinese teachers' use of computer for the teaching of Mathematics Thinking and Reasoning (MTR) is associated with their school type. Specifically, Chinese teachers in school I use computer more for the teaching of MTR. While English teachers in school I used computer more for cultivating students' positive dispositions (PDM).

There is a big difference in the proportion of teachers in China and England using IWB. The IWB is just used by 37.1% of Chinese teachers, while the figure in England is 85.7%. In China, lack of school facilities might be an important reason restricting teachers' use of IWB, especially in school II and III. For example, during the interview, TC3, TC5, and TC6 mentioned that in their schools, the IWB was only equipped in certain classrooms, and they lacked the chance to use the IWB. However, in England, IWB is a commonly seen hardware in mathematics classrooms, even though teachers may not always use it. English teachers may usually use IWB together with computers so that interactive manipulations could be done, and this can be seen by the result that for all strategies of using IWB, English teachers gain highest scores on ID and CC, same as the use of computers. A good example is that TE5 explained how she used IWB to show the *gapminder-would* website. In England, the main pedagogical purposes of using IWB are teaching mathematics knowledge and skills and cultivating students' positive dispositions on mathematics. While in China, IWB is still relatively new to students, and teachers use IWBs more for cultivating students' PDM.

Another big difference appears in the use of 'other technology' (hardware). According to the data, the majority of Chinese teachers (85.2%) use projectors, while only 2.5% of English teachers use other hardware. The Chinese data reveals that across all school types, the ways of employing projector are similar: it is mainly used as a tool for reflecting and discussion. During the interview, Chinese teachers stated that students' works were valued and always treated as important learning resources. All six interviewees claimed that they often selected students' works, either typical errors or special solving methods, and projected them to the screen for whole class reflecting and discussing. Chinese teachers believed that students learn by reflecting and deep thinking, so teachers use various materials and heuristic pedagogy to guide students' thinking and reasoning. As TC6 explained that ''they need to know why this works and that doesn't, why others' (methods) are better. They should reflect and compare. They understand then learned'', and these words were confirmed by the result that Chinese teachers use projector more for mathematics thinking and reasoning.

In England, only TE1 used 'visualiser', which is quite similar to projectors in terms of projecting object to the screen. However, the most common way he used the visualiser was demonstration. For example, in the observed lesson, he constructed triangles based on certain conditions, and asked students to follow what he did. TE1 explained that by using visualiser to model, students could observe each step of the drawing much more clearly. He also claimed that when students accomplish tasks excellently, he would use the visualiser to project the good work for all students to learn and follow. However, little words had been said on transforming students' works into learning resources for classroom reflecting and discussing for a deep understanding. Actually, in all English lessons being observed, I have noticed that students were given around 25 to 30 minutes to do exercises, during which teachers walked around the classroom and did much individual guidance, but none of them organised students to reflect their answers, and neither good solving methods nor errors have been proposing for discussion. It seems to me that English teachers rarely guide students to reflect and discuss their works.

Finally, the situations of using smart-phones are quite similar in China and England. In both countries, most schools have clear regulations to against students' use of mobile phones in the school area, and even against teachers' use of mobile phones in classrooms. Although there were some teachers (such as TC4) used mobile phones for teaching, most teachers were not familiar with the pedagogical use of mobile phone.

7.2 Comparison on Influential Factors

The questionnaire also investigates what factors influence teachers' use of technology in instructions, and the results reveal that for Chinese teachers, there are six factors found to exert impacts on teachers' uptake of technology: *School facility and resource*; *School support*; *Knowledge*; *Training*; *Professional activity*; and *Skill*. For English teachers, the influential factors are *Pedagogical beliefs*; *School facility and resource*; *Knowledge*; *Student*; *School support*; and *Skill*.

Teachers' knowledge and skills were found to be influential in both countries. According to the interviews, most teachers in China and England held similar opinions on the influence of knowledge and skills. Teachers admitted that having enough knowledge of and being skillful in technology would increase the likelihood of adopting technologies, and teachers mentioned two common difficulties that stopped teachers' use of technologies. One was that teachers lacked enough knowledge and skills to design and make the courseware (prepare teaching material); another one was teachers' unfamiliarity to certain technology. For example, TC1 described an example of *nets of a cub*, where he found difficulty in using the software in creating the courseware. Such difficulty hindered him from using technology. TE4 directly said that he would definitely use more technology with more knowledge and better skills. However, teachers believed that 'user-friendly' technology was more welcomed. In another word, the ''knowledge and skill of such technology should be easy to grasped'' (from TE1). TC2 stated that he would simply learn some skills when he needed to use certain technology, which expressed similar ideas as TE1. Besides, the interview also reveals that teachers' self-motivation could be vital in enhancing their tech-related knowledge and skills. For example, TE5 talked about her learning plan about GeoGebra in summer vacation, which might provide her with more chance to integrate technology into teaching.

School facility and resources were vital in supporting teacher' tech-based teachings, and evidence was found in both countries. In the interview, some teachers compared the observed lesson with the original lesson plan, or with their previous experience, and claimed that the lack of certain technology in their schools changed their way of organising classroom activities (For example, TC2 and TE5 thought about using tablets for the observed lessons). Another example of the importance of school facility and resources was how English school select and buy instructional resource and database (TE2). Compare with Chinese teachers, English teachers used online resources and database more often, and there are a lot of database in the English market. When English teachers were asked how they select database in the market for their teachings, they highlighted the budget of their school or department. TE2 explained that each teacher might have his/her preference of using certain database, but the department would just buy one or two so that some teachers would not use the resources or have to adjust their instruction to cope with the department (TE2). This example implied the importance of school facilities and resources in shaping teachers' tech-based teachings, and might also explained why to some extent teachers in some schools use technologies more often in their teaching practices.

In addition, School supports were also recognised as an important factor in both countries. In China, the school support for teachers' uptake of technology came from a variety of aspects. Firstly, Chinese schools organize tech-related lectures for teachers. For instances, TC2, TC3, and TC6 said that their schools had organised small GSP lectures where experienced teachers who were good at GSP taught novice teachers or those who were not familiar with GSP. Teachers were provided practical advice and skills through the lectures, which might make them used GSP more often in their teachings. Secondly, Chinese schools have developed a mentoring program to enhance novice teachers' professional development. For example, TC3 as a novice teacher was paired with the head of mathematics department in her school, who is an experienced teacher. TC3 always observe her mentor's classes, consult and discuss instructional issues with her mentor. According to TC3, the mentor encouraged her to do the lesson plan creatively and to use different technology. The TC3's observed lesson could be a good example of how she was influenced by her mentors' encouragement. Thirdly, informal communications between teachers are very common in Chinese schools. All Chinese interviewees talked about how they shared experience with colleagues and visited colleagues' lessons for observing classroom teachings, which enhanced their pedagogies, including the use of technology as well. In England, teachers also value inter-colleagues communications. All five interviewees admitted that by sharing with and learning from each other, their pedagogy and the use of resources (including technology) in classrooms had changed. English teachers regularly have department meetings, and in some schools, teacher can share effective pedagogies and resources in the meetings (TE3). Besides, in some schools, teachers are encouraged to visit other classrooms to observe colleague's teaching, for either the whole lesson or part, and teachers would follow what they thought 'good practice' (words from TE3). Interestingly, the study found that in some England schools, teachers of different disciplines are also provided chances to share instructional experiences. For example, TE1, as the head of mathematics department in his school learned the use of visualiser from the department of English and finally brought the device into his department. TE5 also mentioned that in her school, young teachers of different subjects would sometimes gather together to discuss classroom management experiences.

Another factor found to be influential in both countries was the assessment. As explained previously, English teachers and students used calculators quite often, and the main reason, according to all teachers, was the requirement of GCSEs whose two-thirds of content was calculator-based. TE5 also claimed that the requirement of the new GCSEs changed her way of teaching. She explained that new GCSEs valued problem-solving a lot and asked pupils to explore necessary information themselves to work out solutions so she designed more inquiry-based lessons where students were exposed to open-ended questions which require creative thinking rather than simple remembering. Similarly, in China, teachers value the examinations very much and plan their teaching based on the requirement of high-stakes tests. The less use of calculator could be one example. TC6 claimed that teachers would normally ignore or skip tech-related suggestions on instructional materials because 'this has nothing to do with examinations'. This shows that in both countries, assessment exerts an important impact in teachers' teachings.

Besides the similarities, some differences are also revealed.

During the interview, English teachers were asked whether there were tech-related activities in their departments or schools, none of them said yes, indicating that few tech-related activities were organised officially in schools. However, in China, in general there are quite a lot of tech-related activities taking place in the schools or the departments. On the one hand, all Chinese interviewees mentioned the school-based mini-lectures on certain technology (such as GSP and IWB), where teachers were provided specific knowledge and skills of certain technology; on the other hand, other forms of professional activities such as within-school technological competition (as mentioned by TC2 in section 5.5.2) are also commonly seen in schools, and the competition enabled teachers to create different courseware which they could use.

Besides the school-based activities, Chinese teachers are offered chances to attend cross-school activities, which brings them into a wider group to share, communicate and learn. For example, TC1 and TC6 mentioned the micro-lesson video pool program in the city-level educational bureau, and by attending such program teachers were trained specifically about the recording software, and the other way round, teachers were provided more video resources to use for teaching mathematics. TC5 mentioned the city-level teaching competition where all participants were asked to use IWB so he was provided more chances to use IWB in daily teaching works as well.

Professional training is also widely offered in China from school-level to national-level. School-based training is normally simple but more practice-oriented with a great number of concrete examples (described by TC2), and such training is usually coordinated or hosted by experienced teachers. Other types of training include those held by different organisations such as district/city-authorities, university and even national educational administrations. Unlike training in schools, those organised by educational authorities and universities are more formal and comprehensive and covers more content. For example, TC4 said that he had attended various university-based training especially on the development of educational technology, from which he knew the educational use of tablet in different countries, and based on such information, he reflected and improved his own practices. TC6 mentioned the web-based training organised by National Centre for Educational Technology (NCET) where she learned the design of slides for different instructional purposes. From the data collected in both countries, it seems to me that there are much more opportunities in China where teachers are provided with professional guidance in their use of technology in instructions. This finding is consistent with many previous studies (e.g., Voogt *et al.*, 2012; Corkin *et al.*, 2016; Sen & Ay, 2017), which show that various tech-based lessons and educational programmes were effective means to enhance teachers' use of technology.

English teachers' use of technology, unlike their Chinese counterparts, are influenced by pedagogical beliefs, and the students. The interviews with five teachers confirmed these findings.

During the interview, both TE2 and TE3 explained why they didn't often use technology and claimed their belief that non-technology issues were vital in students' learning of mathematics. Specifically, TE2 highlighted teachers' skills of understanding students' thinking process and pointed out that good teacher could always remember and detect where students made errors and then plan the teaching. He added that technology didn't dramatically change school mathematics, but could distract students from learning, so he was trying to avoid using technology. TE3 believed that the core issues for students' mastery of mathematics was repetition and challenge. Repetition made students remember and challenges made them think creatively. To him, technology might work in a few of cases but was not the key component in today's learning, so he didn't always use technology. Both TE2 and TE3 had expressed clearly on how they viewed mathematics learning and the role that technology played in the learning processes, which consisted with their less-technology practices. In contrast, TE1 and TE5 hold different opinions, which also influence their teaching practices. Both TE1 and TE5 highlighted the rapid development of technology in the 21^{st} century and believed that teachers should follow the trend and prepared students to the tech-surrounded world, and thus TE1 and TE5 often explored different technology and tried to integrate them into teachings. During the interview, TE5 expressed that although many schools had regulations against mobile phones, in some classrooms whether or not students could use phones sometimes was decided by the teachers. All these explanations and facts seem to imply that teachers' personal belief about teaching and educational technologies influence their uptake of technologies in teaching mathematics.

English teachers' use of technologies are also affected by students. English teachers would consider students ability and skills to decide whether use certain technologies. For example, TE4 found that technology worked better for lower ability students. This is consistent with studies conducted by Baglama, Yikmis and Demirok (2017) and Hollebrands and Okumus (2017) who discovered that technology benefited lower-ability students more on mathematics learning, and teachers were more likely to introduce technology to students who had problems in routine pedagogies. Besides, the interview also reveals that drawing students' attention and interests is another important issue considered by English teachers. When asked specifically how the technology is used for drawing students' attention, two answers were provided: one was to get students more engaged by using new technology or carefully designed courseware (such as TE4's use of iPad); one was to enable personal learning where students could connect their own experience to the learning content (such as TE5's use of laptop). Whereas in China, although there are teachers valued the use of technology for improve students' engagement in learning, most teachers thought of using technology from the content itself rather than from students. just as TC6 stated: ''I would think more from the content itself, from what I need to teach''.

The findings of the study on teachers' pedagogical beliefs show that its influences on tech-integration are complex and context-bound, which confirms what Tondeur *et al.* (2017) found that school characteristics played important roles in the complex relations between teachers' pedagogical beliefs and their uptake of technology in education. In China, teachers are much more often receive school-level effect (like regular public-observed lessons and peer communications) than their English counterparts, so the school context seems to exert more obvious and direct influence than teachers' personal beliefs. Similar findings have also been discovered by Vanderlinde, Van Braak and Tondeur (2010) whose study showed that in some schools although teachers' pedagogical beliefs were not the same, they shared a common vision of education, and their use of technology was grounded in a shared vision of 'good' education within the school, which indicated the influence of school culture and colleagues communications on teachers' tech-integration rather than their personal pedagogical beliefs. Based on Vanderlinde, Van Braak and Tondeur (2010) work, considering the commonly seen cross-schools activities in China, it might be drawn that the view of what is 'good' instructional practices might be shared by different schools so that teachers' instructional practices in different schools are more similar than we expected.

7.3 General Differences on Chinese and English Teachers' Use of Technology

Based on the data analysis and discussion, some general differences on Chinese and English teachers' use of technology can be found.

(1) Chinese teachers use technology more for explaining mathematics knowledge, while English teachers use technology more for demonstrating exercise/problem-solving steps.

The questionnaire data shows that the computer is the most frequently used device in both China and England, and in both countries, it is used as a tool for presenting learning materials. However, for Chinese teachers it is also often used in the strategy of Explaining and Justifying (EJ), while English teachers often used computers via Calculating and Checking (CC). Moreover, the data reveals that there are over 85% of Chinese teachers who used mathematics-related software (such as GSP), while less than 50% of English teachers used mathematics-related software (including GSP, GeoGebra and Autograph) in teaching practices. These findings might indicate that Chinese teachers used computers more for explaining mathematics knowledge, while English teachers used computers more for guiding and providing examples for students to do exercises.

In addition, the questionnaire data also indicates that besides computer, calculator and IWB, Chinese mathematics teachers frequently use projectors in their teachings, while projectors are not commonly used in England. The interviews reveal that in fact, Chinese teachers used projector mainly for presenting students' works and exercises. The presenting of the works were in two forms: either one student presented and explain his/her (group's) work to the whole class, or the teacher presented some work to the whole class and asked students to do comparison and discussion. This is consistent with what has been found in the analysis of the questionnaire data that for projectors, Chinese teachers' the mean score of RD is significantly higher than that of other strategies. It seems that Chinese teachers are good at turning students' works as teaching resources, and ''use their own creativity or errors to educate them'' (TC1). This is also supported by Pepin et al. (2017), who found that ''learning from student feedback (written, e.g., homework; or feedback in class)'' (p. 269) was emphasised by Chinese expert teachers. In the interviews, Chinese teachers claimed that they often used students' work to guide them to reflect deeply on knowledge and methods. Questions like 'Why certain solution is wrong/better? Why the answer is hard to achieve by one method? Or how certain new problem can be connected to previous solved problems?' were asked. By doing so, teachers guided students to reflect problem-solving strategies, misunderstandings of certain knowledge or to build knowledge-network.

However in England, the mean score of 'other technology' is the lowest one, and according to the observed lessons and interviews, fewer ''why questions'' were asked. More frequently, teachers modelled the steps of how to find the answer to a question, and then passed the prepared exercises to students and asked them to follow teacher's problem-solving steps. By the end of the exercises time, teachers would simply speak out his/her answers and ask students to check theirs. Normally, teachers neither focus on the solving process nor ask students to reflect their answers by comparing with each other.

These findings are consistent with the empirical study from Heitink *et al.* (2016) who found that most teachers considered their uses of technology by reasoning about how the technology strengthened pedagogy and content, but this study reveals in detail that Chinese teachers consider more on the use of technology enhancing students' deep understandings of the knowledge, while English teacher put more focus on how the effectiveness of pedagogy (such as model) is enhanced by tech-integration.

(2) Chinese teacher emphasise more for group or whole class activities, while English teachers provide students with more chance to use technology individually.

From section 5.3 and 6.3, it can be seen that for Chinese teachers Reflecting and Discussing (RD) is an important strategy for nearly all technologies (except for IWB); for English teachers, the all technologies are mainly used via Illustrating and Demonstrating (ID) and Calculating and Checking (CC), which might indicate that Chinese teachers emphasise more for group or whole class activities in teaching mathematics. However, in England, the calculator is widely and frequently used (over 87% of teachers used calculators), and it is used mainly for calculating which is an important part in the process of doing exercises and solving mathematics problems. The classroom observations and interviews from China and England confirmed the questionnaire data and provided more detailed information.

In China, classroom exercises come from various forms. Some teacher use worksheet (such as TC4) which contains key concepts, theorems, examples and exercises, but more commonly teachers just put the exercises (normally 3-5) onto slides which are presented in the front screen of the classroom, and teacher will provide students with relatively short time (less than 5 minutes) to try to solve them first, and then pick up several students to explain their potential solving-ideas. Normally, these different ideas will be evaluated by the teacher or other students, and then based on the evaluation, the example will be solved (either by the teacher or one student who provided correct solution). Then the teacher will provide all students around 10-15 minutes to do exercises. During the exercise time, the teacher also walks around the classroom. The teacher would individually guide a few of students, but focuses on finding either typical errors which many students made, or creative solving method which is different from the majority. After the exercises time, the teacher will specially select students' works to present to whole class through the projector[37], and ask students to compare, reflect, evaluate and discuss. The time for the whole class discussion is normally not less than that for doing exercises.

While in England, the majority of teachers often use worksheet where only exercises are listed (usually 10), and the worksheet doesn't contain content like key concepts, theorems and examples.

[37] Some teachers would directly ask a few of students to do the exercises on the blackboard, or ask them to copy their solving process onto the blackboard.

The teacher solves an example on the blackboard/white board, and then gives students quite a long time (usually half of the whole lesson time) to do exercises of the worksheet. In some cases, the teacher will use textbook instead of worksheet, and asks students to do exercises printed on certain pages of the textbook (this has been observed in TE1's lesson). During the exercises time, the teacher will walk around the whole classroom to see if any students encounter problem and feel difficulty in doing exercises, and if that is the case, the teacher will provide individual guidance to the student. There are always some exercises which allow students to use calculator, but usually, the use of calculator is just for obtaining numerical answers only. Another example comes from TE5, who believes that technology enables each student to connect the learning content with their own experience, so she always tries to provide students the chance of using computers individually.

(3) Chinese teachers use technology more for mathematics knowledge itself while English teachers use technology more for applying mathematics knowledge in various contexts.

From the questionnaire data, it can be seen that Chinese teachers used computers and projector more often than other technologies in teaching mathematics, and such two technologies were more often used for the teaching of Mathematics Thinking and Reasoning (MTR) than other purposes, which might suggest that Chinese teachers use technology more for mathematics knowledge itself and for guiding students to understand mathematics knowledge deeply.

According to the interviews, the most commonly mentioned reasons for Chinese teachers to use various technology were either the increase of content of lessons, or a better explanation of the knowledge. For example, in TC1's observed lesson, the use of slide enabled him to cover ''a large quantity of information and content'' (said by TC1), and made these content a logic network for pupils to remember and understand. Similarly, the use of Excel in TC2's lesson was mainly for showing students the instability of 'frequency', based on which the concept of 'probability' was distinguished from 'frequency'. Chinese teachers often connect school mathematics with students' life experience and use real-life examples to explain mathematics knowledge, but they provide less opportunities for students to apply mathematics to solve various real-life problems. In TC3's lesson, she asked students to use previous learned knowledge and methods to explore new knowledge, which was the application of mathematics within the subjects rather than cross disciplines or in realistic problems. Her lesson is very typical in China, where teachers highlight mathematics knowledge and thinking a lot.

In England, however, calculators, computers and IWBs were the most commonly used technologies and the questionnaire data shows that English teachers used such technologies mainly for cultivating students' Positive Disposition towards Mathematics (PDM) and the teaching of Mathematics Knowledge and Skills (MKS), rather than for the teaching of Mathematics Thinking and Reasoning (MTR). The English national curriculum highlights students' ability in applying mathematics knowledge in solving various problems, as well as their understanding of the function of mathematics in daily lives and in developing other disciplines. (DfE 2013; 2014) It might indicate that English teachers focus more on the use of technology for applying mathematical knowledge in various contexts. Actually, the classroom observations and interviews from the five English teachers, to some extent, confirmed the above findings.

According to the classroom observations and interviews, English teachers tried to use technology to find more chances for students to apply learned knowledge in different backgrounds. For example, TE5 always provides students with opportunities to connect mathematics with real life situations as she demonstrated in the observed lesson where laptops were used to explore large data of different nations. In the interview, she said that she usually browsed mathematics websites or blogs which contained 'big problems' (problems about how maths is applied in real-life), and these problems were vital in her teachings. TE3 didn't use technology in teaching, but still said that he often tried to connect mathematics with physics and showed students how mathematics knowledge could be used to solve different physics or mechanical problems. He encouraged students to raise different questions, and by searching through the internet, he could think and explore the questions together with his pupils.

(4) English teachers use technologies in more diverse ways than Chinese teacher.

Teachers in both countries adopted a wide variety of technology in preparing teaching materials and classroom instruction, but it seems that English teachers used technologies to serve for more aspects of instruction. In China, there seems only a few teachers use technology for after class activities. For example, in the questionnaire, although there were 79.9% of teachers who indicated that they used subject-based websites, the examples that teachers provided were just websites for collecting teaching materials (such as lesson plan and courseware). During the interviews, only TC4 claimed that he used tablet to assist students' learning in various aspects from pre-view, classroom teaching to homework and review, while others just limited the use of technology in creating courseware and downloading resources for classroom teaching. However in England, there were 87.4% of teachers who indicated that they used subject-based websites and the examples provided in the questionnaire were different in nature. Some of them were for teachers to obtain educational information, some were for students to do exercises and revisions. Three interviewees (TE1, TE4 and TE5) stated that in their schools, online resources-based homework (such as MyMaths and Hegarty Maths) were often used and teachers liked using such resources to guide students' review as well.

The Internet is more frequently used in England for classroom teaching. In China, teacher rarely have access to the internet in classroom teaching because the computers in the classroom are disconnected to the internet (mentioned by TC5 and TC6). Besides, Chinese teachers tend to avoid using internet in lessons because they worry about the quality of the Internet connection, and do not want to lose time in dealing with technical problems (mentioned by TC1). While in England, the questionnaire data shows that 38.7% of teachers used online applications and programs in classroom teaching. Four interviewees said that they had used the Internet in classrooms for teachings. They had either looked for information online through search engines to answer students' inquiries (such as TE3), or logged in learning website for certain topics or organised inquiring activities based on online database (such as TE5's lesson).

In addition, the common technology adopted by teachers from both countries are used differently. For example, slides is good for presenting and demonstrating, and besides that, English teachers use the slides in more ways. TE5 described how she used slides to roll various questions for recap, where the slides were used as an instructional game for exercises-activity. While Chinese teachers used PowerPoints in less diverse ways, and all interviewees just mentioned how they used slides to present things like concepts and exercises. However, it should be mentioned that this finding has just been found through the interviews, and further studies are needed to see if such difference is a general situation.

7.4 Explanations of the Differences

(1) Differences on the understanding of learning process

A salient difference between China and England is that teachers hold different understandings of how a knowledge is learned and mastered, which might influences their teaching behaviours.

As mentioned in chapter 5, Chinese mathematics teachers highlight the knowledge itself as well as the reasoning and thinking process, so a subjected-oriented view on mathematics learning has been held by the majority of teachers. The subject-oriented view in China can be reflected in two aspects. Firstly, all my Chinese interviewees stated that in mathematics classes, concepts, theorems, principle and rules were of high importance, and therefore in practice, teachers always considered using technology based on whether the adoption of technologies enhance students' understanding of the knowledge. A good example could be TC2, who specially designed two experiments in his lesson and used Excel to generate data and draw graphs to try to help students understand the difference between frequency and probability. TC5 presented over 10 equations in his lesson and kept asking students to differentiate fractional equations from other equations. Gu, Huang and Marton (2004) summarised a mathematics teaching method called teaching with variations (also called '*bian shi jiao xue*' in Chinese). Simply speaking, teaching with variations means providing students with different problems or situations for a certain piece of knowledge (such as a concept or a theorem), where the essential features of the knowledge are highlighted while the irrelevant and background information are changed. According to the authors, teaching with variations is good for helping students understand the knowledge deeply, and it is widely used in Chinese mathematics classrooms. Secondly, rigorous mathematical languages, terms and notations are used in Chinese lessons, and rigorous proofs are highlighted. According to TC1, Chinese teachers believed that rigorous mathematical languages, terms and notations were part of mathematics learning and the mastery of correct languages, terms and notations was good for children's learning of advanced mathematics knowledge. TC1 highlighted that proofs contained important mathematical thoughts and methods, and the proving process was good for students' understanding of theorems and rule. This might explain why a lot of Chinese teachers use specific software (such as GSP) to explain theorems and to inspire students to discover how the theorem can be proved.

While in England, according to my observation, teachers take a more pragmatic view of mathematics teaching and learning, and less rigorous mathematical languages, terms, and notations are used. English teachers highlight the application of mathematics knowledge rather than the subject itself, and normally they spend little time in either explaining the knowledge structure within mathematics (although they might know it) or inspiring students to understanding proofs of different theorems. For example, in TE3's lesson, he directly introduced sine and cosine rules without any explanation about how the rules were formed or why the rules were correct. Before asking students to do exercises on the worksheet, TE3 just explained the formulas of the rules. To him, the mastery of the rules is to apply the rule correctly in solving problems. TE2 directly expressed his definition of understanding mathematics in the interview, in which he said that '[m]y definition of true understanding in maths is if I wake someone up in the middle of the night when they're asleep and I give them the problem. If they can do it, they understand'. TE2 thinks that correct applying mathematics knowledge in solving problem is the key of mastery. So in English classrooms, real-world examples are highlighted and much time has been given to students individually for exercises, and less time has been provided for knowledge discovery and understanding, and fewer chances are given for pupils to compare and reflect each other's works.

(2) Different emphasis on collectives and individuals

Easter culture is always regarded as more collective (e.g., Leung, 1992; Li, 2006; Zheng, 2006), and this view is also reflected in several aspects in Chinese mathematics education for both students and teachers. For students, on the one hand, due to the unified textbooks, students are asked to learn same content in a similar pace regardless of their differences in abilities, as TC5 explained that by using projector to ask students to demonstrate their exercises, he could know ''if most students understand the knowledge in the similar pace''. Besides, the interviews also show that Chinese teachers like using students' typical errors or good works for discussion and it is an effective way to show all pupils what is incorrect, and what is encouraged. While individual guidance might be less effective in terms of enabling all students to understand in a similar pace. On the other hand, according to my observations and interviews, unlike English schools where children are classed based on their abilities and taught with different content, Chinese students are distributed randomly to a class, so classes are parallel (with mix-ability students), which seems to be better for the delivery of same knowledge. The Chinese way of organising students in learning seems reflects some aspects of Chinese culture of education, which is termed by researchers as Confucian heritage culture (CHC) (Wong, 2008; Leung, 2014), in which learners' efforts (rather than talents) are highly valued and it is believed that everyone can perform excellently as long as s/he works hard and never give up.

Chinese teachers always participant in collective instructional activities in schools. As described in chapter 4 (section 4.3.2), in each Chinese school, there is a subject-based 'Teaching Research Group' (TRG), which is responsible for teachers' professional development in the school. Fan, Miao and Mok (2015) stated that ''in a sense, the mathematics TRG is equivalent to the 'Department of Mathematics' in many other countries, but the TRG focuses more on research on classroom teaching and professional development'' (p. 52). According to the interviews, the TRG in the school always organize small-scale training. For example, TC2, TC3 and TC6 mentioned the GSP training conducted by the TRG in their schools. Within the TRG, there are sub-organisations called Lesson Planning Groups (LPG, also known as '*bei ke zu*'), which is consisted by teachers teaching same grade level. All the Chinese interviewees said that in their schools, the LPG often organised teaching and research activities such as mutual observing lessons. Because teachers in the same LPG taught the same grade level, it was possible for them to be observed of teaching the same topic. After the lesson observations, comparing, reflecting, and commenting were conducted collectively. The collective instructional practices such as preparing lessons together and observing and comparing different teachers' lessons, according to the interviewees, were good for teachers' professional growth, especially for novice teachers who lack enough experiences. In my opinion, such activities might also make Chinese teachers more likely to be influenced by colleagues, and more likely to practice consistently with the majority teachers rather than act personally. This might explained why the influence of personal pedagogical beliefs has not been detected, while school support, training, and professional activities are found to be influential in teachers' uptake of technology.

In England, however, fewer collective activities are organised. According to my observation, in schools, children were clustered based on their abilities, so they learned with different peers for different subjects. There was no unified textbooks in England, and all interviewees told me that in their schools teachers used different textbooks for different classes (even teaching the same topic). Besides, teachers always prepared different worksheet to suit students in different classes. According to my observation, the class size in England (all were less than 30 students) was smaller than that in China (all were around 45 students). The small size class in England might also make individual guidance more realistic.

In terms of teachers' professional activities in schools. According to the interview, there is few subject-based training in schools, and teachers have few chance to participate in inter-schools communications and exchange organised by professional organisations and groups. Besides, although teachers in mathematics department regularly meet, the main discussion is to decide the learning topics for each group of students. Teachers may share effective teaching methods and strategies, but they lack enough time and chance to observe formally each other's teaching and do reflection, sharing and comments afterwards. Although teachers are encouraged to reflect and communicate their teaching experiences with each other, they are respected to teach in their own ways. TE1, as the head of mathematics department in his school, said that ''I respect every teachers of their ways of teaching… Everyone works in his own way.'' This might explain why in English schools, teachers' instructional practices are shaped and influenced more by personal pedagogical beliefs than their Chinese counterparts.

(3) Differences on the management of educational practices

The above two points can be related to an explanation at a higher level, i.e. educational management system, that is how mathematics teachers are managed in different nations.

First, the two countries recruit mathematics teachers very differently. As I explained in chapter 4, in China, it is very hard for a non-mathematics degree holder to become a mathematics teacher in secondary schools. While in England, only part of mathematics teachers own mathematics degree in universities. Due to the lack of enough mathematics teachers in England, there are teachers owning maths-related degree (such as physics and engineer, such as TE3 and TE5), and also some hold irrelevant degrees (such as history, politics etc. such as TE4), and hence these mathematics teachers are not subject specialist (unlike Chinese teachers), and thus they might lack profound mathematics knowledge to guide all students for deep mathematical thinking and discussions. This might be why most Chinese mathematics teachers focused on helping students understand mathematics subject knowledge itself while English mathematics teachers highlight the application of mathematics in different disciplines and real life.

Second, teachers' workloads are different which may influences teachers' participation of various professional activities. The lack of enough mathematics teachers in England might also result in teachers' heavy workloads, which again decreases the likelihood for teachers to attend various professional activities. According to my interviewees, most mathematics teachers in England are assigned to teach over 5 classes (of different years) with over 20 hours' teaching work. However in China, all my interviewees told me that normally each secondary mathematics teacher taught only two classes (of the same grade), with around 10 lessons per week (about 7.5 hours' teaching work). So Chinese teachers seem to have more time in preparing and reflecting their instructions, and in attending other professional activities such as online trainings or relevant competitions.

Third, teachers' participations in subject-based professional developments are different between China and England. Although there are several organisations and groups[38] in England (NCTL, 2016) which are specially established for promoting mathematics education, teachers rarely attend the professional activities. According to my interviews, these professional activities were voluntary and it was almost fully decided by teachers themselves whether or not to attend such activities. In the interviews, all English teachers mentioned that it was common for teachers to attend out-school activities and trainings focusing on administration and management, while very few teacher attend subject-specific pedagogical activities and trainings, and cross-school activities are fewer. However in China, the establishment of Teaching and Research Office (TRO) brings many chances for teachers to learn, discuss and study the instruction of certain discipline in detail (mathematics for example in my study). TRO frequently organises various professional activities for school teachers. For example, TRO fellows regularly visit schools to observe classroom teachings and then make comments to help teachers improve subject-teaching. All the Chinese interviewees said that in each semester, they would attend at least one professional activity organised by TRO. Normally, a typical activity was observing classroom teaching and then teachers discussed and made comments on the lesson. In the discussion, viewpoints of good mathematics educational practices as well as good instructional materials were also talked about. In my opinion, such activity and discussions seem to be an effective way to disseminate educational viewpoints, which might lead to the fact that Chinese teachers are more likely to hold a similar understanding on mathematic education and sometimes practice similarly as their colleagues. For example, all my interviewees highlighted the teaching of mathematics thoughts and methods, and tried to encourage students to reflect problem-solving. In my study, all Chinese participants stated that they have attended different activities organised by TRO, which indicated the influence of TRO in Chinese schools.

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[38] Such as National Centre for Excellence in the Teaching of Mathematics (NCETM), Maths Hubs, Institute of Mathematics and its Applications (IMA), and so on.

Finally, whether use unified textbooks in instructions may also influenced teachers' professional activities and teachings. In China, textbooks of all subjects are used in whole China as an important learning materials. Schools normally do not have the right to choose textbooks, and it is the municipal educational bureau who decides the textbook for schools, so all schools (usually in the same province or city) use the same book (for example, all the Chinese schools I visited used the same set of textbook), and therefore the teaching content is fixed. According to TC1, TC4 and TC6, Chinese teachers usually discuss how certain content can be better taught (including using which technology) with colleagues privately or in LPG meetings. However, in England, teachers said that there was no unified textbooks, and different groups of students would learn different knowledge (even if they were in the same year), so the department meetings were mainly for discussing the teaching content and relevant work arrangement, while it seems that less chances are provided for teachers to discuss good practices and pedagogies formally.

7.5 Summary

Based on the findings from the previous chapters, this chapter compares and discusses Chinese and English mathematics teachers' use of technology in their teaching practices, and the discussion reveals that:

(1) All English teachers used calculators in teaching mathematics, while 23.6% of Chinese teachers didn't used calculators. Within those teachers who used calculators, differences on using strategies are also revealed.

(2) Computers were used by a great number of teachers in both China and England, while the using strategies in the two nations were found different.

(3) A big difference was found in the proportion of teachers in China and England using IWBs, and the differences were also discovered in the using strategies and instructional goals.

(4) Besides calculator, computer and IWB, a majority of Chinese teachers used projector in their teachings, while only 2.5% of English participants used 'other' technology in teaching mathematics. While the use of mobile phones in China and England are quite similar.

As regards the influential factors, the comparisons also discover that:

(5) Teachers' knowledge and skills, school facility and resources and school supports were important factors in both countries. Besides, assessment was also influential in teachers' use of technologies.

(6) In China, professional trainings and professional activities were found to be influential, while in England, those two factors played less important roles, but personal pedagogical beliefs and attitudes, and students were important factors.

Based on the comparisons above, some general differences between Chinese and English teachers' use of technology are discussed. Firstly, in delivering knowledge, Chinese teachers focus more on 'why', while English teachers focus more on 'how', which leads the fact that Chinese use technology more for explaining and justifying, while English teachers use technology more for illustrating and demonstrating. Secondly, Chinese teachers emphasis more on group discussion while their English counterparts emphasis more on individual exercises, which leads the fact that Chinese teacher use technology more for whole classroom activities than English teachers. Thirdly, Chinese teachers emphasise more on mathematics knowledge itself while English teachers emphasise more on the application of mathematics, which leads the fact that Chinese teachers adopt technology more for presenting and explaining the knowledge itself while English teachers use technology more for assisting applications of mathematics. Finally, although teachers in both countries used quite a wide range of technology, English teachers are found to be more diverse in using technology than Chinese teachers.

The author also briefly analysed the above differences, which have been interpreted in the following aspects: First, Chinese and English mathematics teachers have different understandings of learning process as well as the mastery of knowledge; Second, Chinese and English teachers have different emphasis on collective and individual instructional activities. Finally, the management of educational practices in China and England are different.

Chapter 8 Conclusions

This chapter consists of four sections. Firstly, a summary of the main findings is provided. Secondly, implications of this study is discussed. The third section describes some limitations of the study, and finally a number of possible research directions are provided for researchers in relevant fields to undertake in further studies.

8.1 Main Findings and Conclusions

This study aims to investigate and compare Chinese and English secondary teachers' use of technology in teaching mathematics. Specifically, two main questions, as well as the sub-questions are explored:

(I) How do Chinese and English teachers use technologies in teaching mathematics?

  (i) What technologies are used in classroom teaching?

  (ii) How are these technologies used?

(II) What factors influence Chinese and English mathematics teachers' use of technology?

Focusing on the two main research questions, this study yields the following findings:

(1) All English participants used calculators, with the most majority of teachers (87.4%) using scientific calculators. However in China, only 76.4% of the participants used calculators, and both scientific calculator (55.9%) and simple calculators (42.8%) were used by the majorities.

The study also shows that Chinese teachers used calculators mainly via the strategy of Inquiring and Exploring (IE), followed by the strategies of Calculating and Checking (CC) and Reflecting and Discussing (RD), and least used via Illustrating and Demonstrating (ID) and Explaining and Justifying (EJ). While there was no differences in the use of calculator for different instructional purposes. For English teachers, calculators were used mainly via Calculating and Checking (CC), followed by Inquiring and Exploring (IE) and Reflecting and Discussing (RD). In terms of instructional purposes, calculators were more used for the teaching of mathematics knowledge and skill (MKS), rather than mathematics thinking and reasoning (MTR), and the cultivation of positive disposition towards mathematics (PDM).

(2) Almost all Chinese teachers (97.4%) and English teachers (95.8%) used computers in teaching mathematics. 80.3% of Chinese teachers used desk-computers and 39.7% used laptops, while only 4.4% used tablet. Besides, Chinese teachers in School I and II used desk-computers more frequently than their counterparts in school III. In England, 71.4% of teachers used desk-computers, and 58.8% used laptops, and the proportion of teachers used tablet was 31.1% which

was higher than that in China. The chi-square tests revealed that for both desk-computer and laptop, the proportions of English users in School I were significantly different from that in school II and III. However, when we combined 'desk-computer' and 'laptop' together as ordinary computer, no significant difference was found among the three types of English schools.

The study showed that Chinese teachers used computers mainly via the strategy of Illustrating and Demonstrating (ID), and Explaining and Justifying (EJ), followed by Reflecting and Discussing (RD), Calculating and Checking (CC), and Inquiring and Exploring (IE). Moreover, Chinese teachers used computers more frequently for the teaching of Mathematics Knowledge and Skills (MKS), and the cultivation of Positive Disposition towards Mathematics (PDM), rather than for the teaching of Mathematics Thinking and Reasoning (MTR). However, teachers' use of computer for MTR were significantly different between different school types. In England, computers were used mainly via the strategy of Illustrating and Demonstrating (ID) and Calculating and Checking (CC), followed by Explaining and justifying (EJ), Inquiring and Exploring (IE) and Reflecting and Discussing (RD). Computers were more frequently used for Mathematics Knowledge and Skills (MKS), and Positive Disposition towards Mathematics (PDM), rather than for the teaching of Mathematics Thinking and Reasoning (MTR).

(3) Only 37.1% of Chinese teachers used IWBs in teaching mathematics, while 85.7% of English teachers used IWBs. Moreover, Chinese teachers in School I and II used IWBs more often than teachers in School III. However in England, significant difference was only found between school I and school III.

In terms of using strategies and instructional purposes, results showed that Chinese teachers used IWBs mainly via Illustrating and Demonstrating (ID), and Explaining and Justifying (EJ), and IWBs were least used via Calculating and Checking (CC), Reflecting and Discussing (RD) and Inquiring and Exploring (IE); In addition, Chinese teachers used IWBs more frequently for the cultivation of Positive Disposition towards Mathematics (PDM), rather than for other purposes. In England, teachers used IWBs mainly via the strategy of Illustrating and Demonstrating (ID), Calculating and Checking (CC), and Explaining and Justifying (EJ), followed by Reflecting and Discussing (RD) and Inquiring and Exploring (IE); IWBs were more frequently used for the teaching of mathematics knowledge and skill (MSK), and the cultivation of Positive Disposition towards Mathematics (PDM), rather than for mathematics thinking and reasoning (MTR).

(4) Mobile phones were just used by 28.8% Chinese teachers and 10.9% English teachers in the teaching of mathematics. There were significant differences in neither pedagogical strategies nor instructional purposes of the adoption in both countries.

(5) Projector was used by 85.2% of Chinese mathematics teachers, which made it the most

commonly used hardware in China. Chinese teachers used the projector mainly via the strategy of Reflecting and Discussing (RD), and for the purpose of teaching Mathematics Thinking and Reasoning (MTR). While in England, only 38.6% of teachers used projector, and for those who used ‘other’ technology (including projector), it is mainly for the teaching of Mathematics Knowledge and Skill (MKS).

(6) Among all explored software, Microsoft office packages (i.e. Word, Excel and PowerPoint) were most frequently used in both countries. Besides, Geometer’s Sketchpad (GSP) was used by 86.9% of Chinese teachers as a dynamic geometry software for geometry instruction. Similarly, GeoGebra and Autograph were used by 47.0% and 37.8% of English teachers respectively as dynamic geometry software. However, the study showed that data analysis software was only used by around 5% of Chinese teachers.

(7) Teachers from both countries used a wide range of online resources including search engines (mainly Baidu for Chinese, and Google for English), subject-based websites, download pictures and videos, and content-specific programs. Besides, Chinese teachers usually used local instant information exchange packages (either QQ or Wechat) to share and collect teaching materials in their daily works.

(8) As regards the influential factors, the study revealed that School facility and resource; School support; teachers’ Knowledge and teachers’ Skill were four significant factors in both countries. Besides, assessment was found by interviews as another important factor influencing mathematics teachers of both countries of their uptake of technology in instructions. Moreover, the study showed that in China, Training and Professional activity were influential, while in England, Pedagogical beliefs, and Student played important role in impacting teachers’ uptake of technology in teaching mathematics.

8.2 Implications

The findings of the study demonstrate clearly the complicated nature of teachers’ integration of technology in classroom teachings. Based on the findings and conclusions, several implications are provided for practitioners and policy-makers in both nations.

The analysis on teachers’ use of technology in classroom teachings showed that although different technologies were employed in Chinese and English mathematics classrooms, the pedagogical strategies and the instructional goals of using technologies were unbalanced. For Chinese teachers, technologies were less often used as a tool for students’ inquiries and explorations. Computers, although considered by many researchers as good tools for inquiring (Lai & Kritsonis, 2006; Roche, O'Neill & Prendergast, 2016), were used less often via the strategy of Inquiring and Exploring. Similarly, although calculators were used for inquiries, teachers tried to use calculators in classrooms ‘‘as less as possible’’, and therefore the calculator-based inquiry was very occasional. For English teachers, although they used technologies in various ways, the teaching of Mathematics Thinking and Reasoning (MTR) was rarely covered in the instructional goals, which was more likely to lead students’ understanding of mathematics knowledge and skills in a relatively superficial level. Therefore, it is suggested that teachers in both nations should learn from each other to make up the deficiencies. Chinese teachers could provide more chances for students to do inquiry by designing lessons connecting school mathematics knowledge with real-life problems relevant to learners’ experiences or by interdisciplinary problems. In doing so, various technologies could be employed to mathematise context-based problems into mathematical problems before seeking strategies to solve them, and students would be more likely to understand the value of mathematics in other disciplines and daily life. English teachers should pay more attention in guiding students to think and understand mathematics knowledge deeply, and should links different pieces of knowledge together, rather than just making students do exercises on separate topics. Besides, technology could be used to encourage and assist students to do various mathematical activities such as making plausible reasoning and rigorous proofs, which contains important mathematical thinking such as connecting multiple presentations; visualisation and induction by observing patterns. (Ruthven & Hennessy, 2002; Goos, Stillman & Vale, 2007)

Chinese and English teachers should also balance the individual learning and whole-class interactions in instructions. Chinese teachers are good at organising whole-class discussions where students are provided chances to share, reflect, criticise and make comments on each other’s works. (Fan, Miao & Mok, 2015; Miao, 2015) However, less attention was paid to students’ individual learning. There is no doubt that each individual pupil matters and each pupil has his/her own learning pace. However, Chinese classroom structure—a large number of students with mixed abilities-makes individual guidance hard to conduct. TC4 was experimenting such guidance with the help of tablet, from which he could easily follow every student’s progress and give specific advises and supports. From TC4’s example, it is believed that by using such individualised technologies such as computer and portable tablets, pupils could learn in their own paces, and teachers may be able to trace each pupil’s learning process, based on which teachers could individually guide students to more effectively reach the learning goals. In English classrooms, this study echoes many previous studies which found that English pedagogy was severely individualised with much classroom time provided for students to work on their own, rather than to involve in whole-class interactions with their peers. (Kaiser, 2002; Miao, 2015) It is believed that each learner should be given enough time to think independently when learning mathematics, but exchanging and sharing matter as well. English teachers should not ignore the fact that learning is also a process of making social dialogues and interactive activities, which needs a great amount of time for learners to express, listen and negotiate with each other. The whole-class interactive teaching and learning are helpful in generating various ideas, analysis, and solutions, and in such multi-thoughts classrooms, learners are more likely to recognise and understand the knowledge in different faces, and thus making progress more rapidly and holistically.

Besides, in order to improve the integration of technology in instructions, teachers should be more active as a learner, user, reflecter, and exchanger. The findings of this study show that knowledge and skills are important factors influencing teachers' use of technology. In another word, teachers with more knowledge and better skill on certain technology are more likely to employ the technology. Such finding is consistent with what has been found in many previous studies and discussions (e.g., Bingimlas, 2009; Goktas, Gedik & Baydas, 2013). Based on this information, it is suggested that teachers should intentionally absorb tech-information to enrich their relevant knowledge. The channels where information comes can be diverse including books and magazines, professional websites to online resources and social media, and teachers in the interviews claimed that the online resources were increasingly welcomed due to its access-convenience in time and space. Besides, teachers should try to use different technology in practice where experiences can be accumulated and then reflections on such experience will enhance their knowledge and skills. Due to the practical nature of technology integration, teachers should also be more open to the peers' experiences, mutually share practical suggestions on the use of technology. In this way, teachers might expand their knowledge and experience as a group, hence growing professionally more rapidly.

Finally, recommendations are provided for educational administrations of different levels in China and England. Chinese schools are supportive in training teachers to use different technologies, but the school facilities can be sometimes problematic. Although teachers in both countries indicated that technology kept changing and updating, and it was hard for schools to always follow new creations, the interviews revealed that in most Chinese schools, some common facilities, such as IWB, and possibly useful devices, such as tablet, were probably still lacking, which restricted teachers' effectiveness in classroom teachings. It is suggested that Chinese schools' administrators should regularly collect information on teachers' professional needs and try to maintain and supply facilities and resources to ensure teachers' instructions. In England, teachers ask for more time to exchange and communications between colleagues. The data collected from England reveals that teachers benefit from various professional exchanges and communications, although not so many opportunities have been provided. Besides, the study also shows that there are few chances for English teachers to attend professional training, so that they get less information to reflect and improve their subject-teachings. It is thus suggested that English educational administrators should organise more peer exchanges within and between schools so that teachers are able to observe more lessons, share teaching experiences, and update the pedagogical information.

8.3 Limitations of the Study

Due to the nature of the study, the researcher was limited in several aspects from the time being spent to available resources. Although 37 schools have participated in the study, the data is collected just in small areas in China and England, and therefore the sample size of the study is still relatively small. It is believed that richer findings would come up if more schools from more regions in both countries join in the study. Because China and England are both large and diverse countries, the researcher is always well aware that the two regions selected for the study cannot be taken as representative of other areas of the countries concerned, and therefore findings of the study cannot be automatically extended to the whole countries to describe teachers of all kinds of schools such as rural or private schools.

The small sample in the study also brings problems in using advanced statistical methods. As can be seen in Chapter 5 and 6, due to the relatively small number of schools providing questionnaire data, the multilevel modelling can hardly be employed to its full power. In other words, only random slope models can be constructed. However, the study still proved that in both China and England, when considering teachers' use of technology, the between school differences cannot be ignored. It is believed that with more data, the study would generate more detailed findings to explain teachers' tech-related behaviours.

The limitations on time and other conditions in sites have been also reflected in the classroom observations. Firstly, only one lesson in each classroom was observed, and it would be better if a sequence of lessons could be observed for each teacher so that the typicality of their teachings would come out obviously. Secondly, the content of the observed lessons was not exactly the same, and it is very hard to organise uniform teaching topic and content across schools and nations. It is believed that if all observed lessons are the same in the delivering content, more specific findings and deeper comparisons would be generated. However all teachers were asked to deliver their lessons in their usual ways, and the interviews covered questions on teachers' usual ways of using technologies, which I believe can make up the above-mentioned deficiencies to some extent.

Finally, the limitations on resource also mean that for this cross-national investigation, the researcher was the only one—despite supervisors having given useful advices—who independently carried out the study. Although the researcher has made every effort to collect as much information and data as possible, and to maintain a neutral position in interpreting the data, it is still believed that an international team would be much more helpful and effective in working and overcoming various difficulties and biases.

8.4 Future Directions

The present study can be extended in a number of ways, and the obvious extension is to collect data based on the three instruments in more schools from more regions in each country, and thus allowing us to conclude about teachers' classroom practices in a wider area of the countries instead of in just two regions. Besides, in each country, comparisons can be made between private schools and state schools, to see how the school type influence teachers' tech-related classroom practices.

It has been mentioned in the last section that the classroom observations in the present study were conducted in a scale and manner less than desirable due to the limitations in time and resources. Future studies could conduct more in-depth cases studies in the classrooms to generate more detailed data on teachers' tech-related practices, which would provide richer contextual-bonded information for researchers and policymakers to compare and understand mathematics educations in China and England.

Comparisons can also be made between primary and secondary school teachers, or between teachers' teachings of different curriculum stages. For example, to compare teachers' teaching of Key Stage 3 and Key Stage 4 in the UK. Although different content is taught in different curriculum stages, the comparisons would provide evidence to examine whether teachers change the instructional goals or the pedagogical strategies on using technology when students are in the different learning stages. Based on the similar idea, comparisons could also be made between teachers' teaching on different topics, either national or international. For example, how Chinese and English teachers use technology in teaching algebra? Or how Chinese teachers use technology in teaching algebra and geometry? Such studies would shed light on our understandings on how technology is integrated into the instruction of different topics, which enables researchers and teacher educators to design more practical and effective training courses for teachers' professional development.

Appendices A-H

Appendix A Invitation letter

Dear Sir/Madam:

I am a full-time post-graduate research student at the University of Southampton and am currently working on my PhD project. I am writing to you to see if you could help me by letting your mathematics department participating in my study, and I should be so grateful if you offer help.

My study is intended to investigate and compare ‘‘Chinese and English secondary teachers’ use of technology in their teaching of mathematics’’. To do so, I am planning to answer the following questions: (1) what technologies and how they are used in the teaching of mathematics? (2) what factors influence mathematics teachers’ use of technology in their instruction?

Three instruments are adopted for collecting data: questionnaire, classroom observation, and interview. To apply the instruments, a number of schools in Hampshire and Nanjing are randomly selected. Within each selected school, all secondary mathematics teachers will be asked to complete a questionnaire, and two teachers will be observed for their classroom teaching followed by interviews for about 45 minutes.

The participating schools and individuals will be kept strictly anonymous in all of the research reports, and all the data will be kept confidential and only for research purpose. As your school has been chosen in my sample, I sincerely hope that you and your department would be willing to participate in my study, and of course, I am more than happy to send you a copy of the final report if you would like to read. Thanks again for your reading and help!

Sincerely yours

Kun Xiang (Signature)

Appendix B-1 Teacher Questionnaire (English)

Teacher Questionnaire

This questionnaire is part of a study on mathematics teachers' use of technology. ***Here 'technology' refers to hardware (or facilities), software applications and online resources.*** *All information collected in this study is only for research purpose, and will be kept strictly confidential. Under no circumstances, will the name of the school or individual be published.*

Your responses are of great importance to us, so please try to answer all questions as best as you can. Thanks for your cooperation!

Should you have any queries, please contact me (Kun Xiang) by email: K.Xiang@soton.ac.uk

Part A. Background Information

1. Gender: Male ☐ Female ☐
2. Age: 20 to 29 ☐ 30 to39 ☐ 40 to 49 ☐ 50 to 59 ☐ ⩾60 ☐
3. (1) The name of your school is ________________

   (2) How many years have you taught Mathematics? _________ years

   (3) During this academic year, what topics are you teaching? (Please tick *all* that apply)

   Number ☐ Algebra ☐ Probability ☐ Statistics ☐

   Geometry and measure ☐ Ratio, proportion and rate of change ☐

   Other ☐ (Please specify ____________________)
4. (1) What is the highest degree you have?

   Bachelor's ☐ Master's ☐ Doctorate ☐ Other ☐ (Please specify:__________)

   (2) Which qualification(s) do you have for teaching? (Please tick *all* that apply)

   PGCE ☐ PGDE ☐ Other ☐ (Please specify:____________)

   (3) Please specify if you are a:

   Subject Leader in Education (SLE) in Mathematics ☐

   Lead Practitioner (LP) that in line with National Standard ☐

   Advanced Skills Teacher (AST) in Mathematics ☐

   None of the above ☐

Part B. Please recall any technology that you have used for teaching mathematics in classroom for this school year (2015—2016), and answer question 5 to 7.

5. Have you used the following *electronic devices* for teaching mathematics? Please tick *all* that apply.

a. Simple calculator (can be used for four arithmetic operations) ☐

   Scientific calculator (can be used for irrational operations, like finding square root of a number) ☐

   Graphical calculator (can be used for drawing graphs of functions) ☐

   Symbolic calculator (can be used for inputting letters for symbolic operations like factorisation) ☐

b. Desk-computer ☐ Laptop ☐ Tablet (including iPad) ☐

c. Interactive Whiteboard ☐ Data Projector ☐

d. Smart mobile phone ☐

e. Other hardware and devices ☐ (Please specify: _________ _________ _________)

6. Have you used the following software for teaching mathematics? Please tick *all* that apply.

a. Microsoft Word ☐ Microsoft Excel ☐ Microsoft PowerPoint ☐

b. Symbolic manipulation & graphing package, Such as

   Autograph ☐ DERIVE ☐ Mathematica ☐

   Maple ☐ Others ☐ (Please specify:_____________)

c. Dynamic Geometry Software, Such as

   Geometer's Sketchpad (GSP) ☐ GeoGebra ☐ Cabri ☐

   Cinderella ☐ Others ☐ (Please specify:___________)

d. Statistical software (Fathom ☐ SPSS ☐ Stata ☐ R ☐)

   Other Statistical software ☐ (Please specify: __________________)

7. (1) Have you used the following online-resources for teaching mathematics? Please tick *all* that apply.

a. Search engines (Google ☐ Yahoo ☐ Bing ☐) Online videos or animations ☐

   Others ☐ (Please specify: ______________)

b. Maths-websites, such as MyMaths, NRICH Maths ☐ Online application, such as Logo, Desmos ☐

   Others ☐ (Please specify: _______________)

Part C-1. Technology can be used to calculate and generate numerical and symbolic outcomes quickly. Please recall your teaching experience during this school year (2015-2016), and tick how often you use different technologies to do so.

8. I use the following technology to generate answers for classroom exercises so that students can check their work.

a. Calculator	Never ☐	Occasionally ☐	Monthly ☐	Weekly ☐	Daily ☐
b. Computer	Never ☐	Occasionally ☐	Monthly ☐	Weekly ☐	Daily ☐
c. Whiteboard	Never ☐	Occasionally ☐	Monthly ☐	Weekly ☐	Daily ☐
d. Mobile phone	Never ☐	Occasionally ☐	Monthly ☐	Weekly ☐	Daily ☐
e. Others	Never ☐	Occasionally ☐	Monthly ☐	Weekly ☐	Daily ☐

9. After teaching a specific topic (e.g. sin α=cos(90°-α)), I use the following technology to generate concrete examples to confirm.

a. Calculator	Never ☐	Occasionally ☐	Monthly ☐	Weekly ☐	Daily ☐
b. Computer	Never ☐	Occasionally ☐	Monthly ☐	Weekly ☐	Daily ☐
c. Whiteboard	Never ☐	Occasionally ☐	Monthly ☐	Weekly ☐	Daily ☐
d. Mobile phone	Never ☐	Occasionally ☐	Monthly ☐	Weekly ☐	Daily ☐
e. Others	Never ☐	Occasionally ☐	Monthly ☐	Weekly ☐	Daily ☐

10. I use the following technology to generate examples to guide students to find a conclusion. (For instance, from the examples of the factorisation of x^2-1, x^3-1,…to find how to factorise x^n-1.)

a. Calculator	Never ☐	Occasionally ☐	Monthly ☐	Weekly ☐	Daily ☐
b. Computer	Never ☐	Occasionally ☐	Monthly ☐	Weekly ☐	Daily ☐
c. Whiteboard	Never ☐	Occasionally ☐	Monthly ☐	Weekly ☐	Daily ☐
d. Mobile phone	Never ☐	Occasionally ☐	Monthly ☐	Weekly ☐	Daily ☐
e. Others	Never ☐	Occasionally ☐	Monthly ☐	Weekly ☐	Daily ☐

11. I use the following technology to generate numerical examples to help students understand some abstract knowledge. (For instance, calculate 1/n for different integer values of n to show students that with n increasing, the value of $1/n$ decreases and tends towards to 0.)

a. Calculator	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐
b. Computer	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐
c. Whiteboard	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐
d. Mobile phone	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐
e. Others	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐

12. I let students use the following technology for self-learning of procedures. (For instance, ask students to trial and improve.)

a. Calculator	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐
b. Computer	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐
c. Whiteboard	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐
d. Mobile phone	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐
e. Others	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐

13. I let students use the following technology to calculate when they do problem solving or inquiry so they can focus more on solving strategies than on calculation.

a. Calculator	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐
b. Computer	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐
c. Whiteboard	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐
d. Mobile phone	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐
e. Others	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐

14. I let students use the following technology to calculate when they do problem solving or inquiry so they can find out the solution easily and become confident in mathematics.

a. Calculator	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐
b. Computer	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐
c. Whiteboard	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐
d. Mobile phone	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐
e. Others	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐

Part C-2. Technology can be used to combine and present different resources. Please recall your teaching experience during this school year (2015-2016), and tick how often you use different technologies to do so.

15. I use the following technology to present a combination of resources such as pictures, videos, animations, etc. to attract pupils' interest.

a. Calculator	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐
b. Computer	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐
c. Whiteboard	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐
d. Mobile phone	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐
e. Others	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐

16. I use the following technology to present a combination of resources such as pictures, videos, animations, etc. to show students the connection between mathematics and real-life situations.

a. Calculator	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐
b. Computer	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐
c. Whiteboard	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐
d. Mobile phone	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐
e. Others	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐

17. I use the following technology to show students that mathematical objects can be presented in various ways. (For instance, the unequal relations between numbers can be presented in a number line.)

a. Calculator	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐
b. Computer	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐
c. Whiteboard	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐
d. Mobile phone	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐
e. Others	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐

18. I use the following technology to present statistical data in various ways to guide students find patterns in the data.

a. Calculator	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐
b. Computer	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐
c. Whiteboard	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐
d. Mobile phone	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐
e. Others	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐

19. I use the following technology to make connections between different presentations (formula, graph, table etc.), so that students have better understanding of the topic. (For instance, the connection between roots of a function and the corresponding equation; the graph of a function and the corresponding inequality)

a. Calculator	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐
b. Computer	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐
c. Whiteboard	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐
d. Mobile phone	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐
e. Others	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐

20. I use the following to save and re-use students' work (or typical errors) for classroom discussion.

a. Calculator	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐
b. Computer	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐
c. Whiteboard	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐
d. Mobile phone	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐
e. Others	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐

Part C-3. Technology can be used to demonstrate knowledge dynamically. Please recall your teaching experience during this school year (2015-2016), and tick how often you use different technologies to do so.

21. After I explain some topics, I use the following technology to dynamically demonstrate and confirm what had been taught. (For instance, the shape of cross-intersection of a cube varies depending on the angle of the cross section)

a. Calculator	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐
b. Computer	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐
c. Whiteboard	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐
d. Mobile phone	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐
e. Others	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐

22. I use the following to demonstrate mathematical processes dynamically to stimulate pupils to discuss and understand the topic. (For instance, simulating throwing a dice to generate number to represent frequency of rolling a 1, and ask student to discuss the difference between frequency and probability.)

a. Calculator	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐
b. Computer	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐
c. Whiteboard	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐
d. Mobile phone	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐
e. Others	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐

23. I use the following to draw some graphs (such as Fibonacci Spiral) dynamically to show the beauty of mathematics.

a. Calculator	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐
b. Computer	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐
c. Whiteboard	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐
d. Mobile phone	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐
e. Others	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐

24. I use the following to demonstrate dynamically how the change of parameters influence the change of mathematics object (For instance, how the change of parameter of *a*, *b*, and *c* influence the graph of $y=ax^2+bx+c$).

a. Calculator	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐
b. Computer	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐
c. Whiteboard	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐
d. Mobile phone	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐
e. Others	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐

25. I use the following to demonstrate graphing process, such as drawing the graph of a function, drawing a symmetric figure or a mathematical similar figure, etc.

a. Calculator	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐
b. Computer	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐
c. Whiteboard	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐
d. Mobile phone	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐
e. Others	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐

26. I use the following to generate a certain kind of figure for students to observe to discover phenomena. (For instance, by dragging, students may find that an angle inscribed in a semi-circle is always 90°.)

a. Calculator	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐
b. Computer	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐
c. Whiteboard	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐
d. Mobile phone	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐
e. Others	Never ☐	Occasionally☐	Monthly ☐	Weekly ☐	Daily ☐

Part D. Technology-integration in classroom instruction is a complex issue, and it can be influenced by various situations. The following statements concern the factors that impact the use of technology in teaching mathematics. Please read the statements carefully, and tick the corresponding box to indicate your level of agreement.

	Strongly Disagree	Disagree	Agree	Strongly Agree
27. I am familiar with the commonly used technology (such as calculator, computer, Interactive Whiteboard, etc.).	☐	☐	☐	☐
28. I know what topics can be better taught with the help of technology.	☐	☐	☐	☐
29. Generally speaking, my knowledge about technology influences whether I use technologies in teaching.	☐	☐	☐	☐
30. When I encounter technical problem in the process of teaching with technology, I can usually resolve it myself.	☐	☐	☐	☐
31. Generally, I can use different technologies to prepare teaching materials.	☐	☐	☐	☐
32. Generally speaking, my skills about technology influences whether I use technologies in teaching.	☐	☐	☐	☐
33. I believe that technology can help student learn mathematics better.	☐	☐	☐	☐

	Strongly Disagree	Disagree	Agree	Strongly Agree
34. As a teacher, I should be a helper to assist pupils to discover knowledge.	☐	☐	☐	☐
35. I am confident when I use technology to teach in the classroom.	☐	☐	☐	☐
36. I can manage the whole classroom when I teach with technology.	☐	☐	☐	☐
37. Generally speaking, my beliefs about technology influences whether I use technology in teaching.	☐	☐	☐	☐
38. There are enough facilities in the school for me to use when I want to teach with technology.	☐	☐	☐	☐
39. When I apply to use certain facilities or technological resources for teaching, it is normally easy to be approved.	☐	☐	☐	☐
40. The facilities in my school are relatively obsolete or out-of-date.	☐	☐	☐	☐
41. Generally speaking, the facilities and resources in my school influences whether I use technology in teaching.	☐	☐	☐	☐
42. I can easily find technicians in the school to help when I encounter some technical problems.	☐	☐	☐	☐
43. I always discuss with my colleagues our experiences of using technology in teaching.	☐	☐	☐	☐
44. The head of maths department of my school usually encourages us to use technology to teach.	☐	☐	☐	☐
45. Generally speaking, my school culture about using technology (previous three aspects, see 41 to 43) influences whether I use technology in teaching.	☐	☐	☐	☐
46. The textbook I use provides many suggestions about using technology to teach.	☐	☐	☐	☐
47. The instructional materials (such as teachers' instructional handbook) I use provides many suggestions about using technology to teach.	☐	☐	☐	☐
48. Generally speaking, I usually use technology in teaching when the curriculum materials (such as textbook and other instructional materials) suggest me do so.	☐	☐	☐	☐
49. The number of students in my classroom influences my use of technology to teach.	☐	☐	☐	☐
50. In my class, students are familiar with technology.	☐	☐	☐	☐

	Strongly Disagree	Disagree	Agree	Strongly Agree
51. Generally speaking, students in my class influence whether I use technology in teaching.	☐	☐	☐	☐
52. I always attend out of school lectures or conferences to obtain knowledge and information about technology for teaching.	☐	☐	☐	☐
53. I have participated out of school professional trainings (such as those organised by local authority or universities) associated with technological integration.	☐	☐	☐	☐
54. Generally speaking, the professional lectures and training that I attended influence whether I use technology in teaching.	☐	☐	☐	☐
55. The educational inspections organised by different levels (including local authority) push us to use technology to teach.	☐	☐	☐	☐
56. I always attend cross school professional exchanges and information sharing.	☐	☐	☐	☐
57. Generally speaking, the cross school professional exchange and activities influence whether I use technology in teaching.	☐	☐	☐	☐

58. Besides the previously mentioned factors, what other factors do you think have influenced whether you use technology in teaching? ____________________

Many thanks for your help! Besides the questionnaire, I still need some lesson observations and interviews for my study. Is it possible for me to observe one of your lessons and ask you some questions later on? As a reward, I'll send you a brief report about you and English mathematics teachers in terms of using technology in teaching after data analysis. ☐ Yes ☐ No

If yes, please contact me by e-mail, or leave your email address or telephone number here, and I'll contact you soon. ____________________

Appendix B-2 Teacher Questionnaire (Chinese)

初中数学教师使用技术进行教学 调查问卷

*本问卷是‘中英数学教师使用技术进行教学’的研究工具的一部分。**本研究只涉及教师教学所使用的技术（包括作业布置和检查），而不涉及学生课下的自学。这里的‘技术’包括<u>硬件设备</u>，<u>软件程序</u>和<u>网络资源</u>三大类。**本问卷收集的所有信息都将仅用于学术研究，所有信息都将保密。问卷所涉及的学校及参与者名称将不会出现在本研究的任何报告中。您的回答对本研究至关重要，请尽可能完成所有问题。非常感谢您的帮助！有任何问题请联系：K.Xiang@soton.ac.uk*

A. 基本信息

1. 性别: 男☐ 女☐
2. 年龄: [20, 30) ☐ [30, 40) ☐ [40, 50) ☐ ≥50 ☐
3. (1) 您所在学校名称是: ______________
   (2) 您教数学多少年了? ________ 年
   (3) 在本学年（2015-2016），您所任教的年级是: 七年级☐ 八年级☐ 九年级☐
4. (1) 您已取得的最高学历是：专科☐ 本科☐ 研究生(硕士☐ 博士☐)
   其他☐ (请具体说明: ________)
   (2) 您的职称是：无☐ 中教二级☐ 中教一级☐ 中学高级☐ 教授级☐
   (3) 您是否为特级教师? 是☐ 否☐

B. 现在请您回忆，在本学年(2015—2016)您使用了哪些技术进行数学教学，并回答以下问题，没有合适的选项则不用勾选。

5. 请问您是否用过以下***硬件设备***教数学？(不包括学生课下自学) <u>请勾出所有您用过的设备</u>
   a. 简单计算器（只能进行四则运算）☐ 科学计算器（能进行开方等无理运算）☐
   图形计算器（能进行函数图形绘制）☐ 符号计算器（能输入字母，进行因式分解等运算）☐
   b. 台式电脑 ☐ 笔记本电脑 ☐ 平板电脑(含 iPad) ☐
   c. 电子白板 ☐ 电子投影展台 ☐
   d. 智能手机 ☐
   e. 其他电子设备 ☐ (请具体说明: __________ __________ __________)

6. 请问您是否用过以下***软件和应用程序***教数学？(不包括学生课下自学)<u>请勾出所有您用过的程序</u>
   a. Word 文档☐ Excel 文档☐ PowerPoint 文档☐
   b. 符号运算和绘图软件程序, 如
   Maple ☐ DERIVE ☐ Mathematica ☐ 其他 ☐ (请具体说明: ________)
   c. 动态几何软件程序， 如
   几何画板☐ GeoGebra ☐ 超级画板☐ 其他 ☐ (请具体说明:________)
   d. 动态数据软件 Fathom☐ 统计软件(如 SPSS, Stata, R 等)☐(请具体说明: ___________)
   其他统计与数据分析软件☐ (请具体说明: ___________)

7. 您是否用过以下***网络资源和程序***教数学? (不包括学生课下自学) <u>请勾出所有您用过的资源和程序</u>
   a. 一般网络资源：搜索引擎(百度☐ 其他☐请具体说明_______) 网络图片或视频资源 ☐
   通讯资源(QQ☐ 微信公众号☐ 其他☐请具体说明_________)
   其他一般网络资源☐ (请具体说明: ___________)
   b. 数学网络资源：专业网站(搜索教学素材和练习等) ☐ 数学互动程序(如下载的 Flash) ☐
   手机应用程序（猿题库 app☐ 作业帮 app ☐ 其他☐请具体说明: ______)
   其他数学网络资源☐ (请具体说明: ___________)

C-1. 信息技术可以用来进行运算，快速地生成数值或符号结果。请回忆您这一学年（2015—2016）的教学情况，综合来看，勾选出您是如何利用不同的技术设备进行数学教学的。以下陈述描述了运用技术进行教学的基本方式，部分陈述附有实例辅助理解，但请注意该陈述不仅限于例子所述情况。

8. 我用以下技术生成或展示课堂练习的答案让学生核对。

a. 计算器	从不 ☐	很少 ☐	几乎每月 ☐	几乎每周 ☐	几乎每天 ☐
b. 电 脑	从不 ☐	很少 ☐	几乎每月 ☐	几乎每周 ☐	几乎每天 ☐
c. 电子白板	从不 ☐	很少 ☐	几乎每月 ☐	几乎每周 ☐	几乎每天 ☐
d. 智能手机	从不 ☐	很少 ☐	几乎每月 ☐	几乎每周 ☐	几乎每天 ☐
e. 其他设备	从不 ☐	很少 ☐	几乎每月 ☐	几乎每周 ☐	几乎每天 ☐

9. 完成某些知识的讲解后 (如 $\sin\alpha=\cos(90^{\circ}-\alpha)$), 我会利用以下技术进行具体数值的计算作为例子来验证。

a. 计算器	从不 ☐	很少 ☐	几乎每月 ☐	几乎每周 ☐	几乎每天 ☐
b. 电 脑	从不 ☐	很少 ☐	几乎每月 ☐	几乎每周 ☐	几乎每天 ☐
c. 电子白板	从不 ☐	很少 ☐	几乎每月 ☐	几乎每周 ☐	几乎每天 ☐
d. 智能手机	从不 ☐	很少 ☐	几乎每月 ☐	几乎每周 ☐	几乎每天 ☐
e. 其他设备	从不 ☐	很少 ☐	几乎每月 ☐	几乎每周 ☐	几乎每天 ☐

10. 在教学中，我会利用以下技术生成具体的例子引导学生归纳出一般结论。 (如利用技术生成 x^2-1, x^3-1,…等的因式分解式子，然后让学生归纳如何将 x^n-1 因式分解。)

a. 计算器	从不 ☐	很少 ☐	几乎每月 ☐	几乎每周 ☐	几乎每天 ☐
b. 电 脑	从不 ☐	很少 ☐	几乎每月 ☐	几乎每周 ☐	几乎每天 ☐
c. 电子白板	从不 ☐	很少 ☐	几乎每月 ☐	几乎每周 ☐	几乎每天 ☐
d. 智能手机	从不 ☐	很少 ☐	几乎每月 ☐	几乎每周 ☐	几乎每天 ☐
e. 其他设备	从不 ☐	很少 ☐	几乎每月 ☐	几乎每周 ☐	几乎每天 ☐

1

11. 在教学中，我会利用技术生成具体数值的例子，引导学生直观地理解某些数学思想。（如利用技术设备计算当 n 取不同的整数值时，$1/n$ 的值，由此让学生获得随着 n 增大，$1/n$ 会逐渐减小并趋于 0 的极限思想。）

a. 计算器	从不 ☐	很少 ☐	几乎每月 ☐	几乎每周 ☐	几乎每天 ☐
b. 电 脑	从不 ☐	很少 ☐	几乎每月 ☐	几乎每周 ☐	几乎每天 ☐
c. 电子白板	从不 ☐	很少 ☐	几乎每月 ☐	几乎每周 ☐	几乎每天 ☐
d. 智能手机	从不 ☐	很少 ☐	几乎每月 ☐	几乎每周 ☐	几乎每天 ☐
e. 其他设备	从不 ☐	很少 ☐	几乎每月 ☐	几乎每周 ☐	几乎每天 ☐

12. 我会让学生利用以下技术设备自学某些知识。（如要求学生绘制直角三角形并测量其三边长，再通过信息技术设备计算三边的平方，以此自学勾股定理。）

a. 计算器	从不 ☐	很少 ☐	几乎每月 ☐	几乎每周 ☐	几乎每天 ☐
b. 电 脑	从不 ☐	很少 ☐	几乎每月 ☐	几乎每周 ☐	几乎每天 ☐
c. 电子白板	从不 ☐	很少 ☐	几乎每月 ☐	几乎每周 ☐	几乎每天 ☐
d. 智能手机	从不 ☐	很少 ☐	几乎每月 ☐	几乎每周 ☐	几乎每天 ☐
e. 其他设备	从不 ☐	很少 ☐	几乎每月 ☐	几乎每周 ☐	几乎每天 ☐

13. 在学生进行问题解决或探究活动时，我会让他们使用以下技术设备进行计算，让他们用更多的时间反思解题方法和步骤。

a. 计算器	从不 ☐	很少 ☐	几乎每月 ☐	几乎每周 ☐	几乎每天 ☐
b. 电 脑	从不 ☐	很少 ☐	几乎每月 ☐	几乎每周 ☐	几乎每天 ☐
c. 电子白板	从不 ☐	很少 ☐	几乎每月 ☐	几乎每周 ☐	几乎每天 ☐
d. 智能手机	从不 ☐	很少 ☐	几乎每月 ☐	几乎每周 ☐	几乎每天 ☐
e. 其他设备	从不 ☐	很少 ☐	几乎每月 ☐	几乎每周 ☐	几乎每天 ☐

14. 在学生进行问题解决或探究活动时，我会让他们使用以下技术设备进行计算，以便更快地得出结果，提高数学学习的信心。

a. 计算器	从不 ☐	很少 ☐	几乎每月 ☐	几乎每周 ☐	几乎每天 ☐
b. 电 脑	从不 ☐	很少 ☐	几乎每月 ☐	几乎每周 ☐	几乎每天 ☐
c. 电子白板	从不 ☐	很少 ☐	几乎每月 ☐	几乎每周 ☐	几乎每天 ☐
d. 智能手机	从不 ☐	很少 ☐	几乎每月 ☐	几乎每周 ☐	几乎每天 ☐
e. 其他设备	从不 ☐	很少 ☐	几乎每月 ☐	几乎每周 ☐	几乎每天 ☐

C-2. 信息技术设备可以用来整合多种资源。请回忆您这一学年（2015—2016）的教学情况，综合来看，勾选出您是如何利用不同的技术设备进行数学教学的。

15. 我会利用以下技术设备展示多媒体资源（如图片，音乐，影片，动画等）来吸引学生注意力。

a. 计算器	从不 ☐	很少 ☐	几乎每月 ☐	几乎每周 ☐	几乎每天 ☐
b. 电 脑	从不 ☐	很少 ☐	几乎每月 ☐	几乎每周 ☐	几乎每天 ☐
c. 电子白板	从不 ☐	很少 ☐	几乎每月 ☐	几乎每周 ☐	几乎每天 ☐
d. 智能手机	从不 ☐	很少 ☐	几乎每月 ☐	几乎每周 ☐	几乎每天 ☐
e. 其他设备	从不 ☐	很少 ☐	几乎每月 ☐	几乎每周 ☐	几乎每天 ☐

16. 我会利用以下技术设备展示多媒体资源（如图片，音乐，影片，动画等），以此向学生展示数学与生活的联系。

a. 计算器	从不 ☐	很少 ☐	几乎每月 ☐	几乎每周 ☐	几乎每天 ☐
b. 电 脑	从不 ☐	很少 ☐	几乎每月 ☐	几乎每周 ☐	几乎每天 ☐
c. 电子白板	从不 ☐	很少 ☐	几乎每月 ☐	几乎每周 ☐	几乎每天 ☐
d. 智能手机	从不 ☐	很少 ☐	几乎每月 ☐	几乎每周 ☐	几乎每天 ☐
e. 其他设备	从不 ☐	很少 ☐	几乎每月 ☐	几乎每周 ☐	几乎每天 ☐

17. 我会利用以下技术用不同方式展示数学对象，帮助学生学习知识点。(如在不等式教学中，用数值，代数式，图象等多种方式呈现不等式。)

a. 计算器	从不 ☐	很少 ☐	几乎每月 ☐	几乎每周 ☐	几乎每天 ☐
b. 电 脑	从不 ☐	很少 ☐	几乎每月 ☐	几乎每周 ☐	几乎每天 ☐
c. 电子白板	从不 ☐	很少 ☐	几乎每月 ☐	几乎每周 ☐	几乎每天 ☐
d. 智能手机	从不 ☐	很少 ☐	几乎每月 ☐	几乎每周 ☐	几乎每天 ☐
e. 其他设备	从不 ☐	很少 ☐	几乎每月 ☐	几乎每周 ☐	几乎每天 ☐

18. 我会利用以下技术用不同方式展示数学对象，引导学生发现规律。(如在统计中，将大量数据展示成散点图，引导学生发现这些数据有集中或离散的趋势等，以此进行平均值和方差等的教学)

a. 计算器	从不 ☐	很少 ☐	几乎每月 ☐	几乎每周 ☐	几乎每天 ☐
b. 电 脑	从不 ☐	很少 ☐	几乎每月 ☐	几乎每周 ☐	几乎每天 ☐
c. 电子白板	从不 ☐	很少 ☐	几乎每月 ☐	几乎每周 ☐	几乎每天 ☐
d. 智能手机	从不 ☐	很少 ☐	几乎每月 ☐	几乎每周 ☐	几乎每天 ☐
e. 其他设备	从不 ☐	很少 ☐	几乎每月 ☐	几乎每周 ☐	几乎每天 ☐

19. 我会利用以下技术用不同方式展示数学对象，帮助学生建立知识点间的联系。（如将函数图像和数值表格联系起来帮助学生建立函数零点与图像与坐标轴的交点的关系；或函数图像与其对应不等式的解集关系）

a. 计算器	从不 ☐	很少 ☐	几乎每月 ☐	几乎每周 ☐	几乎每天 ☐
b. 电 脑	从不 ☐	很少 ☐	几乎每月 ☐	几乎每周 ☐	几乎每天 ☐
c. 电子白板	从不 ☐	很少 ☐	几乎每月 ☐	几乎每周 ☐	几乎每天 ☐
d. 智能手机	从不 ☐	很少 ☐	几乎每月 ☐	几乎每周 ☐	几乎每天 ☐
e. 其他设备	从不 ☐	很少 ☐	几乎每月 ☐	几乎每周 ☐	几乎每天 ☐

20. 我会用以下技术设备保存和展示学生的练习（或典型错误），并通过课堂讨论让其他学生学习。

a. 计算器	从不 ☐	很少 ☐	几乎每月 ☐	几乎每周 ☐	几乎每天 ☐
b. 电 脑	从不 ☐	很少 ☐	几乎每月 ☐	几乎每周 ☐	几乎每天 ☐
c. 电子白板	从不 ☐	很少 ☐	几乎每月 ☐	几乎每周 ☐	几乎每天 ☐
d. 智能手机	从不 ☐	很少 ☐	几乎每月 ☐	几乎每周 ☐	几乎每天 ☐
e. 其他设备	从不 ☐	很少 ☐	几乎每月 ☐	几乎每周 ☐	几乎每天 ☐

C-3. 信息技术设备可以用来动态地呈现知识。请回忆您这一学年（2015—2016）的教学情况，综合来看，勾选出您是如何利用不同的技术设备进行数学教学的。

21. 完成某些知识的讲解后，我会利用以下技术设备将数学过程动态地展现出来，以此加深学生对这一知识点的印象。（如在解释完用平面截正方体会得出不同形状的截面后，再用技术动态展示；或讲解完正方体的不同的展开图后，用技术动态展示等）

a. 计算器	从不 □	很少 □	几乎每月 □	几乎每周 □	几乎每天 □
b. 电 脑	从不 □	很少 □	几乎每月 □	几乎每周 □	几乎每天 □
c. 电子白板	从不 □	很少 □	几乎每月 □	几乎每周 □	几乎每天 □
d. 智能手机	从不 □	很少 □	几乎每月 □	几乎每周 □	几乎每天 □
e. 其他设备	从不 □	很少 □	几乎每月 □	几乎每周 □	几乎每天 □

22. 我会利用以下技术设备模拟数学过程引发学生讨论和学习。（如模拟多次掷骰子的过程，并让学生观察某一点数出现的次数，并讨论频率和概率的区别）

a. 计算器	从不 □	很少 □	几乎每月 □	几乎每周 □	几乎每天 □
b. 电 脑	从不 □	很少 □	几乎每月 □	几乎每周 □	几乎每天 □
c. 电子白板	从不 □	很少 □	几乎每月 □	几乎每周 □	几乎每天 □
d. 智能手机	从不 □	很少 □	几乎每月 □	几乎每周 □	几乎每天 □
e. 其他设备	从不 □	很少 □	几乎每月 □	几乎每周 □	几乎每天 □

23. 我会利用以下技术设备动态作图 (如勾股树) 向学生展示数学美。

a. 计算器	从不 □	很少 □	几乎每月 □	几乎每周 □	几乎每天 □
b. 电 脑	从不 □	很少 □	几乎每月 □	几乎每周 □	几乎每天 □
c. 电子白板	从不 □	很少 □	几乎每月 □	几乎每周 □	几乎每天 □
d. 智能手机	从不 □	很少 □	几乎每月 □	几乎每周 □	几乎每天 □
e. 其他设备	从不 □	很少 □	几乎每月 □	几乎每周 □	几乎每天 □

24. 我用以下技术设备动态演示某一数学对象是如何随参数变化而变化的。（如参数 a, b, c 的变化是如何影响二次函数 $y=ax^2+bx+c$ 的图像的)

a. 计算器	从不 □	很少 □	几乎每月 □	几乎每周 □	几乎每天 □
b. 电 脑	从不 □	很少 □	几乎每月 □	几乎每周 □	几乎每天 □
c. 电子白板	从不 □	很少 □	几乎每月 □	几乎每周 □	几乎每天 □
d. 智能手机	从不 □	很少 □	几乎每月 □	几乎每周 □	几乎每天 □
e. 其他设备	从不 □	很少 □	几乎每月 □	几乎每周 □	几乎每天 □

25. 我会用以下技术设备展示作图过程，帮助学生学习相关知识。（如展示完整的函数作图过程，或展示几何图形的平移，对称，缩放等变换）

a. 计算器	从不 □	很少 □	几乎每月 □	几乎每周 □	几乎每天 □
b. 电 脑	从不 □	很少 □	几乎每月 □	几乎每周 □	几乎每天 □
c. 电子白板	从不 □	很少 □	几乎每月 □	几乎每周 □	几乎每天 □
d. 智能手机	从不 □	很少 □	几乎每月 □	几乎每周 □	几乎每天 □
e. 其他设备	从不 □	很少 □	几乎每月 □	几乎每周 □	几乎每天 □

26. 我会利用以下技术设备生成和操作几何图形，让学生发现规律。(如利用作图工具拖拽的功能形成大量的三角形，让学生发现虽然形成的三角形各异，但它们的内角和是不变的)

a. 计算器	从不 □	很少 □	几乎每月 □	几乎每周 □	几乎每天 □
b. 电 脑	从不 □	很少 □	几乎每月 □	几乎每周 □	几乎每天 □
c. 电子白板	从不 □	很少 □	几乎每月 □	几乎每周 □	几乎每天 □
d. 智能手机	从不 □	很少 □	几乎每月 □	几乎每周 □	几乎每天 □
e. 其他设备	从不 □	很少 □	几乎每月 □	几乎每周 □	几乎每天 □

D. 将信息技术整合进日常教学中是一项复杂的工作，有效整合会受到一系列因素的影响。以下各项陈述指出了部分影响数学教师进行整合技术的教学的因素。请仔细阅读这些陈述，并基于您在本学年（2015—2016）的教学情况，勾选适合的方框，来表达您的赞同或不赞同程度。

	非常赞同	赞同	不赞同	非常不赞同
27. 我熟悉常用技术设备(如计算器，电脑，电子白板等)的用法。	□	□	□	□
28. 我知道哪些内容更适合利用信息技术进行教学。	□	□	□	□
29. 总的来说，我认为关于信息技术的知识影响了我是否使用技术进行教学。	□	□	□	□
30. 当我在运用技术进行教学，遇到技术问题时，我基本上能自己解决。	□	□	□	□
31. 我能运用不同的技术准备教学材料。	□	□	□	□
32.总的来说，我认为我的使用信息技术的技能影响了我是否使用技术进行教学。	□	□	□	□
33. 我相信信息技术能帮助学生更好地学习数学。	□	□	□	□
34. 作为一位教师，我应该更多地以帮助者或者助手的身份来辅助学生进行知识的探索。	□	□	□	□
35. 当我运用技术进行教学时，我感到自信。	□	□	□	□
36. 当我运用技术进行教学时，我能很好地管理整个课堂。	□	□	□	□
37. 总的来说，我认为关于信息技术的信念影响了我是否使用技术进行教学。	□	□	□	□
38. 我校有充足的技术设备和资源供我用于教学。	□	□	□	□

	非常赞同	赞同	不赞同	非常不赞同
39. 当我向学校申请技术设备或资源用于教学时，通常很容易被批准。	□	□	□	□
40. 我校技术设备较陈旧落伍。	□	□	□	□
41. 总的来说，我校的技术设备和资源影响了我是否使用技术进行教学。	□	□	□	□
42. 当我遇到有关技术设备的问题时，我能很方便地找来技术人员帮忙。	□	□	□	□
43. 我经常与同事交流运用技术进行教学的经验。	□	□	□	□
44.我校教研组长经常鼓励我们使用技术进行教学。	□	□	□	□
45. 总的来说，我校在信息技术上的文化环境 (即以上三项) 影响了我是否使用技术进行教学。	□	□	□	□
46. 我使用的教科书有很多让我运用技术进行教学的建议。	□	□	□	□
47. 我使用的备课材料或教学准备材料（非教科书）有很多让我运用技术进行教学的建议。	□	□	□	□
48. 总的来说，当教学材料（教科书和备课材料）建议我使用技术进行教学时，我会使用技术进行教学。	□	□	□	□
49. 我认为我所教班级里的学生人数会对我是否使用技术进行教学有影响。	□	□	□	□
50. 我所教班级里的学生对信息技术较为熟悉。	□	□	□	□
51. 总的来说，我认为班级里的学生情况影响了我是否使用技术进行教学。	□	□	□	□
52. 我经常参加校外的有关运用技术进行教学的(不定期的)讲座（包括网络讲座）和会议获取相关信息和知识。	□	□	□	□
53.我经常参加校外的有关运用技术进行教学的培训班。(如由教育局或大学定期举办的讲座和专业培训班，包括网络培训)。	□	□	□	□
54. 总的来说，我所参加的培训班和讲座(包括网络讲座和培训) 影响了我是否使用技术进行教学。	□	□	□	□

	非常赞同	赞同	不赞同	非常不赞同
55. 由教研室或教育局等组织的教学检查促使我使用技术进行教学。	□	□	□	□
56. 我经常参加区或市里的教研活动（如区教研会或公开课等）。	□	□	□	□
57. 总的来说，这些区或市里的教研活动影响了我是否使用技术进行教学。	□	□	□	□

58.除了以上提及的因素外，您认为还有什么因素对您是否使用技术进行教学有影响？ ______________________

亲爱的老师，谢谢您的帮助和支持。除了问卷外，本研究还需要收集课堂观察和访谈的数据。请问您是否愿意继续参与本研究，让研究者观察一堂您的数学课，并在课堂观察后简单地询问您一些问题呢？如果您愿意，本人愿意在研究结束后将研究结论整理成一份简单的报告赠予您。谢谢您！

如果您愿意，请通过邮件 K.Xiang@soton.ac.uk 告知；或留下您的电话或 e-mail，本人将尽快联系您，谢谢！ ______________________

Appendix C Notes for Classroom Observation

Classroom observation is adopted to find out what technologies are exactly used in mathematics classrooms and from pedagogical perspectives, how are these technologies used. In addition, specific questions can be raised from the observation for interviews afterward so that more detailed information about teachers' tech-integration can be obtained for analysing.

The following questions are used to guide the observation process so that the researcher can aware what phenomena should be observed and what information should be recorded.

A. Background information of the class

1. Is it an ordinary classroom or a computer-suit? If it is a computer-suit, what is the ratio of computers over students, or how many students share a computer?
2. How many students are there in the class?
3. How are the students arranged? Being grouped or sit individually?

B. Instructional process

1. What is the topic of this lesson? (Is there any new concept, theorem, formula, procedure, etc. being introduced to students?) What is the purpose of the lesson?
2. What technologies are used during the lesson? (What hardware? What software? What online resources?)
3. By whom is it used? (Teacher? Students? Or both?) How is it used? (What functions are used and through what pedagogical strategy?)
4. If there is new knowledge (concept, theorem, formula, procedure, etc.) being introduced, what technology and how is it used for the introduction?
5. Is any difficulty that teacher or students encountered when they use the technology?
6. If students are asked to use technology, is there any technical instruction before their use? Are they use the technology in groups or individually?

Checklist for observation

A. Background Information

1. Venue:	Regular classroom	Mathematics classroom	A computer-suit
2. Teacher's gender		3. classroom size	
4. Students' sitting arrangement (Sit individually? Grouped? Or other style? Draw draft on the right)			

B. About the Instruction

5. The topic of this lesson: ____________________________________

   (Is it a new concept? Theorem? Problem-solving activity? Mathematical thinking based instruction? Or others?)

6. Is there any difficulty that teacher or students encountered when they use the technology, and what are they?

7. What technology are students asked to use? Is there any technology-specific instruction before their use? Are they use the technology in groups or individually? Are students familiar with the technology? Are they skillful in doing the asked tasks with the technology?

8. What technologies are used?

Hardware (number)	Ratio of student over device	Who use it (S or T or both)	What function is used?	Through which strategy

Software/Online sources	Who use it (S or T or both)	What function is used?	Through which strategy

Appendix D Interview Protocol

1. What was the purpose of the lesson I observed? (What topic you introduced? For what target is your lesson?)

2. I observed that you have used several technologies in instruction (specify the technologies), are you familiar with these technologies? How do you think of the function of different technology in this lesson? (To introduce new knowledge in an interesting way? To demonstrate the most difficult part of the lesson? To attract students' attention? Etc.)

3. Let's talk about the topic you taught today, is it the usual way that you teach? (How do you compare today's lesson with previous ones that you taught in a different way?)

4. How do you know the way you use technology for this topic? (Learn from pre-/in-service professional training? Lear from the textbook or instructional materials? Learn from books and journals? Learn from colleagues? Etc.) Was it always useful and made the topic easier for pupils to learn?

5. Did you try to get children's reactions and attitudes towards using technology in mathematics class? Is applying technology useful to involve the children to learn and to do mathematics?

6. How many pupils are there in your class? Is it easy and convenient for you to adopt technology for instruction in a class with such number of pupils? Are they good in term of knowledge and skill of using various technology? What is your opinion about the relationship between the number of pupils in the class and the ease of use technology or the usefulness of technology in instruction?

7. Let's discuss more on the technology we've mentioned before. Do you know other functions of the technology for teaching mathematics? Did you adopt these functions in classroom teaching recently? Can you give me some examples? How did you learn these ways? (Or why not?)

8. What is the main reason for you to think about using technology for instruction? (Personal belief and interests? Some knowledge is hard to explain and need to be demonstrated via technology? Pupils need to be attracted by technology? Technology is a must for inspection and national test? Administrators' encouragement? Etc.) (Or the main reasons for not using technology?)

9. Have you encountered some technical problems when you use the technology? Can you give me some examples? How did you solve it? Whom can you turn for help? Is it easy for you to find them and get their help, and are they actually useful?

10. Have you attended some professional trainings for pre-eservice period as well as in-service period? Is there some information about using technology in instruction? How do you think of the trainings? Are they useful?

11. Are there any tech-related activities in the school or in mathematics department that encourage you to use technology in instruction? (Such as school-based lectures and trainings, competitions, exchanges with colleague?)

12. What textbook and instructional materials are you using now? Is there any useful information on these materials for you to use technology in the teaching of mathematics?

13. How do you think about the devices in the school? Are they enough and new for you to use? How about the network at school?

14. Is there a computer-suit dedicated for mathematics department? If yes, can you apply for using it easily? If no, will you be willing to use it if there are some (or use it more if it is easy to apply and use)?

15. Do you know the attitudes of you head of department or other administrative? Is it encouraged to use a specific technology or different technologies in teaching? (for mathematics or for general)

16. Besides the factors we discussed above, what other factors you think might influence your use of technology in instruction?

Appendix E Demographic information of the Chinese teachers

Table F-1. Distribution of Chinese participants by sex

	Frequency	Percentage
Female	131	57.2%
Male	97	42.4%
Missing data	1	0.4%
Total	229	100%

Table F-2. Distribution of Chinese participants by age group

	20-29	30-39	40-49	⩾50	Total
Frequency	37	105	67	20	229
Percentage	16.2%	45.9%	29.2%	8.7%	100%

Table F-3. Distribution of Chinese participants by highest educational degree

	3-year diploma	Bachelor’s	Master’s	Doctorate	Total
Frequency	5	193	31	0	229
Percentage	2.2%	84.3%	13.5%	0	100%

Table F-4. Distribution of Chinese participants by professional titles

	None	Junior Grade	Intermediate Grade	Senior Grade	Total
Frequency	18	35	134	42	229
Percentage	7.9%	15.3%	58.5%	18.3%	100%

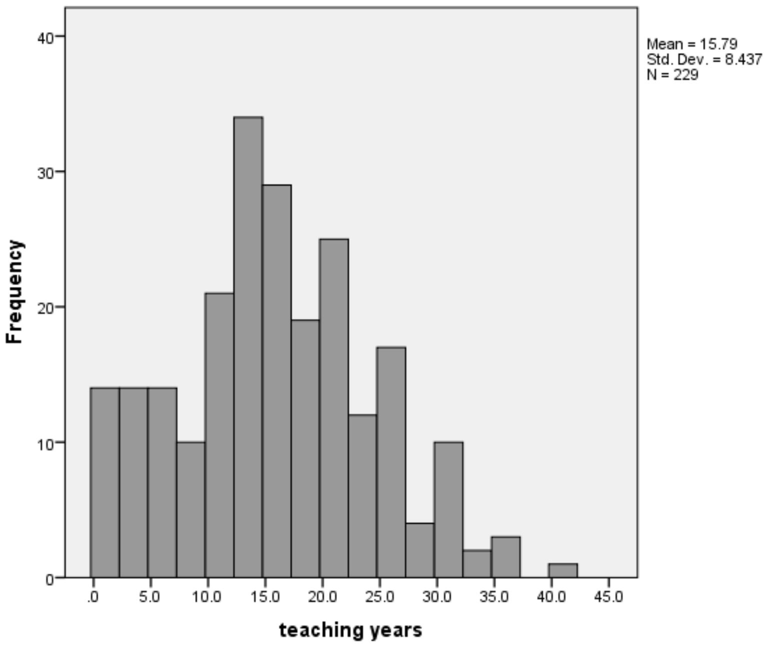

Figure F-1. Distribution of Chinese participants by years of teaching mathematics

Appendix F Statistic tests of Chinese questionnaire data

Table F-1. Distribution of the numbers of Chinese teachers among three school categories ticking different online resources

Technology: Search engine (Baidu)

	Category I School	Category II School	Category III School	Total
No	20	6	8	34
Yes	96	57	42	195
Total	116	63	50	229

Chi-square test: χ^2=1.991 df=2 p=0.370

Technology: Downloaded pictures and videos

	Category I School	Category II School	Category III School	Total
No	85	41	33	159
Yes	31	22	17	70
Total	116	63	50	229

Chi-square test: χ^2=1.647 df=2 p=0.439

Technology: Instant information exchange packages (QQ)

	Category I School	Category II School	Category III School	Total
No	72	35	29	136
Yes	44	28	21	93
Total	116	63	50	229

Chi-square test: χ^2=0.769 df=2 p=0.681

Technology: Instant information exchange packages (Wechat)

	Category I School	Category II School	Category III School	Total
No	77	39	34	150
Yes	39	24	16	79
Total	116	63	50	229

Chi-square test: χ^2=0.538 df=2 p=0.764

Technology: Subject-based websites

	Category I School	Category II School	Category III School	Total
No	29	7	10	46
Yes	87	56	40	183
Total	116	63	50	229

Chi-square test: χ^2=4.906 df=2 p=0.086

Technology: Interactive programs				
	Category I School	Category II School	Category III School	Total
No	103	54	44	201
Yes	13	9	6	28
Total	116	63	50	229
Chi-square test:	χ^2=0.364	df=2	p=0.834	

Technology: subject-based educational mobile apps (Yuantiku)				
	Category I School	Category II School	Category III School	Total
No	97	55	42	194
Yes	19	8	8	35
Total	116	63	50	229
Chi-square test:	χ^2=0.453	df=2	p=0.797	

Technology: subject-based educational mobile apps (Zuoyebang)				
	Category I School	Category II School	Category III School	Total
No	82	45	42	169
Yes	34	18	8	60
Total	116	63	50	229
Chi-square test:	χ^2=3.454	df=2	p=0.178	

Table F-2. Analysis of Variance of Chinese mean score of the three school categories on each technology

		Sum of Squares	df	Mean Square	F	Sig.
calculator	Between Groups	.084	2	.042	.664	.516
	Within Groups	14.260	226	.063		
	Total	14.344	228			
computer	Between Groups	8.961	2	4.480	68.136	.000
	Within Groups	14.861	226	.066		
	Total	23.822	228			
IWB	Between Groups	.381	2	.191	4.025	.019
	Within Groups	10.706	226	.047		
	Total	11.088	228			
Mobile phone	Between Groups	.102	2	.051	2.204	.113
	Within Groups	5.220	226	.023		
	Total	5.322	228			
other	Between Groups	.050	2	.025	.565	.569
	Within Groups	10.037	226	.044		
	Total	10.088	228			

Appendix G Demographic information of English teachers

Table H-1. Distribution of English participants by sex

	Frequency	Percentage
Female	76	63.9%
Male	43	36.1%
Total	119	100%

Table H-2. Distribution of English participants by age group

	20-29	30-39	40-49	⩾50	Total
Frequency	40	61	10	8	119
Percentage	33.6%	51.3%	8.4%	6.7%	100%

Table H-3. Distribution of English participants by highest educational degree

	Bachelor's	Master's	Doctorate	Missing	Total
Frequency	89	26	3	1	119
Percentage	74.8%	21.8%	2.5%	0.9%	100%

Table F-4. Distribution of English participants by mathematics topics being taught

	Number	Algebra	Probability	Statistics	Geometry	Ratio	Other
Frequency	119	119	119	111	119	117	6
Percentage	100%	100%	100%	93.3%	100%	98.3%	5%

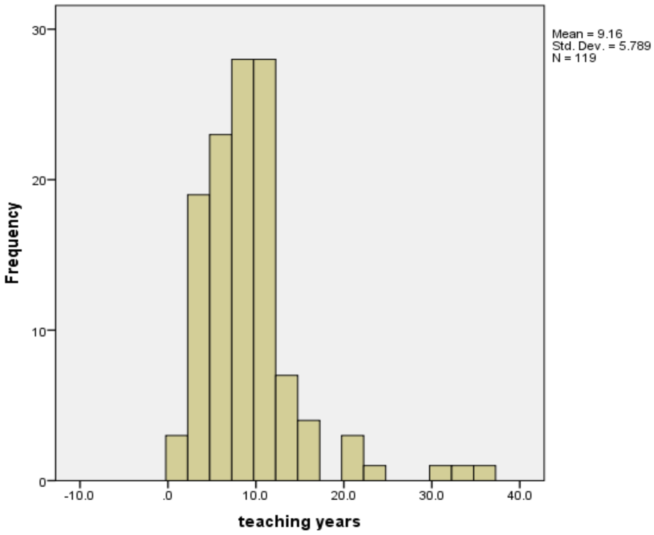

Figure F-1. Distribution of English participants by years of teaching mathematics

Appendix H Statistic tests of the English questionnaire data

Table H-1. Distribution of the numbers of English teachers among three school categories ticking different online resources

Technology: Search engine (Google)

	Category I School	Category II School	Category III School	Total
No	8	6	11	25
Yes	36	31	27	94
Total	44	37	38	119

Chi-square test: χ^2=2.167 df=2 p=0.338

Technology: Downloaded pictures and videos

	Category I School	Category II School	Category III School	Total
No	15	17	19	51
Yes	29	20	19	68
Total	44	37	38	119

Chi-square test: χ^2=2.316 df=2 p=0.314

Technology: Subject-based websites

	Category I School	Category II School	Category III School	Total
No	2	4	9	15
Yes	42	33	29	104
Total	44	37	38	119

Fisher-Freeman-Halton exact test*: p=0.028

Technology: subject-based online applications

	Category I School	Category II School	Category III School	Total
No	23	26	24	73
Yes	21	11	14	46
Total	44	37	38	119

Chi-square test: χ^2=2.823 df=2 p=0.244

Table H-2. Analysis of Variance of English mean score of the three school categories on each technology

		Sum of Squares	df	Mean Square	F	Sig.
calculator	Between Groups	.179	2	.089	.812	.446
	Within Groups	12.782	116	.110		
	Total	12.961	118			
computer	Between Groups	.344	2	.172	.411	.664
	Within Groups	48.656	116	.419		
	Total	49.001	118			
IWB	Between Groups	3.386	2	1.693	3.046	.051
	Within Groups	64.482	116	.556		
	Total	67.868	118			
Mobile phone	Between Groups	.056	2	.028	2.395	.096
	Within Groups	1.393	116	.012		
	Total	1.449	118			
other	Between Groups	.002	2	.001	.831	.438
	Within Groups	.112	116	.001		
	Total	.113	118			

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