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FACULTY OF SOCIAL, HUMAN AND MATHEMATICS SCIENCES

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Investigating Students' Use of Learning Resources in Mathematics: A Comparative Study of Secondary Schools in Shanghai and England

By

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ABSTRACT

FACULTY OF SOCIAL, HUMAN AND MATHEMATICS SCIENCES

Mathematics Education

Thesis for the degree of Doctor of Philosophy

INVESTIGATING STUDNETS' USE OF LEARNING RESOURCES IN MATHEMATICS: A COMPARATIVE STUDY OF SECONDARY SCHOOLS IN SHANGHAI ANF ENGLAND

Yi Wang

This thesis investigates how secondary school students use learning resources in mathematics in Shanghai and England, compares the resource use between the two places, and examines what factors influence the resources use in the two contexts.

In this study, learning resources refer to the things presenting mathematics, which can be utilized by students in their learning of mathematics in school education, including five paper-based resources and three electronic resources. Originated from Vygotsky's Activity Theory, resource use was constructed as activities incorporating those resources in the learning of mathematics. A conceptual framework was established based on Rezat and Sträßer's socio-didactical tetrahedron to take into account contextual factors and to embody the relations between those components.

Quantitative approaches dominated the processes of data collection and analysis, which were triangulated and complemented by qualitative methods. Six research instruments, including student questionnaire, teacher questionnaire, parent questionnaire, student focus group interview, teacher one-to-one interview, and classroom observation, were designed and developed to collect data. The participants of this research involved 161 Shanghai seventh and eighth-grade students from three state-funded schools and 206 England year-seven and eight students from three maintained schools along with their mathematics teachers and parents.

The results revealed that Shanghai students relied heavily on paper-based resources and used them in various situations, had a strong sense of self-regulation behind their resource use, and thought highly of the helpfulness of learning resources in their learning of mathematics. While England students usually incorporated both paper-based and e-resources in mathematics learning, used the resources mainly depending on teachers' instructions, and held a relatively critical view of the helpfulness of the resources. More differences than similarities were found between the two places and there existed some significant associations between the contextual factors and the resource use, which indicated that the constructed factors could explain students' resource use and even the differences of resource use to a certain extent.

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Content

List of Figures

List of Tables

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Chapter 1 Introduction

1.1 Background of the study

Over the last few decades, policymakers, educational leaders, researchers, and teachers have increasingly realized the crucial role of instructional resources in didactical practice, and the issue of how instructional resources, including syllabus, technology, and textbooks, are incorporated in teaching and learning has been a hot topic in the international arena of research on mathematics education. Addressing this issue may promote the development of relevant resources, help teachers optimize teaching strategies, and improve students' learning experiences.

Researchers are concerned about curriculum materials while investigating mathematics teachers' teaching (Remillard, Herbel-Eisenmann, & Lloyd, 2011). The relationship between teachers and teaching materials has been explored, discussed, and studied from many perspectives. For example, Collopy (Collopy, 2003) took curriculum materials as a professional development tool and investigated how a mathematics textbook affected teachers' learning, Manouchehri and Goodman (Manouchehri & Goodman, 1998) tried to understand the connections between mathematics curriculum and teaching practice, and a more recent book (Lianghuo Fan, Trouche, Qi, Rezat, & Visnovska, 2018) pointed out that research related to teachers' resources as a new and dedicated scientific field is noticeable in the mathematics education community.

However, the issue of students did not receive significant attention from researchers, teachers, and policymakers. For instance, in a large sense, textbooks are the main teaching and learning resources in mathematics classrooms. When it comes to textbook use and its impact, a large number of studies investigated teachers' use of mathematics textbooks, which implies that textbooks, from the teachers' perspective, are seen as a teaching material rather than a learning resource (e.g. Sosniak & Stodolsky 1993; Nicol & Crespo 2006). Indeed, it has taken much time and effort to discuss textbook use from the teachers' perspective (e.g. Chavez–Lopez, 2003; Johansson, 2006; Y. Zhu & Fan, 2002) because, to some extent, teachers are supposed to incorporate textbooks in their teaching purposefully while students seem to use textbooks only when they are asked to do so, especially in primary and secondary schools. Naturally, students' use of textbooks is taken as some result of teachers' textbook use, such as the impact of teachers' use of textbooks on students' opportunity to learn (see Haggarty & Pepin 2002). With the increasing recognition of a "student-centred" mode of classroom instruction, students' use of textbooks has attracted some attention in recent years (Randahl, 2012; Rezat, 2009b, 2013; Weinberg, Wiesner, Benesh, & Boester, 2012). In fact, instructional resources can refer to any resources used by teachers and students within or beyond classrooms, while *learning resource* differentiates the resources used by students with the purpose of learning from those resources used by teachers for teaching, although there is always some overlap; for example, textbooks are used by both teachers and students in many cases. Recently, “learning resource” was mentioned as the topic of a study group in the 13th International Congress on Mathematics Education (ICME) in 2016 to extend the research focus from textbooks to all resources used in mathematics learning. Generally speaking, learning resources are the objects facilitating learners’ learning, as the mediator presenting and passing knowledge in addition to teachers’ instruction. Therefore, learning resources play an important role in both self-study and didactical situations, and it is necessary to explore students’ interactions with learning resources, such as researchers have done to investigate the relationship between teachers and teaching materials.

As mentioned previously, textbooks are treated as a teaching material in most cases, so this accordingly raises issues, such as what resources students use in their learning of mathematics and how they interact with those resources. Workbooks can be considered as a supplement to exercises in textbooks. Fleisch et al (2011) conducted an experiment to examine the different effects of using a conventional textbook and a selected workbook on students’ mathematics performance at primary level in South Africa. The control group contained all the classes in grade 6 from 22 public schools using the conventional textbooks, while the experimental group had the same sample size but with a project learner workbook in which the exercises were mostly repetitive and contained numerical activities designed to consolidate concepts that had been taught. The findings showed that there were no significant differences in mathematics achievement between the control group and the experimental group. However, it is worth mentioning that, though called “workbook”, it still played the same role as the textbook since it was routinely used in classroom instruction as the conventional textbooks during the experiment.

Moreover, with the introduction of new technologies into the classroom, researchers have explored how advanced technologies shape students’ learning of mathematics from different perspectives (Masalski, 2005; Wenglinsky, 1998). Nevertheless, the focus of those studies mostly was teachers’ integration of different technologies in their teaching practice, though the results did suggest that it improved students’ learning experience.

It can be seen that people know little about what students really use in their learning of mathematics; in other words, knowledge of students’ interaction with learning resources is lacking. The main reasons could be that students’ use of learning resources seems trivial and it relies on teachers’ instructions to a certain extent, especially for students at lower year levels.

In short, existing studies on learning resources mainly focus on textbooks and technologies, which have drawn considerable attention from all over the world recently, whereas other materials supporting students’ learning of mathematics are relatively less mentioned compared to them.

Specifically, for studies on resource use, researchers did a great deal of work on the teachers' perspective with various purposes, e.g. to establish the link between pedagogy and curriculum. However, for students' use of learning resources, the existing research has made some attempts but these have still been scattered, and only a few studies involved secondary school students and provided substantial details about the use of these resources.

1.2 Need for the study

1.2.1 Why a study of learning resources?

As discussed above, in the community of education, researchers have paid close attention to the resources used in instructional situations (e.g. syllabus, textbooks, and technologies) and the influences of teachers' resource use on didactical practice. However, the resources used by students for their learning are relatively less mentioned.

In the beginning, a study of textbook use within and beyond mathematics classrooms (Lianghuo Fan, Chen, Zhu, Qiu, & Hu, 2004) comes to mind. The researchers found that *textbooks serve more as a teaching resource than as a learning resource in Chinese classrooms (p.238)*. In fact, this does not happen only in Chinese classrooms. In Germany, after the educational reform in 1968, teachers were still the major audience of textbooks (even for the students' version) and the educational theories were addressed to teachers, though the reform highlighted the students' central position in instruction (Keitel, Otte, & Seeger, 1980). Moreover, Keitel et al.'s report on how teachers valued textbooks showed that teachers thought that textbooks were not suitable for students' revision purposes. In England, teachers said they rarely expected students to use textbooks for any learning purposes except exercises considering students' inability in reading and understanding texts, even when questions in context were read and abstracted by teachers. The immediate effect is that when students have access to textbooks, many seem unable to use them to support their learning (Haggarty & Pepin, 2002). Therefore, it is reasonable to pose the question, What other resources do students use in their learning of mathematics when textbooks are not considered a proper choice?

Also, Fan et al.'s (2004) study pointed out that most teachers often resorted to other resources to deepen students' understanding, and half of the in-class examples were selected from non-textbook resources, which implies that textbooks are insufficient in terms of the number and quality of examples. However, they did not define those resources but just summed up them as "other materials". In other words, according to their study, other resources in addition to textbooks existed for students to do mathematics, but it was still unclear what those "non-textbook" resources were and how students worked with those resources.

To summarize, previous studies on resource use mainly focus on mathematics teaching, i.e. how teachers use resources to teach mathematics, rather than mathematics learning, i.e. how students use resources to learn mathematics. Even if discussing textbooks, a resource supposed to facilitate learners' learning with the students' version, researchers paid much more attention to how teachers used these materials instead of the students' side. Nevertheless, this does not mean that researchers are not interested in the latter, and there must be some reason behind this (see section 2.2.1). Therefore, due to the lack of studies on students' interactions with resources, this study entirely takes the students' stance to investigate resource use in their learning of mathematics and goes beyond textbooks and technologies to a macro scope by conceptualizing "learning resources" in mathematics, which coincides with the international attention on instructional materials and does contribute to research on educational resources from a different perspective.

1.2.2 Why a comparison between England and Shanghai?

Researchers in mathematics education have been paying great attention to international comparisons for a long time. In the past half century, they have undertaken various kinds of internationally comparative assessments of students' mathematics achievement and teachers' knowledge of pedagogy in mathematics (Kilpatrick, 2014); for instance, the international large-scale surveys, TIMSS (Trends in International Mathematics and Science Study), and PISA (Programme for International Student Assessment). In a sense, students' achievement quantifies the outcomes of their learning, while many other aspects can also reflect and even influence the process as well as the result of mathematics learning. Therefore, researchers are not satisfied with achievement comparisons and keep investigating the stories behind students' performance, which stimulates the development of comparative studies in mathematics education.

As a member of the Organization for Economic Co-operation and Development (OECD), the United Kingdom has participated in six rounds of PISA since 2000. Taking account of different education systems in the United Kingdom, PISA samples schools in England, Scotland, Wales, and Northern Ireland separately, and presents the results for each of the regions respectively. England celebrated its performance on the mathematical literacy scale in PISA 2000, but then it experienced a continuous decline in the following several rounds (Sellar & Lingard, 2013).

Apart from OECD countries, an increasing number of partner countries and economies were involved in PISA. As a representative of mainland China, Shanghai independently participated in PISA in 2009. With its first appearance in PISA, Shanghai ranked in first place on all scales, namely, reading, mathematics, and science (OECD, 2010). These results attracted world attention, not only in the area of education but also in economy and policy. Shanghai's outstanding performance even aroused the new terms "PISA-shock" and "looking East" (Sellar & Lingard, 2013). The former Secretary for Education in the UK, Michael Gove, noticed the impressive performance of Shanghai and regularly referred to the need for England to learn from such top performing systems (Gove, 2011a, 2011b; Sellar & Lingard, 2013).

Specifically, UK's scores held firmly in these years, which were close to the OECD average except science. However, Shanghai performed noticeably well on all three scales, especially on mathematics, with 119 points above the OECD average in 2012[1]. In fact, according to the analysis of background data provided by PISA, the possible reasons for Shanghai's success are high expenditure, parental pressure, and the longest time spent on homework (Lu, 2014; H. Wang, 2014; X. Zhu, Lu, & Shen, 2013). Along with the reform of economy and the opening up of society, China's educational system has experienced decentralization and re-centralization since 1976 (C. Zhang & Akbik, 2012). Especially, China attempted a transition of education pattern from an "overload" mode (students burdened with too much school work) to a "homework free" mode at the beginning of the 21st century, which was trying to imitate the educational systems from western countries, like the United Kingdom. Shanghai, one of the most developed cities in China in terms of economy and internationalization, has experienced several educational reforms to improve its system. It implies that while the UK government is keen to improve the educational system by learning from top-performing regions, Shanghai is looking to western countries at the same time. Indeed, many high-performing Pacific Rim countries have paid attention to England to learn ways of developing students' creative and problem-solving skills (Hodgen, Monaghan, Shen, Staneff, & Halifax, 2014).

Accordingly, exchanges and communication in mathematics education between the two places have been launched. The Department for Education of England conducted three national collaborative projects, one of which is the England–China project (Hodgen et al., 2014). In September 2014, 71 teachers from England spent two weeks observing lessons in Shanghai. Then their Shanghai colleagues made a return trip two months later, and 29 teachers from Shanghai demonstrated lessons in selected primary schools across England. Similar exchanges at secondary level were launched in September 2015 (MathsHubs, 2014).

For learning resources, specifically, the teacher-exchange project revealed many differences in the use of mathematics learning resources between England and Shanghai. Ben McMullen, a deputy head at Fox Primary School, shared his experience in a Shanghai classroom: "*In Shanghai, every child of the same age is on the same page of the same text book at the same time*" (Weale, 2015). Undoubtedly, Shanghai mathematics lessons made a deep impression on McMullen; for example, the whole-class activity "open your textbooks" surprised the English educator, which also suggests that the use of textbooks in England and Shanghai is significantly different.

[1] Source: OECD, PISA 2009, 2012 database.

Moreover, the UK imported a series of mathematics workbooks from China, which have been helping Shanghai students' study in mathematics for more than 20 years (Zhao, 2015). Collins published these workbooks under the name of "One lesson One Exercise of Shanghai Maths" in the autumn of 2015 with the purpose of helping students to lay a strong foundation, to nurture deep learning, and to develop problem-solving skills in mathematics (Collins, 2015). However, some voices from England hold the opinion that chanting and repetitive practice seem formulaic and could not enhance students' understanding of mathematics (J. Cooper, 2015). Therefore, it is because of the desire to know each other as well as increasing communication and exchange that the idea emerged to investigate the differences and similarities in using learning resources in mathematics between England and Shanghai. It is one step closer to the reality of how students in the two places use learning resources in mathematics, and the comparison echoes the frequent communication between the two places, which can help teachers, mathematics educators, and policymakers know more about their students' learning experiences and each others' systems, and better make "evidence-based" decisions for educational improvements.

1.3 Research questions

The general aim of this study is to investigate students' use of learning resources in their learning of mathematics. Specifically, this study is intended to, firstly, describe secondary school students' interactions with various learning resources in mathematics learning, then make a comparison of the resource use between England and Shanghai, and finally, explain the results by examining the association between some contextual influences and the students' resource use in the two places. Correspondingly, three research questions are listed below:

1. How do secondary school students in England and Shanghai use learning resources in their learning of mathematics?

2. What are the similarities and differences in students' resource use in mathematics learning between England and Shanghai?

Naturally, to further interpret the results, this study also deals with the following:

3. What are the factors that influence students' use of learning resources in mathematics in England and Shanghai?

1.4 Outline of the thesis

Chapter 1 introduces the background, the significance, and the research questions of this study.

Chapter 2 summarizes the relevant literature related to learning resources, students' interactions with learning resources in mathematics, and possible factors that influence classroom practice and students' learning activities, including the use of learning resources.

In Chapter 3, the first section elaborates the theoretical foundation of this study, including why this study turns to Activity Theory, how the theory was connected to learning and teaching, and how the theory was applied to mathematics education, especially to students' mathematics learning. Additionally, on this theoretical basis and drawing partially on the previous studies reviewed in Chapter 2, the second part of Chapter 3 conceptualizes the key terms of this study: learning resources (i.e. what learning resources are examined in this study), use (i.e. how the interactions between students and learning resources are defined and described in this study), and the factors that may influence resource use in England and Shanghai.

Chapter 4 introduces the educational contexts in Shanghai and England in terms of geography and demography information, education systems, school systems, and curricula to provide a relatively whole image of the teaching and learning environments in the two places.

Chapter 5 describes the research design and procedures of this study, including the consideration of using mixed methods and the illustration of how data are collected, analysed, and interpreted in this study.

The following three chapters present the findings of this study. Chapters 6 and 7 report the analysis and results for how students use learning resources in mathematics as well as the contextual factors for resource use in Shanghai and England respectively. Chapter 8 reports the comparison of students' resource use between the two places and finds the association between resource use and the constructed factors.

Chapter 9 discusses the findings according to practical contexts, puts the results into relevant research areas of mathematics education, and teases out a sophisticated understanding to answer the research questions of this study.

Chapter 10 summarizes the whole research, provides conclusions based on the findings, discusses some implications for teachers, parents, school administrators, and policymakers on how to improve students' learning experiences working with learning resources, and recommends several directions for further studies.

Chapter 2 Literature Review

To investigate students' use of learning resources and compare their use in different contexts, it is necessary to figure out 1) how the concept of learning resources has been constructed in mathematics and which resources have been discussed before, 2) how others have defined, measured, and described students' resource use from different perspectives, and 3) what factors have been considered as the explanations for students' use of learning resources.

For the research on learning resources, empirical and theoretical studies on various resources serving classroom practice are reviewed to draw a picture of the resources facilitating students' learning and to generate an idea of the conceptualization of learning resource.

The review of research on the use of learning resources in mathematics comprises an independent section pertaining to textbook use and another section with respect to the use of other learning resources, which is to see what kind of data related to students' use of learning resources were collected and how the data were interpreted in their studies.

For the research on what factors influence students' use of learning resources, there are few studies directly identifying the explanatory factors for students' resource use in different educational circumstances. Thus, the scope of the review is extended from resource use to teaching and learning activities in and after class, which could involve the use of learning resources.

2.1 Research on learning resources

When searching studies on resources or materials used by students in their learning of mathematics, there are fewer results than expected, which suggests that it is an under-researched area in mathematics education.

Nevertheless, learning materials have been greatly discussed in language learning. Tomlinson (2012) who is the founder of the Materials Development Association (MATSDA), defined materials for language learning as "*anything that can be used to facilitate the learning of language*". The relevant materials included textbooks, videos, graded readers, flash cards, games, websites, and mobile phone interactions. Though language learning is different from the learning of mathematics in terms of the contents, study approaches, and many other aspects, Tomlinson's study sheds a light on the conceptualization and examples of learning materials.

For mathematics education, textbooks are the substantial materials in didactical practice as mentioned earlier, which is also a reason for the dramatic increase of studies on mathematics textbooks. However, textbooks may not be the only material when it comes to mathematics learning. As mentioned earlier, a difference exists between teachers and students in the frequency of using textbooks in mathematics lessons, which implies that textbooks should be considered more as teaching resources than learning resources (Lianghuo Fan, Chen, et al., 2004). Therefore, it is necessary to explore what other resources appear in students' mathematics learning and how these resources are organized and studied in antecedent research.

TIMSS 2011 and 2015 (Mullis, Martin, Ruddock, O'Sullivan, & Preuschoff, 2009; Mullis & Martin, 2014) surveyed the resources that mathematics teachers used in their teaching, which provided implicit information about which learning resources students were given in mathematics lessons, including textbooks, workbooks or worksheets, concrete objects or materials, and computer software. Also, the survey asked teachers whether calculators and computers were available to students.

The large-scale comparative study stands outside the students' position investigating teaching materials and resources to illustrate the contextual information behind students' mathematics performance in different countries. Therefore, its purpose is not to construct a definition for teaching or learning resources but to list what teachers may use in their classroom.

A longitudinal study tracking students' classroom experiences for 10 years drew a picture of children's actual experiences of learning mathematics (Walls, 2007). This study began when the participants started their third year of primary schooling in New Zealand, and ten seven-year-old students randomly selected from ten different schools were asked to draw a picture of themselves doing mathematics. Almost all of their drawings displayed a child sitting in front of a desk with an opened book. Ten years later, these participants were 16 years old and about to complete their 11^{th} year of schooling. They were contacted to be involved in the survey again and asked to talk about their mathematics lessons at school and describe their experiences in mathematics learning. The dialogues between researchers and the students indicated that students spent most of the time on written tasks during a mathematics lesson at secondary level. They mentioned the learning resources used in their classrooms as textbooks, exercise books, and worksheets.

Walls' study suggests an important reality that the interactions between students and learning resources take most of the time in mathematics learning, no matter which primary or secondary stage in New Zealand, a British Commonwealth country. It employed different methods to collect qualitative data based on the expression ability of children at different age groups. Although it did not conceptualize "learning resource" because the research aims were to find out students' engagements in mathematics classrooms and their experiences as well as perceptions of learning mathematics, it did present some examples of learning resources that were frequently used by students, and specific activities incorporating the use of those resources, which was a first-hand understanding of students' interactions with learning resources in mathematics.

Also, notes are a learning resource that students often take as a reviewing reference for exams (Sutherland, Badger, & White, 2002). As a study strategy, note taking is a common activity in mathematics lessons (Weinstein & Mayer, 1986), which has a long research history in educational psychology (e.g. Crawford 1925). Many studies have shown that taking and reviewing notes has a positive correlation with academic achievements (Kiewra, 1987; King, 1992; Sutherland et al., 2002; Titsworth & Kiewra, 2004). For example, Kiewra (1983) quantitatively analysed eight undergraduate students' course notes and found that the students who took and reviewed their own notes achieved better than those who took notes but reviewed provided notes, or did not take notes then reviewed provided notes.

Moreover, with the development of technology and economy, the availability of multimedia in mathematics classrooms had a significant growth during the last decades (Zbiek, Heid, Blume, & Dick, 2007). Printed or paper-based material is no longer the only form of learning resource in mathematics, as information and communication technology (ICT) have come out, which is a focus that researchers have paid great attention to when referring to resources supporting students' learning in recent decades. In fact, ICT is always regarded as a teaching aid in instructional practice and researchers have revealed teachers' ICT use from various aspects (e.g. Keong et al. 2005; Kreijns et al. 2013; Webb 2013; Zbiek et al. 2007). Meanwhile, many studies have paid attention to how different forms of new technologies (e.g. social media, computer games, and e-learning systems) can be incorporated into students' learning.

For example, Bruke and Snyder (2008) illustrated how YouTube could be integrated into college health education courses to enrich the learning environment for students. Irwin et al. (2012) examined students' perceptions of using Facebook as an interactive learning resource at a university. A total of 253 students and 4 teachers from Griffith University's Gold Coast campus participated in the survey. The high percentage of students (81.9%) engaging with the course Facebook page and 76.4% recommending Facebook as a learning resource in the future course implied that it had the potential to promote collaborative learning in higher education. Moreover, Gaudet and Hilton III (2013) reported the adoption of an open learning system at a community college mathematics department in Arizona, USA, which has about 11,000 students enrolled each semester. It attempted to solve the problem of the lack of immediate access to class materials and the increasing costs of educational books and supplies. The system provided three learning resources for students: e-textbooks, e-workbooks with online lessons, and online assessments, at a cost of approximately 15 dollars per student, which was nearly an 86% decrease in cost compared to traditional copyrighted materials. It provided information about possible forms of online mathematics resources and indicated that the virtual learning materials do benefit teaching and learning practice from both the students' and school's perspectives.

For mathematics education, Ma and Li (2010) reviewed the existing literature since 1990 related to computer-based learning in K–12 (kindergarten to grade 12) classrooms and found that computer technology had significant and positive effects on mathematics achievement, after analysing 85 independent effect sizes extracted from 46 studies involving 36,793 learners. Since computer-based technology considerably enhances students' mathematics learning, then what specific resources are available on computers facilitating students' learning of mathematics? The following case studies give several examples of some computer-based programs used by students in mathematics lessons. Marrades and Gutiérrez (2000) presented the processes of 16 students in their fourth grade of secondary school working with dynamic geometry computer software to construct proofs, and verified the helpfulness of a computer-based environment in improving students' understanding and constructing of geometric proofs. After 30 weeks' intervention (two 55 minutes classes per week), the two top-performance students did improve their skills of justification and all the students began to feel confident with deductive reasoning and formal proofs. Moyer et al. (2005) examined how virtual manipulatives helped children understand mathematical concepts and skills. They observed a full-day kindergarten class (18 children) learning patterns with virtual pattern blocks and a second-grade class (19 students) learning numbers with virtual base-ten blocks in Virginia, and concluded that the virtual environment enabled the children to test their mathematical ideas, clarify their understanding of mathematical concepts, and communicate their thinking with others. Moreover, Parke (2005) described a laboratory activity in a secondary school in America, in which a class of students were exposed to a spreadsheet program to learn statistical measures of central tendency and variability, and found that students performed confidently with dealing with data when the calculations were operated by the program, and that they became increasingly engaged as the activity progressed.

In addition to computer programs, the internet provides integrative information and interactive resources supporting mathematics learning as well. For example, WebQuests offers students opportunities to engage in inquiry-oriented activity and interact with online resources (Dodge, 1995). An observation of ninth-grade students working with WebQuest activities to explore statistics of basketball teams showed that students were actively involved in the learning process and had a real desire to understand and apply the mathematics (McCoy, 2005). Moreover, the computer is not even the dominant device assisting mathematics learning, with the introduction of new portable devices into classrooms and students' daily life. Personal digital assistants, laptops, and smartphones are also equipped with various learning systems and applications enriching the learning environment.

It is not hard to see that, with the development of information technology, the form of electronic resources, including the content and devices, is becoming diversified. Apart from providing alternatives to paper-based resources, such as e-textbooks, and reducing educational cost, ICT enables students to really interact with learning resources by displaying dynamic information, benefits students' learning achievements, and positively influences students' attitudes towards mathematics according to the studies mentioned above.

Nevertheless, though the reviewed studies have involved various resources when it comes to students' learning experiences and achievements, there has been neither a systematic documentation of what resources students use in their learning of mathematics nor a formal conceptualization of learning resource in mathematics education. Moreover, the review indicates that many things facilitating the learning of mathematics can be considered as "learning resource" with different scopes. It presents the neglect and different understandings of the concept. The following paragraphs summarize several conceptualizations and classifications related to learning resources in mathematics.

Firstly, Love and Pimm (1996) conducted research on *mathematics text materials*. According to their study, mathematical text is the language for expressing mathematics while mathematics texts comprise the language and plus possibly comments on the text, static images, spoken words (on audiotapes), and dynamic images (on films, videos, or computer screens). Therefore, they constructed the concept of *mathematics text materials* as those mainly comprising mathematical text, designed for instructional situations. Specifically, they reviewed historical arguments about the distinction between school mathematics texts and "original" mathematics texts written by mathematicians such as Euclid's *Elements*, and highlighted some visible features of mathematics text materials (e.g. texts' forms and the diversity of images) and pedagogical functions (e.g. the content selection and the sequence of texts). It is worth mentioning that Love and Pimm's work provided a historical view of mathematics texts and referred to various presenters of texts in classrooms such as textbooks, a typical example of commercial publications, and worksheets devised by teachers. However, their conceptualization did not distinguish learning materials from teaching materials in didactical situations. Though the following discussions involved both students' work with texts and teachers' intervention with materials, the study stressed the pedagogical aspect of mathematics text materials, which implied that it tended to treat the materials as teaching resources rather than learning resources.

Moreover, Love and Pimm classified mathematics text materials by their relation to textbooks. Specifically, other media could be seen as a transformation of mathematical texts, which were classified by several "lines of descent" from the textbook. One line led to interactive computer software that specified some objects in words and symbols. A second line led to a number of supplementary materials to a single textbook, such as booklets, workbooks, and other physical materials. The third line showed the importance of learning resources beyond classrooms (e.g. mathematical matters in newspapers). The last line led to an alternative version of texts, for example, electronic textbooks (Love & Pimm, 1996). These categories revolve around the textbook which is considered as the "bible" in mathematics instruction in some countries such as China, while in the West, textbooks are merely referred to as a "little encyclopaedia" (K. Park & Leung, 2006), which means that textbooks are neither an essential resource that every student owns nor a common material that students use every day. Hence, this classification cannot cover all the situations in different education systems.

With the purpose of evaluating learning materials, Bundsgaard and Hansen (2011) interpreted learning material from a more holistic view; namely, they took it as the equivalent of artefacts, such as textbooks, computers, and blackboards, and specified learning materials by sorting them with their functions, in which way they classified learning materials into three categories. *Functional learning materials* (tools) stood for the facilitation of learning and teaching, including black and white boards, computer applications, projects, and mobile phones; *semantic learning materials* (texts) referred to signs and semantic references, such as films, literature, charts, and pictures; and *"didacticized" learning materials* combined the characteristics of tools and texts from the perspectives of both learning and teaching,such as textbooks, online teaching materials, and educational games.

Bundsgaard and Hansen's constructs and classification of learning materials imply their broad understanding of learning resources in terms of their non-discipline-specific perspective and various facilities available in instructional environments. Compared to Love and Pimm's conceptualization focusing on texts, they made more effort on the presenters of texts (i.e. tools). Their classification clarified "tool" materials, "text" materials, and the materials that integrate texts into tools, which seems adequate for investigating the connections between materials and learning potential as well as competences that their research addressed, but may be redundant for merely exploring the use of learning materials in didactical situations. Also, they did not make it clear whether they stood on the side of students or teachers when it came to "learning" materials. For instance, the first category of their division referred to functional tools that facilitate "learning" and "teaching", which makes the definition blurred.

To examine resources and their use in the practice of school mathematics, Adler (2000) provided some examples of resource use within an in-service teacher education research project in South Africa. She aimed at presenting a universal framework that teacher educators could employ to investigate teachers' use of resources in mathematics instructions within diverse contexts. Thus, she held a broad view of mathematics resources in schooling. Specifically, she first suggested thinking about resource as the verb *re-source*, which meant to source again or differently, and then conceptualized mathematics resources in teaching practice with four dimensions. The first one was basic resources including all the maintenance of schooling, such as school buildings, water, paper, pens, and human aspects (e.g. teacher–student ratios). The second was human resources that contained two parts: one was related to persons, for example, teachers' knowledge base, another concerned with processes, namely, collegiality. The third was material resources involving technologies (e.g. chalkboards, calculators), school mathematics materials (e.g. textbooks, other texts, and computer software), mathematics objects (e.g. proofs, number lines), and everyday objects (e.g. money, rulers, and newspapers). The fourth category was social and cultural resources including language and time.

Adler’s conceptualization shows her ambitions to take into account all the visible and invisible resources relevant to mathematics teaching and learning. Her standpoint was quite clear that she belonged to the teachers’ and teacher educators’ side. Therefore, all her constructs of mathematics resources focused on the artefacts that teachers use, the environments that teachers live in, and the contexts in which teachers organize instructional activities. Compared to the previous studies, Adler contributed the broadest sense of resources in mathematics education, which did give consideration to almost every aspect of resources in mathematics teaching and learning, and classified various materials into different categories so that relevant research could find the corresponding section in her work. For example, Bundsgaard and Hansen’s concepts of learning materials are the technologies and school (mathematics) materials under Adler’s definition.

2.2 Research on the use of learning resources in mathematics

As mentioned in Chapter 1, the use of mathematics textbooks in instructional practice has been much discussed with the rise of interest in teaching and learning resources. Thus, this section firstly devotes an independent subsection to summarize the relevant literature about textbook use in mathematics education. The second subsection touches upon empirical studies on students’ interactions with digital technologies and a theoretical study analysing the role of artefacts in mathematics education, which introduces a socio-didactical model to understand mathematics teaching and learning by taking artefacts as the fundamental constituents.

2.2.1 Research on the use of mathematics textbooks

For the use of mathematics textbooks, many studies investigate textbook use from the perspective of teaching to disclose teachers’ perceptions and use of textbooks (Lianghuo Fan, Chen, et al., 2004; Love & Pimm, 1996). This may be because of the main purpose of research on textbooks. In fact, TIMSS indicated that textbooks were the most frequent basis of mathematics instruction, and teachers relied heavily on textbooks when teaching mathematics (Hiebert, 2003). In other words, research on textbook use can support teachers’ training and teachers’ professional development to some extent. Another reason for the dearth of research into the use of textbooks from the students’ angle is the difficulty of data collection since their use can be very personalized and trivial (Love & Pimm, 1996). Love and Pimm also questioned what research data there could be regarding students working from textbooks. Also, students are guided by teachers when using textbooks within and beyond the classroom most of the time, based on the fact that textbooks provide teachers with a framework to decide what will be taught, to whom, when, and how (Nicol & Crespo, 2006). This may be the third reason for researchers to enthusiastically investigate teachers' use of textbooks while ignoring the students' side.

However, Rezat (2011) challenged the view that students' use of textbooks always depends on teacher mediation. He pointed out that students used mathematics textbooks not only under the guide of their teacher but also for self-directed learning (Rezat, 2009b). Empirically, he observed mathematics lessons in two German secondary schools with four classes of students in sixth and twelfth grade for three weeks. By following the ideas of Grounded Theory (Strauss & Corbin, 1990), Rezat categorized students' interactions with mathematics textbooks in the process of data analysis and came up with five self-regulated learning activities in which mathematics textbooks were incorporated: (1) solving tasks and problems, (2) practising, (3) acquisition of new knowledge, (4) interest-driven activities, and (5) meta-cognitive learning activities (Rezat, 2011). Furthermore, Rezat carried out another qualitative study of students' use of mathematics textbooks particularly for practising, due to the challenge that he encountered in the previous study to obtain more details related to that (Rezat, 2013). According to the results, three utilization schemes were generalized: *position-dependent practising*, in which case students only practised the same and adjacent task assigned by teachers, *block-dependent practising*, in which case students also chose specific blocks in textbooks for practising, and *salience-dependent practising*, in which case students' selection of practice was dependent on the visual feature of the task. Also, the study indicated that the influence of peers, family, and tutors on students' utilization scheme of mathematics textbooks was significant according to the results of interviews.

Rezat noticed the importance of addressing students' use of textbooks and believed that the qualitative method was the most appropriate way to collect and analyse data on students' actual use of mathematics textbooks, since he wanted to keep the contexts of use original, such as which part of the textbook students used, when and where they used textbooks, and for what reasons. Thus, the research instruments were classroom observations, field notes (for recording time, activities, contents, and remarks on students' textbook use), and a special type of questioning (e.g. sentence-completing task). His studies provided substantial details of how students interacted with textbooks in mathematics learning by accompanying and observing students' study in schools. With the categorization of the five learning activities involving students' use of textbooks in mathematics and a utilization scheme of the use particularly for practising, he made great efforts to investigate the purposes of using textbooks by synthesizing and integrating the collected information related to students' textbook use into specific learning activities. However, other aspects of students' use of textbooks, such as the time students spent on different parts (e.g. instruction texts, examples, and exercises) of textbooks, did not appear as the findings, which results in a deficiency in terms of an overview description of students' use of mathematics textbooks.

Also, though Rezat's studies showed that students did not only use mathematics textbooks when their teachers told them to do so, he stated that teacher mediation played an important role in students' use of mathematics textbooks and took it as a factor of students' textbook use. In particular, he categorized teacher mediation in students' use of textbooks in the learning of mathematics and examined the impact of students' textbook use on teachers' instructional plans as well (Rezat, 2012). Specifically, data on teacher mediation of textbook use were collected from classroom observations and data on both teachers' use and students' use of textbooks in class were recorded in field notes with 4 teachers and 74 students in two German secondary schools. For the result, on one hand, he grouped teacher mediation into three dimensions: direct/indirect, (for distinguishing teachers' influence on students' use of textbooks directly or indirectly), specific/general (for indicating whether teachers referred to a specific section when guiding students' use, which only appeared under direct mediation), and obligatory/voluntary (for identifying if students had to use textbooks at teachers' request or not); on the other hand, he pointed out that students' use of materials interfered with teachers' documentational work, which was regarded as the active part of students' interpretation of the enacted curriculum. In brief, it took the two users of mathematics textbooks, namely, teachers and students, into account to explore the effects of one's use on the other's. For the teachers, it provided a framework for embodying how teachers mediated students' use of textbooks in the classroom, while for the students, it elaborated students' use of textbooks with a few pages and focused on how students' interventions interrupted teachers' instructional plans during a lesson, which is different from his studies that looked at learning activities incorporating students' use of textbooks as mentioned above.

Although studies on textbook use from the students' angle are not as many as those from the teachers' angle, there are still some papers investigating teachers' use of textbooks while mentioning the students' side and raising some issues related to students' textbook use.

Fan et al. (2004) conducted a survey to reveal how teachers and students used textbooks within and beyond mathematics classrooms, involving 36 teachers and 272 students from 12 secondary schools in China, which was designed mainly for studying teachers' textbook use but mentioned some issues from the students' perspective. In this case, they studied the following aspects of student's textbook use, including 1) students' general use of textbooks (i.e. the frequency, timing, and purposes of the use), 2) how students use different parts of texts, such as "drill", "self-test", and "revision", 3) to what extent students think that the use of textbooks is important in mathematics learning, and 4) whether students change their way of using textbooks from the first year to the second year in secondary schools. The study contained both qualitative and quantitative methods. It addressed students' usage of unassigned exercise problems offered in the textbooks and their use of answer sections, and indicated that the majority of students thought textbooks were important in their learning of mathematics. Also, it listed the gaps between teachers' requirements and students' practice. In short, though their study paid much more attention to teachers' use, it tried to explore students' interactions with mathematics textbooks, which shed light on what quantitative data can be collected in terms of students' textbook use.

Haggarty (2002) and Pepin (2001) worked cooperatively on two articles to examine mathematics textbooks and their use in English, French, and German classrooms. They firstly documented the literature related to textbook use within classrooms to disclose 1) the authority of the textbook, 2) who uses textbooks and who makes the decision on who uses them, 3) how textbooks are used, 4) teachers as mediators of the text, and 5) national culture as an influence of what happens in classrooms. They then investigated the similarities and differences in mathematics textbooks at lower secondary level in the three countries, and finally collected empirical data of teacher mediation of textbooks and students' access to textbooks by interviewing teachers and observing classrooms. Their literature review pointed out that textbooks were regarded as the key element of mathematics teaching and learning in France and Germany, while in England textbooks were viewed as one of the teaching resources in their classrooms. They also reported the particularity of students' access to textbooks in England in an independent section. As they described, textbooks were provided by schools as a tradition in England; however, because of financial constraints, schools usually could not afford many textbooks for every student. Therefore, it was very common that students used textbooks within classrooms guided by their teachers but could not take them home. In this case, students in the lower secondary years hardly had opportunities to use mathematics textbooks beyond class and even many students at key stage 4 (year 10 and 11) rarely had access to textbooks at home. Fortunately, schools provided some alternatives: students could buy their own revision guidebooks at key stage 4, and worksheets with learning guides were often issued for homework.

It is worth mentioning that, though Haggarty and Pepin's studies illustrated students' access to mathematics textbooks, especially the situation in England, the main purpose of their work was to investigate teachers' use of mathematics textbooks in order to understand the relationship between the use and pedagogical intentions, as well as various facets of educational traditions in the three countries. The result of the literature review relating to the use of textbooks in classrooms showed their stress on the teachers' stance: firstly, teachers and texts became one authoritative identity as teachers reconstituted and reinterpreted textbooks in their mediation; secondly, textbooks were hardly viewed as a “student book” and though they were addressed to students, teachers were the ones who used textbooks and made the decision on who used them; thirdly, students’ use of textbooks during mathematics lessons was assigned by teachers in all the three countries; fourthly, teachers’ mediation was not only content selection but a wider field involving various pedagogical considerations; and finally, the influence of culture on mathematics textbooks was still uncertain since some researchers held the view that culture did make the forms of representing mathematics diverse in different cultural contexts, therefore, more attention should be paid to all written pages presenting mathematics to students while others deemed that studies on textbooks did not convey determinant information about cultural or national characteristics. In short, Haggarty and Pepin’s work mainly discussed teachers’ mediation of mathematics textbooks, with a document of relevant literature and empirical evidence in the three countries; it mentioned many other facets related to mathematics textbooks, textbook use, and the factors influencing classroom practice, which seems ambitious but unsystematic, and neglected the substantial number of students’ interactions with textbooks even though knowing that their use was assigned by teachers.

Compared to elementary education, there have been more experiences of studying students’ use of mathematics textbooks at higher stages. Randahl’s (2012) research focused on the process of approaching mathematics textbooks and the possible opportunities and constraints influencing students’ use of textbooks at tertiary level, which was carried out with 90 first-year students at the engineering college of a university in north Norway. She employed various survey instruments, including student questionnaire, teacher interview, student interview, session observation, and informal conversation, to collect qualitative data. The questionnaire involved mathematics questions and questions about students’ ideas about learning mathematics and learning resources. Teachers’ interviews were conducted to disclose reasons for the choice of the textbook used in their instruction and to know teachers’ experiences in using the textbooks. Student interviews gathered information on their attitudes toward mathematics and their use of the textbooks, including the timing of using textbooks, reasons for using textbooks, expectations, and perceptions of textbooks (e.g. difficult, easy?). The questions were set as: “Do you use/not use the book during the course? What are the reasons for this?” Classroom observations took place in lectures and task-solving sessions for a period of six weeks to find out the extent to which teachers followed the instructions posed in the textbooks and made references to the textbook, and whether and how students were encouraged to use the textbooks. The findings of Randahl’s study revealed that textbooks were not the predominant resource in students’ learning, given the fact that more than half of the students relied on lecture notes. Nevertheless, the interview with an Asian student provided a different view: the student perceived theories in the textbook as essential and believed that it was necessary to read through all the content. Moreover, with the finding of students' difficulties in using the textbook, Randahl appealed to researchers for more attention to students' use of textbooks and argued that they had focused too much on learning problems.

In some sense, college students study more independently and have greater freedom to choose learning resources compared to secondary school students. Randahl's work employed various instruments to ensure that it was possible to collect data on students' use of textbooks under such a complex circumstance. However, its results were only an excerpt of the data analysis and did not show a complete idea of how students used the textbooks, which seems like a pile of responses to the questions and lack of a strong structure to organize the questions describing students' textbook use.

Weinberg et al. (2012) conducted a large-scale study of students' use of mathematics textbooks at undergraduate level as well. A total of 1156 students from three universities in the United States were involved in this. The study answered which textual components students used, when and why students looked at each component, and how students valued certain characteristics of textbooks. It described and structured the components of textbooks, addressed students' purposes of textbook use, and explored some factors influencing their use. By combining qualitative and quantitative approaches, Weinberg and the co-authors developed a student questionnaire, a student interview protocol, and a journal template for students to report their daily use of textbooks. The main idea of their study seems similar to Fan et al.'s as mentioned previously. The difference is the position of teacher mediation. Fan et al.'s study is mostly from the standpoint of teachers' use of textbooks, interlacing the students' standpoint based on their common features of textbook use. It positioned teachers' use and students' use equally but highlighted teacher mediation in the use, which is also a reason that the paper used more pages to illustrate teachers' textbook use. However, Weinberg et al.'s study took teacher mediation as a potential influence on students' use of textbooks, as Rezat did in his research discussed earlier, which indicates that the positions of teacher and student are no longer at an equal level. In this case, students' textbook use was the main body of their research.

Weinberg et al.'s main contribution is the generation of students' potential reasons for using different textual components of textbooks, such as "use the answers to exercises to check homework", which is similar to Rezat's categorization of students' self-regulated learning activities incorporating mathematics textbooks, such as "solving tasks and problems" and "practising". Also, their study quantified students' use of various parts of the text with different purposes; for example, 89.3% of the students reported that they read the "chapter text" for "looking up definitions", and examined the association between textbook use and the potential influences statistically with Chi-square, which presented a precious experience of depicting students’ textbook use with quantitative data, though it merely covered the purposes of textbook use and several factors that influenced the use (e.g. students’ valuing of textbooks).

In addition to those studies collecting empirical data on students’ use of mathematics textbooks, Rezat (2006) developed a model to describe the relationship between textbooks, students, and teachers based on Vygotsky’s (1978) triangle in Activity Theory. The interacting elements of an activity system are subject, object, and mediating artefact as shown in Figure 1(a). Rezat took textbooks as the mediating artefact since textbooks were considered as the fundamental instrument to learn mathematics. Thus, applying Vygotsky’s triangle to the activity of learning mathematics, he presented a model of textbook use from the students’ perspective as displayed in Figure 1(b). Moreover, the influence of teacher instruction on students’ use of textbooks cannot be neglected. Thus, looking upon textbook use as an activity, Rezat regarded teacher mediation as a mediating artefact and constructed a new triangle as shown in Figure 1(c). Then, combining the two triangles in Figures 1(b) and (c) according to their common vertices, he obtained a quadrilateral model (see Figure 1(d)). Finally, to embody the relationship between teachers and mathematics knowledge, Rezat represented the final model of textbook use with a tetrahedron (see Figure 1(e)). The model was established to situate the key agents of mathematics teaching and learning in the classroom and to depict a comprehensive picture of the relationships between those elements, which includes different perspectives when it comes to the role of textbooks in mathematics didactical practice. Lately, he expanded this model to a socio-didactical tetrahedron that involved not only textbooks, but also other resources and social factors related to mathematics teaching and learning, which will be discussed in the next section.

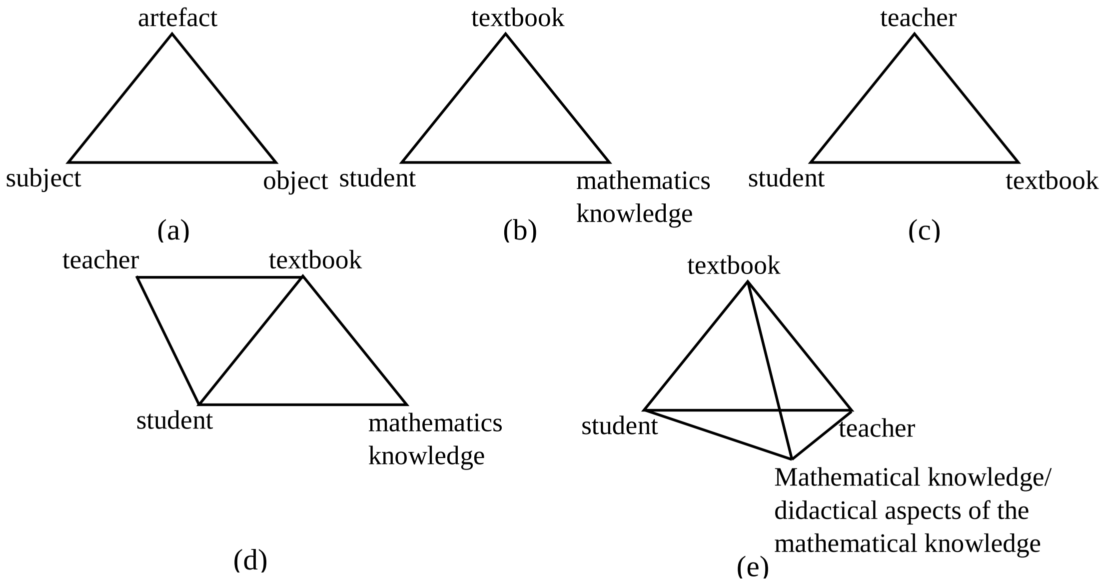


Figure 1 The evolution of Rezat’s model of textbook use in mathematics

2.2.2 Research on the use of other learning resources in mathematics

As discussed in Chapter 1, the previous studies on learning resources mainly focus on textbooks and technologies, and it seems that there is hardly any research experience in terms of collecting empirical data related to students' use of other resources such as worksheets, exercise books, and their analogue, in addition to textbooks and technologies. Therefore, this section firstly summarizes the research on students' use of technologies in mathematics learning.

Indeed, the proper integration of technology into education has positive effects on teaching and learning in primary and secondary schools (Norris, Sullivan, Poirot, & Soloway, 2003). For students' use of technologies in their learning of mathematics, the benefits include increases in test scores, development of early literacy skills, and a deepening of students' understanding of mathematical and science concepts (O'Donnell, 2011). However, the investigation of students' interactions with technologies in their learning of mathematics always seems like a report of classroom experiments for introducing the technologies into instructional practice. For instance, Bakker and Frederickson (2005) reported two sixth-grade classes from a middle school in a suburban area in the mid-west of the United States using data analysis software to learn distributions and growing samples. With the software, students could make their own plots, analyse large data sets, and calculate quickly descriptive statistics, like means and medians. Students' descriptions of the software and their using experiences were displayed to show students' enthusiasm about using the software. They drew the conclusion that though the incorporation of the software facilitated students' learning of statistics with various plots and larger data sets, plotting and analysing data by hand were still supposed to be involved as a basic skill in instructional practice. Similarly, Vincent (2005) investigated students' learning of mechanical linkage with an interactive geometry simulation. The research took place in a middle school of the United States with 29 top-performing girls studying in eighth grade. During the six-week intervention covering eighteen 50-minute lessons, students were introduced to the concept of geometric proof and completed seven conjecturing–proving tasks related to mechanical linkages. The results showed that the participation in interactive tasks aroused students' curiosity about the mechanical linkages so that they constructed pen and paper proofs and interactive geometry investigations with the same enthusiasm, which built up their confidence to approach valid geometry argumentations. It is clear that those descriptions of students' interactions with the statistic and geometric software were just narrative reflecting students' experiences and feelings about using the technologies. The results of their studies primarily revealed the positive effect of doing mathematics with the technologies and the convenience that the software brought to instructional practice. In other words, the descriptions and findings of technology use in these studies are technology-specific cases to a great extent, in which situation they can hardly be adopted in the investigations of students' interactions with other learning resources.

However, from a holistic view, some researchers have referred to the use of "other" learning resources after their modelling of textbook use in mathematics education. In order to illustrate the role of artefacts in mathematics teaching and learning, Rezat and Sträßer (2012) developed Rezat's model of textbook use to the socio-didactical tetrahedron. The original intention of his study was to introduce new technologies into the didactic tetrahedron (Figure 1(e)). On their way to integrate the artefacts used in mathematics education, such as textbooks, rulers, computers, and other new technologies, they noticed that the non-physical tools such as language, diagrams, and gestures also played an important role in mathematics education. They finally pointed out that "*teaching and learning of mathematics depend heavily on the existence of material representations of the immaterial mathematical structures*". Also, to incorporate the invisible social mediators of education, they drew upon Engeström's (1998) models of teaching and learning activity in school (which will be further interpreted in the next chapter) to build the socio-didactical tetrahedron (see Figure 2).

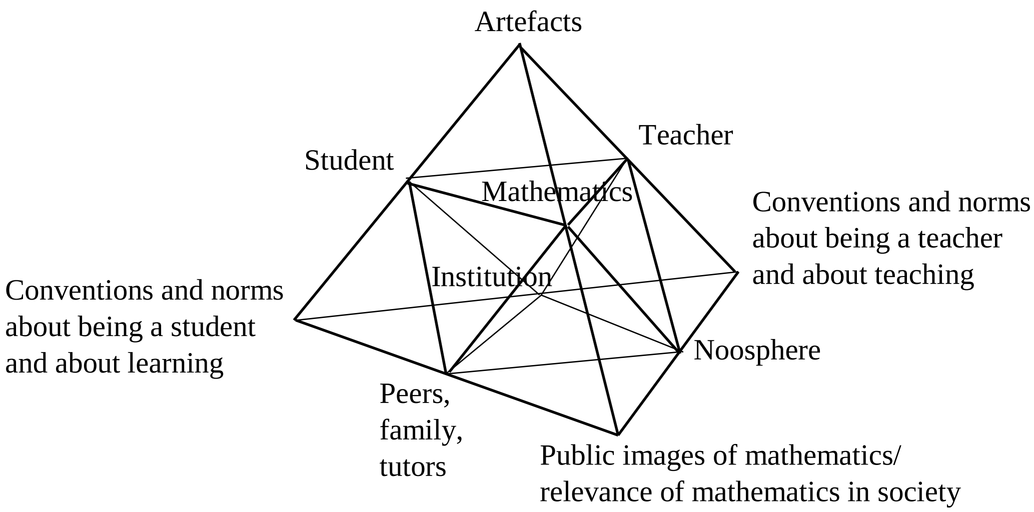


Figure 2 Rezat and Sträßer's socio-didactical tetrahedron

In this model, artefacts refer to not only technologies but also all resources used in mathematics teaching and learning. Mathematics is taken as the object of teaching and learning activity. It is necessary to mention that the social mediators in Engeström's model of the activity system are *rules*, *community*, and *division of labour*. With this proposition, peers, families, and tutors belong to the community of students in terms of learning, while teachers have their own community made up of their colleagues, and, in a broader sense, the noosphere. Institution is the third and shared community that refers to schools in most cases. Similar to the different communities between teachers and students, conventions and norms about being a student and being a teacher, which corresponds to the social mediator of "rules" in Engeström's activity system, are also distinguished in the sense of different identities. Finally, the vertex of public images of mathematics or the relevance of mathematics in society reflects the influence of public views and relevance of mathematics on the teaching and learning with artefacts, which is related to different roles of mathematics in socially productive activities and corresponds to the "division of labour" in Engeström's model.

Although Rezat and Sträßer's tetrahedron did not investigate any specific use of learning resources, it hinted at which agents would be involved when it comes to artefact use in the learning and teaching of mathematics. Since it is hard to draw the whole picture of instructional practice in mathematics and give in-depth consideration to every specific aspect at the same time, Rezat and Sträßer highlighted that their article and model only depicted the whole image of a didactical situation and its driving forces in mathematics teaching and learning, but the theoretical model had no empirical evidence at that moment. Also, they neglected some connections on each side (compared to Engström's triangle, such as the connection between artefacts and peers, family, and tutors), avoided distance or other measures between the components, and rejected any directivities of the segments in their model to "*capture the systematic whole of the relations*", as they claimed in the article. On all accounts, the integration of different relations and perspectives in the socio-didactical tetrahedron is a significant action for understanding the role of artefacts in the big picture of mathematics education, which provides an example of dealing with the relationships between didactical situations (the structure containing student, teacher, mathematics, and artefacts) and their facilitators in mathematics. Therefore, the conceptual framework of this study takes it as a base which will be developed in the following chapter.

2.3 Research on what influences students' use of learning resources

For an in-depth understanding of students' resource use, it may be credited to social and cultural contexts as Rezat and Sträßer's construction. Unfortunately, there are not many studies identifying the factors that influence students' use of learning resources in mathematics directly, even if confined to the research area of textbook use; therefore, what has been summarized here is the literature mentioning the factors that could influence classroom practice and students' learning, which possibly involve the use of various learning resources.

Leung (1995) conducted a comparative study to characterize the classroom practice in Beijing, Hong Kong, and London and explained the differences and similarities between the three places from a cultural perspective. The study took place at junior secondary education stage; 18 schools with various backgrounds from each of the cities were selected and 112 mathematics lessons were observed in total. For classroom norms, he paid attention to lesson structure, whole-class activities, group activities, off-task in individual activities, and teachers' use of textbooks. For instructional practice in mathematics, his observation focused on the following six aspects: the use of rigorous language, mathematics flexibility, conformity and a rigid view of mathematics, memorization, expectations, and examinations. In order to explain the differences as discussed in the results, he abstracted four characteristics of Chinese culture from the relevant literature: *the social orientation of the Chinese*, which emphasized the characteristics of compliance (Bond & Hwang, 1986) and obedience, *the Chinese stress on memorization and practice*, *the high expectations on student achievement* and *the attribution of success and failure, and the attitude towards study*, which regarded study as a hardship. The results indicated that there were significant differences in classroom practice between the three places, and cultural differences in attitude towards mathematics learning and teaching could account for the differences in class sizes, "off-task" time, and lesson structures to a great extent, which suggested that it would be necessary to take cultural perspectives into account when interpreting the findings of comparative studies on instructional practice in mathematics.

In a more recent study, Leung (2006) made a link between mathematics education and contextual diversity based on the data collected by TIMSS 1999. In order to obtain a deeper understanding of the differences in mathematics achievements in large-scale international studies, he illustrated the differences in students' and teachers' attitudes towards mathematics, social resources, and educational systems between different cultural traditions. For students' attitudes towards mathematics, he focused on the importance of mathematics, positive attitudes towards mathematics, and self-concept in mathematics. For teachers' attitudes, two main ideas were discussed: one was about mathematics itself, and another was related to mathematics education, involving the aims of mathematics education, the factors influencing mathematics content taught in classroom, and the factors affecting students' success and failure. Additionally, Leung also summarized teachers' teaching styles and confidence in preparation to teach mathematics in the selected regions. For societal resources, he compared the wealth of a country with the measures of gross national product (GNP), national education expenditure (% of GNP), and educational resources provided by governments, schools, and families. Finally, for educational systems, the study focused on curriculum, time spent on in-school instruction, and time spent on out-of-school study in mathematics. The findings indicated that the various instructional and societal variables examined in the study could hardly explain the differences between Western and Eastern mathematics education in terms of student achievement. Nevertheless, though there was no empirical evidence, Leung's final discussion incorporating cultural backgrounds might explain the differences to some extent since the top achieving countries in TIMSS 1999 shared a common culture, roughly referring to the Chinese or Confucian culture.

Leung's two studies showed that the cultural perspective might play an important role in interpreting the differences in some facets in mathematics education between different contexts and regions. His studies attempted to establish the connections between cultures and the practical contexts of mathematics education by categorizing the characteristics of Chinese culture related to mathematics, study, and education, as well as generating classroom norms and conventions in different countries. However, these works are still at ground-level stage, do not have any proofs supporting the connections, and suggest the difficulty in terms of collecting empirical data as the evidence.

With regard to cultural contexts, Li and Fischer (2004) took a general view to explore the influence of cultures on learning modes. Taking China and the United States as the comparison subjects, they compared the following four components of students' beliefs in different cultures about learning: *the purpose of learning*, *the process of learning*, *kinds of achievement* (or forms of excellence of learning) *and affect* (what influences the success and failure of learning). Li asked college students to sort more than 200 terms related to learning (or *xuexi* in Chinese) by the similarity in meaning and then asked the students to describe their ideal learners in addition to those prescribed words given to them, in order to obtain a full image of beliefs about learning. Combining results of the terms mapping and the verbal descriptions, they concluded that individual beliefs were far from individual: they were actually formed by the orientation of their cultural beliefs, which helped define the purpose of learning, process of learning, achievement of learning, emotions and attitudes involved in the first three dimensions, and equipping students to face the difficulties in study. Compared to Leung's studies, Li and Fischer's work paid more attention to subjective perceptions other than objective practice in terms of the cultural contexts, and mainly focused on students' learning activities regardless of subject areas. To be specific, Leung noticed the cultural effects on different education systems by observing classroom practice, while Li and Fischer raised the same concern by categorizing individual beliefs about learning. The two paths lead to the same destination probably because the practice is the embodiment of individual beliefs, which are rooted in the cultural orientation of a group of people, as Li and Fischer concluded.

Particularly, one example investigating the influences of students' beliefs about their textbook use is provided by Weinberg et al. (2012) with 1156 students from three universities in the United States. They gave a stronger relationship between students' beliefs about mathematics textbooks and their textbook use by drawing on Schoenfeld's description (1992, p. 359) pertaining to students' beliefs about mathematics and Lloyd and Behn's (2002) list of values to construct a framework investigating the possible influences of beliefs about textbook use. To be specific, they came up with five primary perceptions that students might have about textbooks at tertiary level: *1. a textbook should explain the "big idea" of the course. 2. a textbook should explain the "underlying concepts" of problems. 3. a textbook should give examples to explain the material. 4. a textbook should give examples that can be used to complete homework. 5. a textbook should highlight important equations and definitions.* Also, Weinberg et al. noted that teachers' instructions shaped the interactions between students and textbooks. Thus, they defined two other types of factors influencing students' use of textbooks: one was related to the teachers' instructions that students perceived about textbook use, and another was about the degree to which the textbook was perceived to be aligned with the course (based on the assumption that the closer the textbook was related to the course content, the more possibly the teachers and students would rely on the textbook). The findings showed that teachers' instructions and students' beliefs about textbooks resulted in some significant variances in students' textbook use; for example, the proportion of students who valued the fact that "a textbook highly explained the big ideas of the course" and read the textbook for "better understanding" was significantly larger than those who used textbook for the same reason but held a different value of the textbook, while the correlation between students' textbook use and course alignment with the textbook was not statistically significant. In brief, Weinberg et al.'s study quantitatively established the association between students' perceptions of mathematics textbooks as well as teachers' instructions and their interactions with the textbook, and provided empirical evidence supporting the existence of the relationship between beliefs and resource use in mathematics learning.

Schoenfeld's elaboration about students' beliefs mentioned above is just one aspect of his discussion related to the impact of an individual's perceptions of behaviours in mathematics education. He held the view that an individual's understandings and feelings shaped the way of one's engagement in mathematics activities (Schoenfeld, 1992, p. 358). Therefore, he discussed the impact of beliefs about doing mathematics from three angles: student, teacher, and society, by reviewing the relevant literature. For the students' part, Schoenfeld extended Lampert's (1990) list of students' beliefs about the nature of mathematics, and concluded that students' beliefs about mathematics mostly came from their experiences in the classroom and shaped the ways in which they learned mathematics based on the data from a study conducting year-long classroom observations of high school geometry classes in a suburban school in New York (Schoenfeld, 1988). For the teachers' part, Schoenfeld documented two case studies (Thompson, 1985) to support the view that a "*teacher's sense of the mathematics enterprise determined the nature of the classroom environment that in turn shape student's beliefs about the nature of mathematics*." (p.359). Finally, from the societal perspective, he mentioned the classification of beliefs about mathematics learning according to a series of reports on cross-cultural studies (Stigler & Perry, 1989): *belief about what is possible (i.e. what children are able to learn about mathematics at different ages); beliefs about what is desirable (i.e. what children should learn); and beliefs about what is the best method for teaching mathematics (i.e. how children should be taught)* (p.196). In fact, students' and teachers' beliefs about mathematics interplay with each other since teaching and learning are a mutual process in classrooms. Specifically, Schoenfeld's study proved that teachers instil thoughts, beliefs, and even values to students in their teaching, which form students' beliefs and learning habits to some extent, and actually, in turn, students' reactions and performance also influence teachers' perceptions and teaching strategies. Moreover, educational activities always involve different groups of people, such as students, teachers, and parents, who definitely reflect a part of social ideology as Schoenfeld concluded.

Most studies mentioned above focus on interpreting different patterns of teaching and learning with people's beliefs, while Gershenson and Holt (2015) did quantitative research to investigate the gender and socioeconomic status (SES) gap in homework time use with the data from the 2003–2012 waves of the American Time Use Survey (ATUS) involving 5058 students in the age group of 15–19, and the data from the Educational Longitudinal Study of 2002 (ELS) involving 13,210 students in tenth grade. It also examined a great number of social indicators that might explain students' gender discrepancies in doing homework. The gaps were estimated conditionally on a set of control variables: race and ethnicity (for taking into account cultural differences in time use), geographic locales (based on the assumption that living in a metropolitan area can differentiate school fixed effects), household characteristics (e.g. the number of children and parents' marital status), academic ability, extracurricular activities, parents' involvement in children's education, and students' educational expectation. Since the study did not specialize in any subjects, the authors took students' course-taking as a control factor as well. The results showed that the existence of a gender gap was statistically significant in unconditional regressions. However, it was hard to identify the real reasons for this gap. For instance, the authors found that students' participation in extracurricular activities, such as part-time jobs and babysitting, did not result in any gender gaps, and other factors' effects were insignificant as well, according to their findings.

The reasons for including such a study concerning gender differences in homework time use are based on the following points. Firstly, doing homework is obviously bound up with the use of learning resources since teachers can assign homework from textbooks, workbooks, and other resources. Secondly, Gershenson and Holt's study discussed a rich set of social factors that might be explanations of the gender gap in completing homework, which describes a scene of after-school life in a western education system. Thus, it hints at some social aspects that this study could take into account for explaining the use of learning resources, such as parental involvement in children's education. Thirdly, Gershenson and Holt's analysis of control variables sheds light on the importance and complexity of the underlying causes of students' learning activities, which suggests that it is not easy to find a clear clue for the differences in students' behaviours in learning.

Returning to the comparison of resource use in mathematics learning between England and China, there are two reports linking ethos to textbook use from the perspective of the English government. Gibb's (2015) speech reflects that resource use in classrooms can be affected by social ideology. His speech in the PA/BESA (Publisher's Association/British Education Studies

Association) 2015 conference argued that the anti-textbook culture was not a common phenomenon in the Anglosphere but that this ethos has prevailed for a long time in England. He shared a story of a lesson inspection, where a teacher typed the contents of textbooks onto handouts for the next-day lesson to make the material more like a teacher-created one. It seemed that English teachers felt shame for using textbooks in classrooms. In fact, Gibb did reveal a notion among English people that only bad teachers relied on textbooks. To some extent, teachers' choice of resources determines the main learning materials for their students. In this case, teachers' prejudice about textbooks considerably reduces the students' opportunity for using textbooks. Meanwhile, Gibb emphasized the importance of textbooks and other well-organized resources to students: *the need to sequence instruction so not to overburden working memory, the need for prior knowledge to contextualise future teaching, the benefits of testing as a means of improving recall, and the importance of spaced practice and revisiting topics*, and further highlighted the central role of these resources within a school-led education system.

Bokhove and Jones (2014) did research to explore mathematics textbook use in England from teachers' perspectives based on the Office for Standards in Education (Ofsted) reports. Their text analysis showed that the frequency of term "textbook" in Ofsted reports declined sharply after 2004, as did the term "resources", which was coincident with the presence of the term "over-reliance". Such a result implies that England experienced a considerable decrease in textbook use fourteen years ago and the social perceptions of teacher's over-reliance on textbooks might be a reason for the decrease. It is worth noting that England's government has no preference in assigning any resources for teaching and learning so that teachers have a great autonomy in their instruction. In this case, which resources teachers use is determined by their own beliefs and schools' financial support to a certain extent. However, in China, the central government explicitly spells out that students should use textbooks for every subject of the national curriculum at compulsory education stage (Ministry of Education of the People's Republic of China, 2015a). Considering that textbooks are published multifariously and commercially, the government issues a list of approved textbooks for different regions and schools to choose from. To be specific, 10 series of mathematics textbooks for secondary schools were qualified in the latest government document (Ministry of Education of the People's Republic of China, 2015b). Therefore, compared to social ethos, the government's attitudes affect students' use of learning resources in a more direct way.

To conclude this section, the previous studies indicated that people's beliefs and interactions related to education can influence students' learning activities in and beyond classrooms, which may include the use of various learning resources. In addition to this, the government's policies and interventions do determine resource use in instructional practice to a great extent.

2.4 Summary

The number of studies on students' interactions with learning resources in mathematics is much lower than expected, though some teaching and learning resources have come to researchers' notice since the last century. Many issues related to learning resources have been not well-addressed and even not touched upon.

Which resources used by students in their learning of mathematics have been studied? Empirical studies on mathematics classroom practice and instructional activities involving various resources provide some examples of materials used by students in mathematics learning. Particularly, textbooks and digital technologies (e.g. computer software) are hot topics while other resources, such as workbooks, exercise books, and notebooks, have been largely ignored.

How have learning resources been conceptualized? The term "learning resource" is always used as a known phrase that does not need to be further interpreted, thus there has not been a formal definition of learning resource in mathematics education. Nevertheless, researchers have conceptualized some analogues of learning resources, for instance, *learning materials*, *mathematics text materials*, and *mathematics resources*, by enumerating or classifying the materials from different scopes.

How has the use of learning resources been defined, described, and measured? Namely, what data related to students' use of learning resources have been collected by other researchers? The relevant studies reviewed here employed various research instruments to ensure that the collected data can actually reflect students' use of resources in mathematics learning. Most of the research mentioned self-completed questionnaire, classroom observation, teacher and student interview, and the equivalent, which mainly provided rich qualitative and narrative data, such as when and where students used which parts of textbooks and for what reasons. A few studies provided some general and scattered descriptions about students' use of textbooks with quantitative data, such as scaling the importance of textbooks in students' learning of mathematics.

What factors have been considered to influence students' learning and particularly students' use of learning resources? The factors can be rooted in cultures, such as people's beliefs about learning; didactical and social interactions, for example, teachers' teaching and parental involvement in children's learning; and educational policies.

Chapter 3 Conceptual Framework

The primary question of this study is, "How do students use learning resources in mathematics?" To address this question, it is necessary to clarify two key constructs: learning resource, and the use of learning resources. Also, in order to better understand the results of the resource use in England and Shanghai, it is also essential to define the factors that may influence students' use of learning resources in the two places, which calls for a comprehensive understanding of the relationship between students and learning resources as well as other constituents in the learning of mathematics. Therefore, a theoretical basis presenting the holistic view of the role of artefacts in teaching and learning is first introduced here.

3.1 Theoretical foundation

There is little literature about theoretical foundations underpinning the research in mathematics education on resource use from the students' angle while the situation on the teachers' side is better. Remillard, a mathematics education researcher at the University of Pennsylvania, examined key concepts in research on teachers' use of mathematics curricula in more than 70 empirical studies covering 25 years (Remillard, 2005). The review focused on the studies that investigated how teachers interacted with, used, and were influenced by curriculum materials within the classroom, in major journals in the field of mathematics education, general education, and research on teaching, and pointed out the lack of a developed theoretical underpinning and the various constructs of the core concepts.

She gave a general definition of the concept "curriculum use" as *how individual teachers interact with, draw on, refer to, and are influenced by material resources designed for instruction*, and indicated four understandings of curriculum use based on different stances on the relationship between curriculum and teaching, i.e. (1) *curriculum use as following or subverting the text*, which took the curriculum as a fixed text and teacher as an executor of the given material, (2) *curriculum use as drawing on the text*, which viewed the text as one of the resources in teacher's teaching; (3) *curriculum use as interpretation of text*, which regarded the text as a representation of concepts and tasks and emphasized teachers' experience and knowledge in their teaching; (4) *curriculum use as participation with the text*, which saw the text as artefact and tool mediating teachers' teaching activities.

Although learning and teaching are different activities, they interlace with each other in instructional practice. In fact, teaching cannot be separated from learning, while learning with teacher instruction is a dominant pattern in school education. Therefore, the theoretical grounds of teachers' resource use have the certain significance in constructing the foundation of students' use. Nevertheless, the first three conceptions of teachers' curriculum use cannot be naturally adopted for students because of the particularity of the learning activity. Firstly, the connection between resources and learning is more complex than a "transition" in what teachers do between curriculum and teaching practice; secondly, most students do not have many active choices of facilitating materials for learning in school systems, for their learning activities and the involved resources are often designed and selected by teachers; and thirdly, the main tasks in student learning are far more than the interpretation of texts. Therefore, those categories cannot be applied to investigating students' resource use.

For the fourth conception of curriculum use, Remillard noted that the distinguishing characteristic was its emphasis on the activity of using and the dynamic interrelationship between teacher and curriculum. This perspective positions curriculum use in a macro circumstance, namely, teaching activity, and treats teachers and curriculum as two constituents of the activity, which actually stems from Vygotsky's Activity Theory. The relatively developed theory in sociology lays a sound foundation for this category and makes the transplantation possible. Therefore, this study adopts this stance as a starting point of the theoretical ground. Actually, it is not the first time that researchers have constructed a model of students' resource use based on Activity Theory. Rezat and Sträßer (2012) analysed the role of artefacts in the teaching and learning of mathematics by drawing on Engeström's model (1998) of the school system from the perspective of cultural–historical-activity-theory. The following is to trace back to the development of the model and clarify the foundation for constructing the conceptual framework of this study.

3.1.1 Vygotsky's theory in learning activity

The psychological ground of tool use was initiated by the Soviet psychologists, Vygotsky, Leont'ev, and Luria in the 1920s and 1930s (Engeström, Miettinen, & Punamäki, 1999, p. 1).

From the view of social constructivism, Vygotsky went beyond Piaget's cognitive development by taking the environment and context into account in students' learning. Vygotsky's learning theory emphasizes that learning and development cannot be divorced from their cultural-historical context. It stresses the interaction between individual and circumstance, and regards mediation as the key mechanism in development and learning. (Schunk, 2012, p. 242). According to Vygotsky's Activity Theory, all human psychological (higher mental) processes are mediated by psychological tools such as language, signs, and symbols. Children learn these tools from adults in the course of their collaborative activity and internalize the tools to function as mediators in more advanced psychological processes (Karpov & Haywood, 1998, p. 27). However, cultural–historical contexts can determine the language, signs, and symbols to some extent and further, can influence the way that students obtain these psychological tools, the pattern of children–adult collaborative activities, and even the internalization and application of the tools in their psychological processes.

However, it seems that Vygotsky's learning theory overemphasized the effect of environment on students' learning. Evidence exists of purely cognitive development before young children have the opportunity to learn from their culture (Bereiter, 1994), such as some biologically predisposed concepts like the fact that adding increases quantity (Geary, 1995), which indicates that the social ideal and culture are not prerequisites for the occurrence of learning. Indeed, it is academic to have a critical view of a proposed theory, but the impact of social interaction and environment should be taken into consideration in explaining learning and development (Schunk, 2012, p. 243).

3.1.2 Engeström's view of learning from the perspective of Activity Theory

Engeström, a professor of Adult Education and director of the Centre for Research on Activity, Development and Learning (CRADLE) at the University of Helsinki, is seen as the third generation in leading and developing Activity Theory (after Vygotsky and Leont'ev). He explained learning by going beyond the cognitive level and taking it as a transformation of human activities (see Engeström, 1987). To achieve that, he first constructed the structure of human activity (shown in Figure 3) based on Marx's elaboration of general relation of production to distribution, exchange, and consumption in the introduction to *Grundrisse* (Marx, 1973, p. 89).

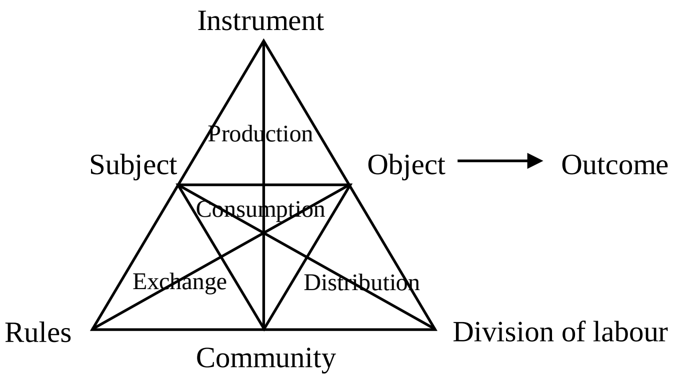


Figure 3 The structure of human activity

As Engeström stated, this model suggested the possibility of studying multiple components and relations of human activity system within a triangular structure, which was to grasp the systemic whole, not every single connection (Engeström, 1987, p. 62).

Though the structure of human activity in Engeström's study is a general model for explaining social existence originating from the framework of materialist dialectics (Davydov, 1999), its idea of mediation and connection between individual and circumstance have impacted many fields of inquiry, including learning and teaching (e.g. Moll, 1992). In fact, learning originally appears as an unintentional and indivisible part of the productive activity (Engeström, 1987, p. 74), which makes it reasonable to adopt the activity model to address learning practice. Therefore, Engeström established his innovative theory of expansive learning activity with the basis of human activity structure by considering three types of activity: the activity of schoolgoing, the activity of work, and the activity of science and art, which were regarded as the candidates for the birthplace of learning activity. School is the central organized institution established to serve human learning; work, or productive activity, is the original context in which learning happens unintentionally for passing craftsmanship from master to apprentice, which still has its own line of learning activity and is relatively independent from schooling; science and art are seen as a search for truth and beauty, or to produce truth and beauty, while learning is the activity that reproduces them, which is rooted in scientific research and artistic creation (p. 75).

Moreover, he applied the model to instructional practice in classrooms to analyse an innovative team of primary teachers in their school work of creating and implementing a new curriculum (Engeström, 1998), which reversely provided empirical evidence for the teachers' part of the model. To be specific, it interpreted activity as *a collective, systemic formation that has a complex mediational structure* (p. 78), the work activity of school teachers as teaching, and the activity of school student as "schoolgoing". Correspondingly, models of teaching and schoolgoing were depicted as a pair of activity system as shown below (Engeström, 1998, p. 80).

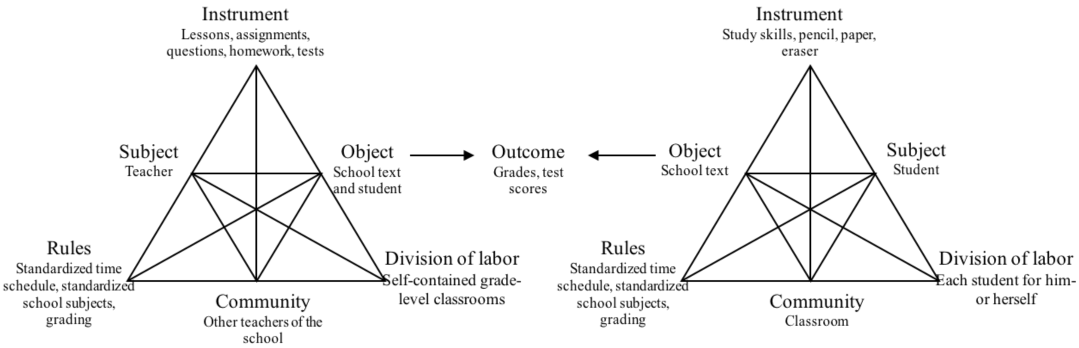


Figure 4 Teaching and schoolgoing as interconnected activity systems

For classroom practice, Engeström deemed that the content and methods of teaching were codified in curricula, textbooks, and study materials, while the structure of school systems was codified by laws, regulations, and budgets. Nonetheless, there exists a middle level forming and reflecting the classroom sphere and school life between them, which consists of grading and testing practice, patterning and punctuation of time, uses of textbooks, bounding and use of the physical space, grouping of students, patterns of discipline and control, connections to the world outside the school, and interactions among teachers as well as between teachers and parents (Engeström, 1998). Therefore, the bottom parts of Figure 4 represent the middle level and take the alienation of the circumstances between teachers and students into account.

For students' "schoolgoing", it is worth mentioning the reversal of object and instrument in

Engeström's model; namely, text was considered as the object, and learned knowledge as well as skills were taken as instruments. In other words, the product of learning activity in schools was the text proving one's ability and experiences of solving assigned problems.

Apparently, Engeström's model of learning activity puts focus on practice rather than knowledge. It discusses learning at the level of human instead of brain, depicts learning activity collectively instead of individually, and concerns the development of the whole society instead of a person. Particularly, Engeström distinguished the activity of learning or study in schools from other types of human learning activities. In his conclusion, the Activity Theory triangle (subject–instrument–object) is interpreted as *human–models–activity* in human learning activity, while in the activity of schoolgoing, it is unscrambled as *pupil–study skills–school text*, which implies Engeström's pessimistic view of traditional school education and may explain why he used the combined word "schoolgoing" instead of the straightforward one "learning" to represent students' activities in schools.

3.1.3 Rezat and Sträßer's adoption of Engeström's teaching and schoolgoing models in mathematics education

With the purpose of investigating the role of artefacts in the teaching and learning of mathematics, Rezat and Sträßer turned to Vygotsky's Activity Theory and noticed Engstrom's teaching and schoolgoing models. They deemed that Engeström's interrelated activity systems distinguished the school life between teacher and student but ignored the communities that both teachers and students were part of (Rezat & Sträßer, 2012). Hence, they constructed the socio-didactical tetrahedron (mentioned in Chapter 2, see Figure 2) to provide a more comprehensive model.

For the learners' angle in the tetrahedron, the student is positioned at the centre of a hexagon that is actually the expanded view of two sides of Rezat and Sträßer's tetrahedron as shown below (Figure 5). The following paragraphs are elaborations and reviews of components and relations in the hexagon in terms of students' artefact use, which is the base of this study's framework.

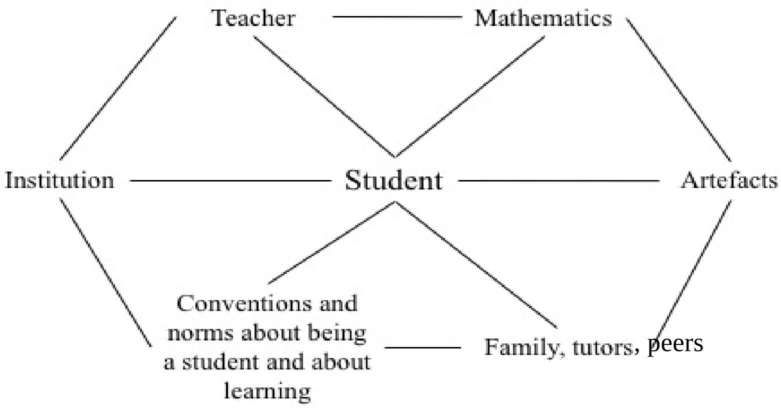


Figure 5 The expanded view of the two sides in Rezat and Sträßer's tetrahedron

Artefact. In fact, the increasing interest of instruments for teaching and learning mathematics comes from the introduction of digital technologies into classrooms. Nevertheless, the artefacts incorporated in mathematics classrooms are more than technologies. For example, textbooks, rulers and compasses, and log tables have been used in mathematics education for a long time before advanced technologies entered classrooms, while the non-physical tools such as language, diagrams, and gestures are also involved in didactical practice. After all, the teaching and learning of mathematics heavily rely on how physical materials represent and express the immaterial structures. (Rezat & Sträßer, 2012). Therefore, the term "artefact" in the model refers to the embodiments supporting teaching and learning process in the broad sense.

The *student–artefact – mathematics* triangle. This basic triangle depicts the tool-mediated activity of learning mathematics. What should be emphasized here is that Rezet and Sträßer reversed the object and instrument in Engeström's "pessimistic" and traditional view of "schoolgoing". They regarded mathematics as the object (or outcome) and viewed texts as well as technologies as the instrument (or artefact) of students' learning activity.

The teacher's role in *students' artefact use.* Rezat and Sträßer modelled the teacher's mediatory role in students' artefact use by adding the vertex of teacher directly on the *student–artefact–mathematics* triangle, whereas the connections between teacher and other components are not fully reflected in the hexagonal expansion, which is complemented by the piece displayed in Figure 6 and combined with the top-right part of the hexagon and adjusted as shown in Figure 7. In fact, Rezat did two studies on textbook use in didactical practice (Rezat, 2009a, 2012), which provided some specific examples of teacher mediation in students' resource use supporting his model.

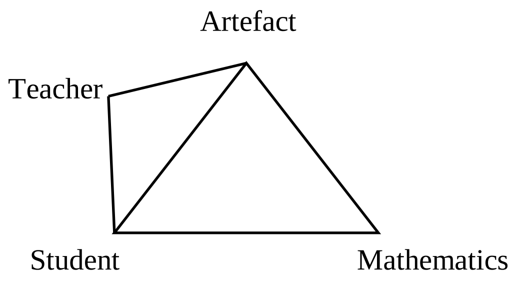


Figure 6 Teacher mediation of students' artefact use (Rezat & Sträßer, 2012)

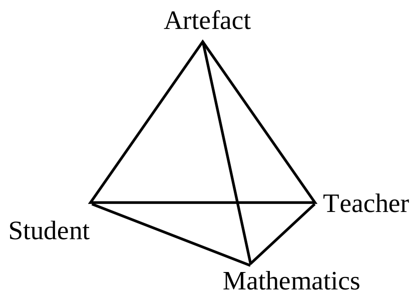


Figure 7 Tetrahedron model of the didactical situation

The social and cultural dimension. The remaining component is the social and cultural dimension related to students' mathematics learning, including the community of students (i.e. their peers, families, and tutors), the institution or school (for incorporating the community shared by both teacher and student), and the conventions and norms about learning and being a student. In this dimension, Rezat and Sträßer kept the idea of community and rules appearing in

Engeström's student model and further improved the meaning of the two components. Firstly, the community of students was extended beyond the classroom, which took parents and others related to after-school activities into account. Indeed, the concept of the students' community (i.e. classroom) in Engeström's model seems narrow from the perspective of learning, but it is adequate to Engeström's "schoolgoing" view of students' activity in school systems.

Secondly, Rezat and Sträßer used the phrase "*conventions and norms*" to describe the established practice, which has a broader sense than "rules" in Engeström's model. They mentioned Yackel and Cobb's (1996) analysis of socio-mathematics norms that are negotiated in communications between teachers and students, and interpreted the "discussion" about conventions and norms in mathematics instructions as an artefact in their socio-didactical tetrahedron. In other words, the conventions and norms highlight didactical interactions between teachers and students, which are specific and dynamic processes, while the rules only focus on standardized timetables, standard school subjects and grading, which are almost a fixed and "dead" practice.

Also, Rezat and Sträßer's incorporation of the institution as the common community for both students and teacher is to make up the school's functioning, which is regarded as rules in Engeström's model as mentioned earlier.

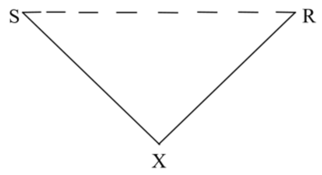
3.1.4 Summary

In short, with the fundament of Vygotsky's Activity Theory and the basic triangle model of subject–artefact–object, Leont'ev attached sociality and collectivity to human activity, based on which Engeström developed the basic triangle to a larger triangle by adding the social and cultural dimension at its bottom and interrelations among all the components. Specifically, with the purpose of structuring the socialized activity of human learning, he adopted Marx's interpretation of productive practice and further applied the model to schooling practice including the teacher's work and students' schoolgoing. Afterwards, transforming the perspective from sociologist to mathematics educator, Rezat and Sträßer established the socio-didactical tetrahedron for understanding the role of artefacts in mathematics teaching and learning by developing and merging Engeström's teacher–student activity system, and its expanded two sides centred on students are the starting point of the framework of this study. A summary of the revolution of the models is presented in Table 1.

Table 1. Models and glossary

Vygotsky

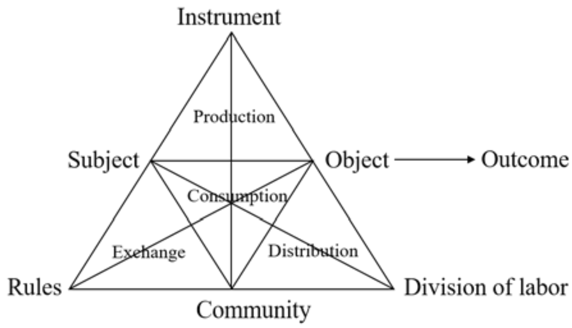
The structure of the mediated act



S: stimulus
R: response
X: intermediate link which can be seen as a second order stimulus (sign) "drawn into" the operation for fulfilling a certain function

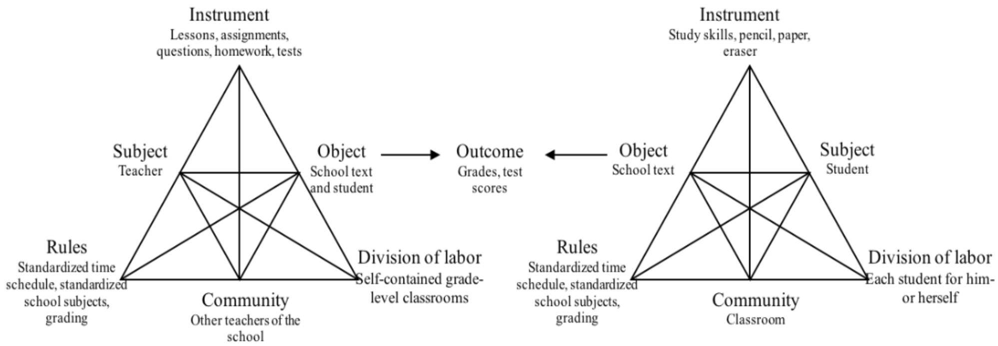
Engeström

The mediational structure of human activity



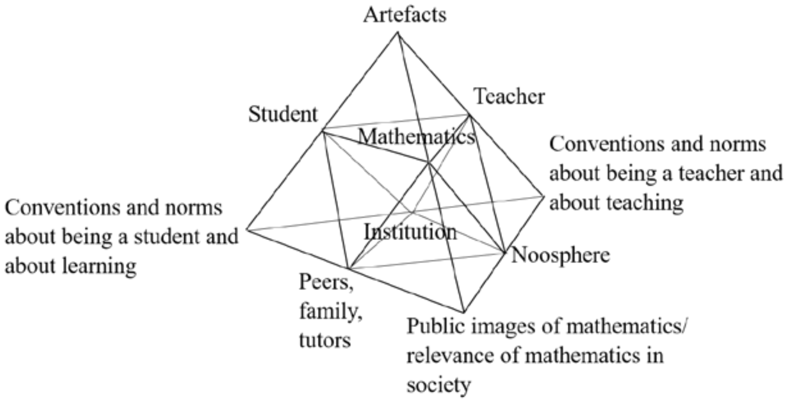
Subject: actors engaged in the activity
Object: the objective of the activity, both something given and something projected or anticipated
Instrument: tools, symbols and representations of various kinds used by actors in the activity system
Rules: collective traditions, rituals, and conventions regulating activities in the system
Community: all relevant actors involved in the system
Division of labour: the division of activities among actors in the system
Outcome: the results that actors can obtain from their engagements in the activity
Production: to create the objects
Distribution: to divide them up according to social laws
Exchange: to parcel out the already divided shares in accord with individual needs
Consumption: the product steps out of the social movement and becomes a direct object and servant of individual need

Teaching and schoolgoing as interconnected activity systems



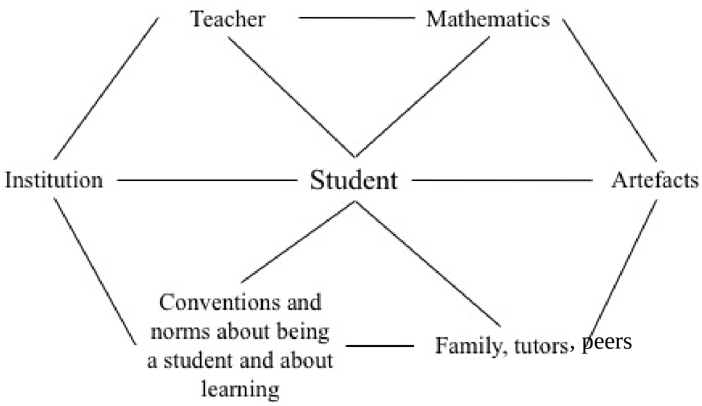
Rezat and Sträßer

The socio-didactical tetrahedron



Student/teacher: the subjects of the activity of mathematics education
Mathematics: the object of the activity
Artefacts: various tools and representations used by teachers and students in the teaching and learning of mathematics, including mathematics textbooks, digital technologies as well as tasks, problems, and language
Conventions and norms about being a student/teacher and about learning/teaching: the rule of the learning/teaching activity
Peers, family, tutors/Noosphere: student's/teacher's community
Institution: the community shared by students and teachers
Public images of mathematics/relevance of mathematics society: public views and relevance of mathematics on mathematics teaching and learning

The expanded view of the two sides in socio-didactical tetrahedron



3.2 Constructs

Firstly, since the term “learning resource” has not been formally constructed in mathematics education, a general conceptualization is given to define the resources used in mathematics learning, followed by a list of specific resources that this study focuses on.

Secondly, a definition of students’ use of learning resources in mathematics is constructed to clarify the interactions between students and the resources discussed in this study, and specific indicators of students’ resource use are generated from the literature review and theoretical basis to describe how students incorporate various resources in their learning of mathematics.

Finally, given the fact that past studies and reports indicate many differences in textbook use in mathematics between England and other regions (e.g. Pepin & Haggarty, 2001), particularly between England and Shanghai (see Weale, 2015), it can be naturally inferred that there may exist differences in students’ use of other resources in mathematics between England and Shanghai as well. Therefore, some explanatory factors are extracted from the relevant literature and formed based on the structure shown in Figure 5 to obtain an in-depth understanding of the resource use in the two places.

3.2.1 Learning resources

In Oxford English dictionary, “resource” is interpreted as “*a stock or supply of money, materials, staff and other assets that can be drawn on by a person or an organization to function effectively, a country’s collective representing minerals, lands and other natural assets, or a source of help and information*”, while “material” means “*the matter from which a thing can be made, and abstractly, information or ideas for use in a creating work*”. It seems that “material” is a part of “resource” to some extent, but this study uses them interchangeably.

The adoption of “learning resource” instead of “instructional resource” in this study is to distinguish the materials for teaching from the materials for learning. Therefore, before defining the concept of learning resources, it is necessary to elaborate the relationship between teaching resources and learning resources, which makes the focus of this study clear since some resources have a dual identity. Teaching resources refer to materials used by teachers in didactical situations. For example, the curriculum standard is definitely a teaching material because it is developed and designed for teacher’s teaching (Remillard, 2005). On the contrary, for learning resources, their users should be learners or students with the purpose of learning. For instance, notes are a learning material since students create their own notes during lessons and may use them for revision after class. However, some materials are often used by both teachers and students, such as textbooks. In most cases, when taking textbooks as the research object, people do not make a distinction between the two but their research questions and aims can show whether the study considers textbooks as a learning material or a teaching material. Therefore, for those resources that can be used by both teachers and students, this study considers them as learning resources in any case because it will only pay attention to the students' side.

Though there are a large number of studies on specific resources available in instructional practice such as textbooks and technologies (e.g. Neal, 2005; Sharples, Corlett, & Westmancott, 2002), few of them embody the concept of learning resource (e.g. Brown, Doughty, Draper, Henderson, & McAteer, 1996). Researchers are more likely to take the concept of learning resource as a known terminology when their studies focus on a specific resource.

According to the literature review, resources used in mathematics instructions can narrowly refer to texts comprising the original mathematics "language" plus some comments on it no matter whether they are presented as words, pictures, or dynamic images (Love & Pimm, 1996), and can broadly be understood as the tools used in instructional practice, and even the environments as well as the contexts in which teaching and learning activities take place (Adler, 2000). It indicates that the research scope determines the definition of the resources embodied in those studies.

Therefore, based on those previous conceptualizations and the research spectrum of this study, "***Learning Resource***" here mainly refers to:

The things which present mathematics and can be utilized by students in their learning of mathematics in school education.

Some explanations and restrictions are necessary to understand the definition.

Firstly, there is no doubt that "things used by students in their learning of mathematics" are the resources supporting students' mathematics learning in practice. However, unlike Adler's (2000) generic conceptualization, this study does not take the basic learning equipment, such as pens, papers, and maintenance of schooling into account, since they are not the resources presenting mathematics. The term "present" is borrowed from Tomlinson's (2011) construct of materials designed for language learners to restrict the forms of the resources. For example, students use compasses to make circles, but the tool cannot "present" mathematics by itself, therefore it is not the focus of this study.

Secondly, the emphasis on "students" and "school" excludes the situations in which children do not attend public education, such as home-schooling, in which case it may involve various self-made materials and "convenient" resources like newspapers and storybooks.

Finally, it is necessary to explain a special information-presenter for students: the teacher. As mentioned in the literature review, the teacher is a mediator between artefacts, mathematics, and students. Nevertheless, teachers are not a "thing" for presenting mathematics in the first place and teachers' knowledge cannot be used by students on their own as well, hence they are not the learning resources discussed in this study. The role of the teacher will be introduced in later sections, which is taken as a motivation of students' resource use and a possible factor influencing students' resource use in this study.

Therefore, combining the practical situation with the literature review, this study classifies learning resources into two categories in terms of the forms of comprising and presenting information: ***paper-based resources*** and ***e-resources*** (see Figure 8). Paper-based resources are traditional school materials, including ***textbook***, ***reference book***, ***workbook***, ***worksheet***, ***notebook,*** and ***other paper-based resources***. E-resources refer to all forms of information presented by electronic devices. Nevertheless, this study is interested in the specific forms of learning materials on electronic devices other than electronic devices per se (explained later). In this case, e-resources are further classified as ***e-book, teaching video, e-learning system***, and ***other e-resources***. Others represent the resources that students may use in their learning of mathematics but cannot be included in the two categories mentioned above.

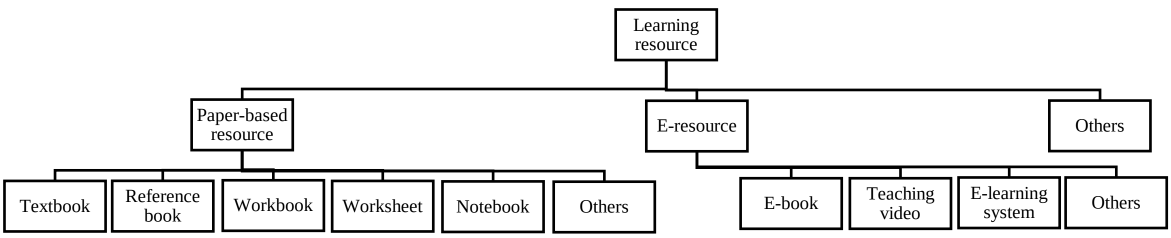


Figure 8 A classification of learning resources

As summarized in the literature review, research on learning resources available in instructional practice and mathematics classrooms primarily referred to textbooks (e.g. Walls, 2007) and the research on students' textbook use in mathematics (see section 2.2.1) indicated the importance of textbooks in mathematics learning. Nevertheless, few studies on textbook use defined what a textbook was, which should not be taken for granted since there are some exceptional cases; for instance in England, students can hardly gain access to textbooks at secondary stage so that they usually have many alternatives like "guidebook" as mentioned in Haggarty and Pepin's (2002; 2001) study. Hence, it is important to clarify whether a book is considered as a textbook even if it is routinely used in classroom instruction. Therefore, in this study, "***Textbook***" represents the book used as a standard work for mathematics learning, which is issued by publishing houses and usually authorized by schools or governments for students to use in mathematics lessons. Moreover, it refers to hard copy only. The electronic copy and all other kinds of transformation of mathematics textbooks are excluded under this definition.

"***Reference book***" is a broad concept and an extension of textbooks. In fact, apart from the textbooks selected by schools, students often have their own choice of books as learning auxiliary. For example, the guidebook mentioned above is an alternative to the textbook in some situations where textbooks are seen as luxuries (Haggarty & Pepin, 2002). Thus, "*reference book*" refers to all the books selected by students themselves as a complement to the "official" textbooks.

In addition to textbooks, there is evidence that exercise books and worksheets are common resources in students' classroom learning (Walls, 2007). In fact, though there are many exercises in mathematics textbooks, teachers often assign additional questions from other books accompanying the textbooks, namely, workbooks or exercise books as homework (Lianghuo Fan, Chen, et al., 2004). Also, students also do practice beyond lessons for self-regulated learning in many cases (Rezat, 2013). This could be one of the reasons that such kinds of book exist and have even formed an industry chain. However there is not a unique name for such material; for example, in England, it is called an "exercise book" or "workbook" while in Singapore it is called an "assessment (or supplementary) book" (Yan, 2014). Therefore, this study takes the term "workbook" as the representative of all, and the definition of "***Workbook***" is an aggregation of all the publications designed for students to do practice.

"***Worksheet***", as explained in Oxford dictionaries, is a paper listing questions or tasks for students. Unlike workbooks, in most cases, they are designed by teachers according to different teaching purposes, other than those published commercially. To some extent, worksheets present the abstract of textbooks and a selection of targeted tasks extracted by teachers. Students use them in mathematics lessons under teachers' guidance as exercises and take them home as assignments as well.

Also, note-taking is a learning strategy that produces material supporting students' learning. Many studies explored the association between the use of notes and academic performance (e.g. Kiewra, 1983, 1987). Indeed, not like the several resources mentioned above, notebooks are easily overlooked because they neglect students' initiative in mathematics learning. The speciality is that notebook is not a ready-made resource for learners to use directly. Students often take notes first and then use them for reviewing or referencing purpose. This study takes the two sequential processes as a whole, which emphasizes the existing form of material other than the content. It also explains the selection of the term "notebook" instead of "note". Therefore, "***notebook***" stands for a book with blank or ruled pages for students to write notes in and probably use the notes for revision and other purposes.

"***Other***" paper-based resources are the materials that cannot be categorized into any of the above.

In the virtual world, information has multimodal formats: text, graphics, audio, video, simulations, games, and animations etc. (Selinger & Kaye, 2014). Thus, the presenters of information are multi-level as well. At primary level, software/applications or programmes integrate virtual information, then at secondary level, electronic devices run these programmes to display the information or interact with users. However, the definition of learning resource in this study restricts the forms of the resources since it may not make sense to say that an electronic device, such as a smartphone, "presents" mathematics. Actually, it is hard to classify electronic resources by specific devices since various personal devices can be incorporated into one's learning in different situations. Therefore, this study defines e-resources according to the primary forms that integrate and present virtual information for students' learning.

"***E-book***" is "*a text analogous to a book, that is in digital form to be displayed on a computer screen*" (Feather & Sturges, 1997). In fact, e-books are accessible on a variety of media nowadays. Many textbook publishers issue the electronic copy and the relevant materials as an alternative or a supplement to their textbook and there is evidence showing that e-textbooks could be widely accepted by students at the secondary stage and have a positive impact on students' achievement (Collins, Hammond, & Wellington, 2002; Maynard & Cheyne, 2005). Particularly, Chinese textbook publishers provide the electronic copies of their textbooks free on websites. In Shanghai, the "Committee for Reforming the Curriculum and Textbooks at Primary and Secondary Schools" is in charge of the compilation and publication of all textbooks used in primary and secondary schools, including the corresponding electronic versions[2]. In England, textbook publishers often issue an e-package as one kind of instructional product. For example, Oxford University Press's mathematics electronic caboodle for key stage 3 comprises student e-textbooks 7, 8, and 9, as well as the auto marked tests and teacher notes with additional problems and solutions (Bettison, 2014). Indeed, it is more like a package for out-school learning, not just an alternative to paper-based textbooks. Thus, it is worth mentioning that the term "e-book" here is not only the electronic copy of a paper-based textbook, workbook, reference book, and the equivalents but also all other electronic publications for mathematics learning in the form of a book.

With the development of technology and the popularization of the internet, online schools or e-learning centres become a possible choice when students are seeking after-school learning assistance (Greenway & Vanourek, 2006). The main online resources are teaching videos and software to provide a structured learning environment (Rose, 2007; John Watson, Murin, Vashaw, Gemin, & Rapp, 2011), while computer programmes are also prevalent in mathematics classrooms according to the literature review, which are the e-resources introduced in the next two paragraphs.

"***Teaching video***" is a video-recorded lesson. With the definition of "e-resources" mentioned earlier, video is another format of organizing the virtual learning materials in mathematics. In most cases, it presents a normal lesson taking place in schools except for the communications and interactions between teacher and student. In fact, some live lessons provide student opportunities

[2] http://www.shkegai.net/index/materialList.aspx

to raise questions and communicate with their instructor but the efficiency and frequency cannot be guaranteed since it is not a face-to-face dialogue after all.

"***E-learning system***" refers to all the software, programmes, web-based platforms, and applications etc. designed for students' learning in electronic environments. The studies on ICT in students' mathematics learning reviewed in Chapter 2 offer many examples of how various computer programs (e.g. spreadsheets and geometry software) and web-based learning systems (e.g. WebQuest) enhance students' learning of mathematics, thus it is a common pattern of virtual learning materials in addition to e-books and videos. In fact, many information technology companies are devoted to developing professional learning systems for different disciplines at different schooling levels. Specifically, Chinese web-based learning platforms have emerged massively in recent years, such as "Mo Fang Ge", a mathematics learning platform for students at primary and secondary level; "Jing You Wang", a web-based platform providing past papers of the high school entrance examinations, and "Baidu Zuo Ye Bang", an application designed by the search engine company "Baidu" for students and teachers to communicate and discuss questions online. Similarly, in England, "Bitesize" is a web-based learning platform involving all disciplines at primary and secondary level, which is run by the BBC.

"***Other***" e-resources are virtual materials that are not included by any of the above. For instance, a student may search for graphs of an unfamiliar function and get them directly from Google Images, or check the definition of parallelograms using search engines and get the answer from Wikipedia. Obviously, neither a Google Image nor a Wikipedia item is an electronic publication, teaching video, or a structured system designed specifically for students' learning. Actually, students use these resources just for getting instant information instead of a goal-directed and systematic learning experience. In this case, these convenient but unintegrated materials can be grouped as other e-learning resources.

Moreover, there are other types of resources used by students in their learning of mathematics. For example, concrete objects, such as cubes and protractors, are also known as resources appearing in mathematics learning. Nevertheless, there is evidence showing that the use of manipulatives in secondary mathematics classrooms is significantly lower than that in primary schools (Howard, Perry, & Lindsay, 1996; Howard, Perry, & Tracey, 1997), which indicates that the use of those resources often happens at early stages (e.g. Kamii, Lewis, & Kirkland, 2001). Also, those assistive tools, like compasses and protractors, are often used when learning specific topics, for instance, compasses are usually used when students are learning circles. Therefore, they are not the focus of this study since it is intended to investigate the use of learning resources in mathematics at secondary stage regardless of the learning topics.

3.2.2 The use of learning resources

The second key construct is the interaction between students and learning resources, namely, students' ***use*** of learning resources. In fact, when it comes to the use of mathematics learning resources, many terms relevant to "use" come to mind, such as "read". Thus, it is necessary to clarify, firstly, what kind of use is discussed in this study, and then to define various descriptions pertaining to the word "use" to embody students' use of learning resources in mathematics, which partially is an integration of the empirical indicators mentioned in the literature review.

In this study, based on the theoretical scope, it takes learning resources as the artefacts mediating students' learning of mathematics and accordingly views the use of learning resources as artefact-mediated activities. Therefore, the ***use*** discussed here involves:

The activities primarily related to paper-based and electronic resources in students' mathematics learning, such as reading and practising.

For describing how students use learning resources, the literature review provides some empirical examples related to mathematics textbooks. Fan et al.'s (2004) study measured the "general use" of mathematics textbooks, which documented the frequency of using different parts of the textbook. Specifically, students were asked how often they used the textbook in the classroom, how much of their homework was directly from the textbook, and how often they read the textbook before, during, and after the class. However, these measures did not draw a clear image of students' use of textbooks since the questions interwove time, place, and even specific learning activities with frequency of use. Weinberg et al.'s (2012) study answered which parts of the textbook students used, in which conditions they used it, and for what purposes with some presupposed items, which seems better structured compared to Fan et al.'s "general use". In their study, the textbook contents were subdivided into "chapter introduction", "chapter text", "examples", "homework problems", and "chapter summary"; the situations in which students used textbooks outside of class were specified as "preparing for class", "doing homework", and "studying for exams"; and the purposes of textbook-use were generated as the following: 1) Read for better understanding, 2) Make sense of definitions or theorems, 3) Look up definitions or theorems, 4) Rephrase/summarize text (for notes, homework, etc.), 5) Read the homework problems to see what ideas come up most frequently, 6) Use the answers to exercises to check homework, 7) Use extra problems and answers to exercises to check understanding of problems that were not assigned, 8) Read or copy homework problems to complete homework assignments, and 9) Look up answers without solving the problems.

Weinberg et al.'s constructs about the purposes and situative conditions of students' textbook-use seem vague as they contain affiliations between different items; for instance, making sense of definitions or theorems can be seen as a specific case of reading textbooks for better understanding. Nevertheless, the constructs shed light on the potential purposes and conditions of textbook-use from students' perspectives, and show how textbook use can be methodically described and analysed with presupposed items.

Additionally, when it comes to the purpose of using mathematics textbooks, Rezat's (2009b) study summarized students' use of mathematics textbooks for self-regulation with five specific learning activities. Specifically, students used mathematics textbooks (as an assistant) to solve tasks and problems, to consolidate what they learned in the mathematics class, to acquire content not taught in the mathematics lesson, to cater to their interest in mathematics, and to echo their self-reflection of the learning in mathematics. In short, without teacher mediation, students use mathematics textbooks for consulting, reviewing, previewing, and satisfying curiosity. Rezat's work presents the phenomenon of students' textbook use of their own will in the learning of mathematics, which generates some specific activities incorporating textbooks such as solving tasks and problems, but still seems unclear in terms of the notion of learning activity; for instance, interest-driven activities, which do not always lead to the learning of mathematics but could be a reason for students to use textbooks.

Therefore, it is essential to define different indicators of students' interaction with learning resources. Firstly, to depict the occurrence or "general use" of learning resource, every measure, e.g. frequency, should be dissociated from the specific learning activity or context to draw a general picture of students' resource use in their learning of mathematics, while for other indicators, e.g. the purpose of resource use, which may involve the information from the environment, the items should take into account the practical situations based on the existing evidence. Hence, the first six indicators of students' resource use are abstracted from the literature review including the ***frequency, duration, timing, access, change***, and ***purpose*** of students' resource use in their learning of mathematics. Specifically:

"***Frequency***" is a concept related to time for answering how often students use a learning resource, which often appears in quantitative studies on textbook use.

"***Duration***" is a concept related to time as well, often accompanying frequency, which is to explore how much time students spend on each learning resource.

"***Timing***" is the other concept of time reflecting the specific occasion of using learning resources, which is to answer the question, When do students use a certain resource? For example, Fan et al. (2004) investigated whether students read textbooks before, during, or after the mathematics lesson.

"***Access***" is related to how students get the resources they need. This construct originates from the literature about English students' access to textbooks (Haggarty & Pepin, 2002; Pepin & Haggarty, 2001). The literature indicated that English students often borrowed textbooks from the classroom during a lesson and hardly had one of their own, which was not common in other countries. Hence, this study collects the empirical evidence of how students obtain not only textbooks but also other resources in the actual situation.

“***Change***” is a concept extracted from Fan et al.’s (2004) paper. His findings suggested that a change existed in using resources from a lower secondary level to a higher secondary level. In reality, some students do admit that they use textbooks and notebooks differently at different grade levels. The change in using strategies may reflect the different learning modes (e.g. textbook-dominated mode) at different year levels.

“***Purpose***” is an indicator of students’ resource use related to specific learning activities in this study, which reveals the reality of what students usually use a certain learning resource for. In fact, many researchers intended to investigate the reasons for using a resource in students’ learning, or in other words, the situations in which students use a learning resource. For example, Randahl (2012) raised the question, What are the reasons for using the book during the course?, Weinberg et al. (2012) generated a list of the potential purposes according to the authors’ experiences as instructors and the students’ textbook-use diaries and interviews, while Rezat (2009b) categorised students’ self-regulated learning activities incorporating mathematics textbooks based on his classroom observations and interviews as mentioned earlier. Therefore, referring to Weinberg et al.’s list and Rezat’s constructs, this study defines six purposes of students’ resource use: 1) preview, 2) in-class exercises, 3) revision, 4) consulting (e.g. looking up definitions and theorems), 5) doing homework, 6) doing extra exercises (not assigned by school teachers), and other purposes.

Secondly, the reasons for using learning resources may be non-task-directed and may even not be related to learning (e.g. looking at images or other salient elements out of interest as mentioned in Rezat’s (2009b) study). Therefore, it should be noticed that the reasons why students use a learning resource in a certain way can be multiple and complicated, since students have various purposes as well as motivations to decide which resources they use and how to use those resources in different situations. To make it clear, this study constructs the purpose of students’ resource use with specific learning activities as enumerated above, while those reasons that are not directly embodied in learning activities, or even may not be related to the learning of mathematics, are categorized as the “motivations” for students’ use of learning resources.

Compared to purpose, “***motivation***” is a more subjective concept with respect to individual’s affects, beliefs, and personality. From a psychological perspective, Ryan and Deci (2000) made a distinction between intrinsic motivation, which was defined as the doing of an activity for its inherent satisfaction; and extrinsic motivation, which was defined as the doing of an activity for some separable outcome. The construct of motivation in this study draws upon Ryan and Deci’s definition and structure, namely, intrinsic motivation and extrinsic motivation, while the extrinsic motivation discussed in this study consists of two sub-factors related to resource use in mathematics learning: external regulation and self-regulation. Additionally, based on Amabile et al.'s (1994) scale for assessing intrinsic and extrinsic motivational orientations of work preference, intrinsic motivation is further divided into two aspects: enjoyment and challenge.

The ***intrinsic motivation*** is aimed at finding the appeal of learning resources to students. For instance, the satisfaction of solving difficult problems in workbooks may motivate a student to use it more often. Thus, this study borrows Amabile et al.'s classification of intrinsic motivation because their Work Preference Inventory (WPI) was designed both for college students and for adults to capture the major motivations for learning and working. Also, the WPI has been refined and developed six times. The seventh version contains enjoyment and challenge as the sub-factors of intrinsic motivation, which has a meaningful structure and good items with long-term stability. Therefore, it is sufficient to follow the items of intrinsic motivation in Amabile et al.'s study.

As elaborated earlier, teachers' instruction guides students to use learning resources, and furthermore cultivates a habit of resource use for students to some extent. Since this study focuses on students' interaction with resources in their mathematics learning, teacher mediation is taken as one of the extrinsic motivations in students' resource use. In fact, it is natural for students to give the answer "My teacher told me to use the textbook in this case" to the question "Why do you use your mathematics textbook?" Also, there are also other determiners of students' use of learning resources in different situations, which will be discussed in the following paragraph.

For ***extrinsic motivation***, the taxonomy of Ryan and Deci detailed different types of extrinsic motivation according to the extent to which it was autonomous. They pointed out that though some behaviours were self-determined, these behaviours had somewhat external perceived locus causality, which suggested there was an extrinsic motivation for the behaviours. For example, a girl who uses workbooks frequently after realizing the importance of practice to her performance has identified the relevance between the use and her self-improvement, which implies that her original intention contains external consequences. Thus, combining with the contexts and the experience of being a student, it chiefly examines two types of extrinsic motivation: one is external regulation, including teacher mediation and parent-supervision, and the other one is self-regulation, covering all the self-directed use due to any degree of external perceived locus causality. In this case, the girl's example should be classified into self-regulation of extrinsic motivation.

The structure of the motivations discussed in this study is shown below:

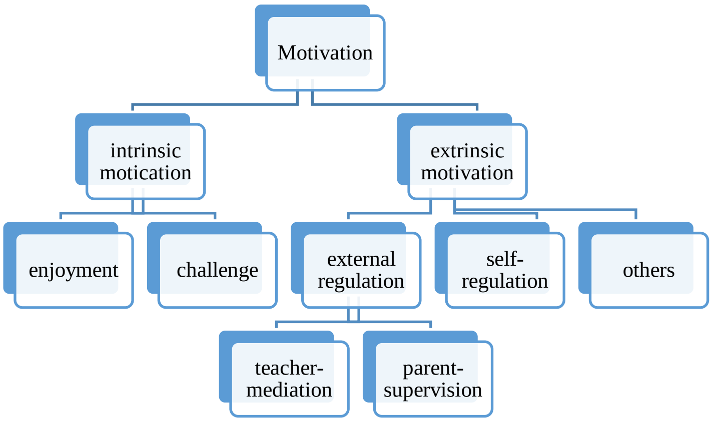


Figure 9 Motivations for using learning resources

Finally, based on the *student–textbook–mathematics* triangle, some researchers attempted to obtain an in-depth understanding of the relationship between students' mathematics learning and textbooks by taking textbooks as a factor in students' mathematics performance (Rezat & Sträßer, 2015). For instance, Törnroos (2001) explored the connection between different mathematics textbooks and students' achievements with the data of TIMSS 1999. His study firstly presented a content analysis of three mathematics textbooks used by 104 Finnish schools in seventh grade, and then investigated which contents were taught by teachers according to teacher questionnaire data of TIMSS 1999; he finally examined the association between students' achievements and the textbooks they used. The results showed that the average scores for the overall mathematics achievement were not considerably different between students using different textbooks. Törnroos's study sheds a light on the impact of textbooks on students' mathematics learning, particularly, in his case, on students' mathematics achievement, which should be taken into account when it comes to the interactions between students and learning resources. Moreover, Lithner (2003) observed three undergraduate students' mathematics reasoning in textbook exercises. With a priori analysis of reasoning structure, his study revealed the differences and similarities between the three students' reasoning during the two-hour sessions that included 4 to 5 exercises each. In Lithner's study, mathematics referred to mathematical reasoning, which suggested that other aspects of mathematics in addition to test scores could be influenced by students' resource use, though textbooks were only considered as a source of exercises and hence there was not a description of students' actual interactions with the textbooks. Therefore, the ***influence*** of students' resource use on their mathematics learning is involved here as the aspect that depicts the outcome of students' use of learning resources.

As elaborated in the theoretical foundation, the *subject–artefact–object* triangle can be seen as the essence for exploring people's activity incorporating instruments and artefacts. Thus, the basic triangle of this study is *student-learning–resource–mathematics* according to the research aims. Mathematics, as the object of students' learning activity, is normally introduced and standardized by the local curriculum at the secondary stage of the schooling system. In most cases, curriculum standards provide the essential knowledge that students need to be educated citizens and the curriculum objectives are regarded as the benchmark that students are supposed to achieve after their secondary school study (Department for Education, 2014). Therefore, taking the curriculum aims as the objects of learning activity at schooling stage, this study abstracts the common parts of the mathematics curriculum in England and Shanghai to construct the concept of *mathematics* that students are supposed to achieve in their learning activities.

Specifically, for England, the curriculum for mathematics aims to ensure that all students:

1) Obtain certain Mathematics Knowledge and Skills: "*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*".

2) Develop Ability in mathematical Reasoning: "*reason mathematically by following a line of enquiry, conjecturing relationships and generalisations, and developing an argument, justification or proof using mathematical language*".

3) Develop Ability in problem Solving: "*can solve problems applying mathematics to a variety of routine and non-routine problems with increasing sophistication, including breaking down problems into a series of simpler steps and persevering in seeking solutions*".

For Shanghai, the curriculum for mathematics aims to equip all students with:

1) Knowledge and Skills: the essential mathematics knowledge and skills for continuing learning and accommodating social productive practice.

2) Process, Ability, and Methods: the experience of mathematical activities in terms of abstraction, exploration, and application; the reasonable methods of mathematical abstraction, exploration, and application; the ability to observe, think, and reason mathematically; and the ability to pose questions as well as ability in problem-solving.

3) Affects, Attitudes, and Values: the experience of combining mathematics with real life, the perception of the value of mathematics, the confidence of learning mathematics, the experience of success in explorative and creative mathematical activities, and the positive affect and values of mathematics.

It is clear that the mathematical knowledge and skills are substantial in both Shanghai's and England's curriculum. For example, mathematical knowledge can refer to the number system and place value, which are the foundation of understanding decimals, fractions, powers, and roots at key stage 3 in England's curriculum, while mathematical skills involve solving equations and arithmetic of integral, fractional, and radical expressions in Shanghai's curriculum. Moreover, the ability in mathematical reasoning and problem-solving is highlighted in England's curriculum and covered by Shanghai as well. For instance, the ability of deductive reasoning in geometry is documented in both the two curricula (key stage 3 in England and junior secondary stage in Shanghai). Thus, synthesizing the common aims of the two curricula, this study specifies the object of the activity of mathematics learning with ***mathematics knowledge and skills***, ***ability in mathematical reasoning***, and ***ability in problem-solving***.

Hence, the ***influence*** of students' resource use on their mathematics learning refers to whether the use of various learning resources helps students enhance their mathematics knowledge and skills, improves their ability in mathematical reasoning, and builds up their ability in problem-solving.

3.2.3 The factors that influence students' use of learning resources in mathematics

Heretofore, the three terms in the *student-learning–resource–mathematics* triangle have been conceptualized and students' use of learning resources in mathematics has been depicted with various indicators of students' interactions with those resources as defined above. Also, there are many other components that constitute didactical situations as well as the social and cultural contexts. Therefore, this section maps the factors that possibly have an impact on students' resource use based on the structure of Rezat and Sträßer's socio-didactical tetrahedron, and constructs the specific indicators according to the relevant literature.

Specifically, the teacher belongs to the didactical tetrahedron in Rezat and Sträßer's model. As depicted in the model, the teacher plays a mediatory role in students' resource use in didactical practice, which is considerably significant according to Rezat's studies on textbook use (Rezat, 2009a, 2012). Therefore, the factor of the teacher is specified here with teacher's instruction related to students' resource use as the ***didactical*** aspect. Also, family, tutors, and institutions are defined as the ***social*** coordinators in mathematics education in Rezat and Sträßer's model. Nevertheless, it seems too broad that the constructs of contextual factors merely refer to some groups of people or an organization. Thus, the factor of family and tutors is specified with parental involvement and out-of-school lessons, while the influence of institutions is not taken into account for the research framework since the schools' main characteristics are settled in this study, which is the control variable in terms of the comparison between Shanghai and England, and will be introduced in the sampling section. Moreover, the factor of conventions and norms about being a student and about learning is actually the consensus derived from the negotiation about classroom practice between teachers and students as Rezat and Sträßer mentioned, but it somehow can be seen as teacher mediation in this particular case of students' resource use; for instance, the norm of "coming to the classroom with the prescribed textbook" seems more like an instruction that students must obey instead of a mutual negotiation in most cases. Meanwhile, the negotiation not only forms the manners and practice for teaching and learning but also triggers values exchanged and instilled between teacher and students. Hence, the instructional aspect of the "negotiation" is integrated into the teacher's factor and the belief-instilling aspect is combined with the factor of public views of mathematics as the ***cultural factor*** remaining in its place, which echoes the prevalent view in international comparative research that the comparison must do more than document occurrence, since education cannot take place in a vacuum and culture is constituted in teaching and learning practice (Clarke et al., 2006).

In short, on the one hand, the construct of the factors embodies the constituents in Rezat and Sträßer's tetrahedron with the practical contexts mentioned in empirical studies to associate the theoretical model with the reality; for example, the constituent of *teacher* is specified with *teacher's instruction* since teaching instruction is the bridge between teacher and students which may influence students' use of learning resources, hence it is necessary to generate the factor by situating teachers in their instructional practice. On the other hand, the factors are generalized and grouped in terms of their relation to students' learning of mathematics to centralize and model the complex circumstance of mathematics learning: the teacher's instruction is included in the didactical situation, parental involvement and attending out-of-school lessons constitute parts of students' social life, and people's values, beliefs, and perceptions of learning resources and mathematics learning are rooted in culture. Therefore, the factors that influence students' resource use in mathematics learning are categorized into three groups: social aspect, didactical aspect, and cultural aspect.

The ***social aspect*** includes ***parental involvement*** and ***out-of-school lessons***. In fact, the relationship between parents' involvement and students' learning achievement has been discussed for a long time (e.g. Swap 1990; Hara & Burke 1998; Fantuzzo et al. 1995). TIMSS was interested in parental involvement in school-related activities; for example, one item in the questionnaire was about parents' supervision of their child's homework completion (e.g. Mullis et al., 1999). Some others were about the quantity of learning resources provided by parents at home (e.g. Mullis, Martin, Foy, & Hooper, 2016). However, there are barely any studies that directly link parental involvement to students' resource use. Actually, parents' intervention in students' learning mostly happens at home with homework, which is obviously related to children's use of learning resources. Thus, based on Gershenson and Holt's (2015) structure of parents' support in students' learning, this study comes up with four indicators of parental involvement in children's mathematics learning, which may be related to resource use: 1) the frequency with which parents check or discuss with children their learning progress in mathematics, 2) the frequency with which parents assist with children's mathematics homework, 3) the frequency with which parents ask children to do mathematics exercises not assigned by their teachers, and 4) the frequency with which parents buy extra learning resources (not advised by the schools) for their children to learn mathematics.

Moreover, PISA 2012 investigated students' engagements in after-school learning activities including doing homework, working with a tutor, taking out-of-school lessons organized by a commercial company, and studying with a parent or other family member[3]. Actually, in addition to parents, tutors are also counted as a constituent related to students' learning community in Rezat and Sträßer's model, while this study embodies it in a broader sense as PISA did, called *out-of-school lessons*, which primarily refer to attending lessons organized by commercial companies, and learning with a tutor. Apparently, although having out-of-school lessons involves the use of learning resources, schooling is still the dominant context in which students interact with learning resources. Therefore, the school-related activities that involve students' resource use constitute the main body of this study, while the time spent on out-of-school lessons is taken as one possible factor for students' use of learning resources.

The ***didactical aspect*** refers to the teacher mediation between learning resources and students. According to the literature review, Rezat has investigated the impact of teachers on students' use of mathematics textbooks and characterized the way in which students' use of mathematics textbooks was affected by teachers in three dimensions: directly/indirectly, specific/general, and obligatory/voluntary (Rezat, 2012). He provided three examples of teachers' referring to textbooks, which indicated three types of teacher intervention in students' textbook use: pointing to the book as a helpful reference when students did tasks and solved problems, assigning homework, and teaching lessons by following the tasks and problems in textbooks. Therefore, there is no doubt that teachers' instruction affects students' use of textbooks as well as other learning resources to a certain extent. However, unlike Rezat's identification of how teachers mediate students' use of textbooks, this study is intended to detect the link between teachers' instruction and students' resource use in mathematics. Therefore, corresponding to the indicators of students' use of learning resources in the previous section, seven sub-aspects describing teachers' instruction related to students' use of learning resources are identified here: 1) the learning resources that teachers ask students to use during the instructions, 2) the frequency with which teachers' instructions incorporate students' use of learning resources, 3) the duration with which teachers' instructions incorporate students' use of each learning resource, 4) the timing in which each learning resources are supposed to be used according to teachers' instructions, 5) the way students are guided by their teachers to gain access to each learning resource, 6) the purpose of teachers' instructions involving students' use of each learning resource, and 7) the changes in teachers' instructions involving students' use of each learning resource compared to the previous academic year.

[3] Source: https://www.oecd.org/pisa/pisaproducts/PISA12_StQ_FORM_C_ENG.pdf

For ***cultural aspect***, as mentioned in the literature review, researchers believed that culture could explain the differences in students' mathematics performance and their learning activities from different contexts, which implies that cultural factors may impact students' interactions with learning resources. For example, school going can be translated as "*du shu*" in Chinese, which is a paraphrase of "*reading books*". It means that learning cannot happen without appropriate materials in Chinese understanding, which may explain Chinese central government's offer of free textbooks for all state-run school students in compulsory education. Thus, the following paragraphs define the cultural factor and elaborate the connection with students' use of learning resources in mathematics.

The 13th ICMI (International Commission on Mathematical Instruction) Study Conference was devoted to comparing mathematics instruction in East Asia and the West. As an international comparative study from the perspective of cultural traditions, the volume considered *culture* as "*one of the two or three most complicated words in the English language*", which may refer to "*the fabric of ideas, ideals, beliefs, skills, tools, aesthetic objects, methods of thinking, customs and traditions*". In that case, it defined culture essentially as "*values and beliefs, especially those values and beliefs which are related to education, mathematics or mathematics education*" (Frederick Koon Shing Leung, Graf, & Lopez-Real, 2006, p. 4). Similarly, in this study, **cultural factor** is defined as **beliefs, especially those beliefs related to learning resources and mathematics learning possibly incorporating the use of learning resources**.

There are two steps to justify the significance of beliefs in explaining students' use of learning resources in different contexts. First is the guiding effect of beliefs about behaviour. In fact, the interest in how students' beliefs about mathematics and mathematics education influence their way of learning has arisen (e.g. McDonough & Sullivan 2014) after the relatively rapid development of similar research on how teachers' beliefs shape teaching practice (e.g. Grootenboer 2008; Pajares 1992; White et al., 2005). Specifically, beliefs often play a filtering role for individuals' behaviours, so that they moderate how students learn mathematics (Grootenboer & Marshman, 2016; Pajares, 1992), and furthermore, influence to some extent how students use resources in mathematics learning (McDonough & Sullivan, 2014). Secondly, a widely cited literature suggested that "*beliefs are often held in groups or clusters*" (Green, 1971), which is to say that beliefs present the perceptions of groups of people rather than an individual. In this study, it naturally clusters people by countries to compare the differences and similarities of students' resource use in England and Shanghai. The beliefs held by English and Chinese people reflecting cultural differences may be helpful to understand the differences and similarities of the resource use between the two places.

In this study, belief is simply defined as "a firmly held opinion". Pajares' (1992) description of various explanations of beliefs in educational research shows the following: *defining beliefs is* *at best a game of player's choice. They travel in disguise and often under alias-attitudes, values, judgments … opinions, ideology, perceptions, conceptions ... perspectives, repertories of understanding, and social strategy, to name but a few that can be found in the literature (p. 309).* This study uses the synonyms (e.g. values, opinions, and perceptions) interchangeably but emphasizes two characteristics of belief: it is difficult to change and it reflects the perceptions of a group of people.

Particularly, this study examines ***beliefs*** in the following aspects: 1) the authority of textbooks in mathematics learning, 2) doing mathematics exercises, 3) the pressure of examinations, especially in mathematics, and 4) the attribution of success and failure in mathematics learning are investigated in this study. Many documents and research evidence show that there are differences in those beliefs between Chinese culture and Western culture, which could influence teaching and learning practice in mathematics, possibly including students' resource use.

For ***the authority of textbooks***, some researchers pointed out the differences in its cultural contexts between East Asia and the West. As mentioned in Wong's study (2006) on the instructional practice of mathematics in Confucian Heritage Culture, there was always a right way (i.e. to follow "certain" rules) to do anything in Confucian beliefs, which was also significant in learning. Biggs (1994) noted that the belief of one right way pervaded instructional practice in Chinese understanding. Hence, effective teaching should offer students a standard path to follow in solving problems. In mathematics, people believe that textbooks always present the most elegant and simplest, namely, the best way in solving problems, while the diversity of solutions is also emphasized in instructional practice (Wong, 2006). Therefore, the crucial role of textbooks in mathematics teaching and learning is obvious in Chinese culture. Moreover, a comparative study of mathematics textbooks of China, England, Japan, Korea, and the United States (K. Park & Leung, 2006) showed that students in many East Asian countries heavily relied on textbooks in order to pass the public examinations to enter the next schooling stage, because of the adherence of their textbooks and examinations to the national curriculum, in which case the textbooks could be regarded as the "bible" of teaching and learning. However, in the United States and England, textbooks did not have the absolute authority in didactical situations. Teachers employed textbooks as a reference and often adopted other materials in their teaching. In fact, what contrasts more with the positive image of textbooks in Chinese beliefs is the recent anti-textbook atmosphere in England as mentioned in the literature review. The anti-textbook phenomenon indicates that people will doubt teachers' ability in teaching if they follow the instructions posed in textbooks. Therefore, a great difference exists in the cultural beliefs about the authority of textbooks between China and England, which can influence students' use of textbooks in their learning of mathematics and should be considered as a potential factor in this study.

Doing exercises can be seen as an essential activity incorporating various resources in students' learning of mathematics. For beliefs about doing exercises, Li, a mathematics education scholar at East Normal University in Shanghai, revealed the meaning and cultural sources of the Chinese belief of "practice makes perfect" (Li, 2006). He pointed out that mathematics educators in the West put more emphasis on the creative aspect of mathematics and considered practice as imitative and dull manipulation in mathematics learning. Western educators believed that doing exercises made the procedures fixed, hence they suggested that teachers should help students internalize procedures and concepts before encouraging repeated drills (Hiebert & Carpenter, 1992, pp. 78–79). However, in China, the idiom "practice makes perfect" is a consensus in mathematics learning. As elaborated in Li's study, many mathematics teachers as well as students believe in the idiom and treat it as an important principle in mathematics learning. There is evidence showing that doing exercises is not only the imitative manipulation of fixed rules but also an efficient way that helps students better understand concepts and procedures (S. Li, 1999). Also, according to the literature review, Leung's (1995) study of mathematics classrooms in Beijing, Hong Kong, and London summarized that Chinese were known to attach greater importance to practice and memorization compared to the West, which did have some implications for the differences in lesson structure between those places. Moreover, Fan et al.'s (2004) study of textbook use in China indicated that all teachers participating in their investigation used "drill" problems posed in the mathematics textbook for in-class exercises and most teachers (81.8%) assigned homework for students from the "exercise" section of the textbook, which in turn suggested that the underlying belief about doing exercises in mathematics learning could influence students' use of textbooks, workbooks, and other resources designed for practice.

The idea of investigating the belief about ***the pressure of examinations*** is extended from the distinct views of practice between East and West. Though achieving a "perfect" score in mathematics is seen as a parochial goal from the perspective of mathematics educators, it is grand enough to students in their learning of mathematics at the schooling stage. Hence, the high pressure of examinations could be a reason why students have to do so much practice incorporating a variety of learning resources in mathematics. The tradition of success in high-stake examination changing one's life has pervaded China for more than 2000 years. The first national examination system was established in the Sui Dynasty (AD 581–604) to recruit and select intellectuals for imperial government. The success brought wealth and honour to the whole family, which was regarded as the only way to improve people's social status. Scholars shouldered the expectation of their family and often endured unimaginable pressure in the process of learning. The imperial examination system was abolished with the vanishing of the last feudal dynasty in 1912. However, in modern China, the national examinations at the schooling stage play the role of the main selection standard for entering schools, colleges, and universities with a good reputation, which also adheres to one's future including career, wealth, and social status This forces students to pursue good scores in examinations, and teachers are often valued by parents for their students' performance in examinations (Leu & Wu, 2006), which implies that not only do learners bear the pressure, but also teachers and even parents. However, in England, the national examination has not been the only standard of intellectual selection. Recommendation was the main way to nominate someone as officials working for the royal court in ancient time. At present, the results of national examinations at the schooling stage is one of the qualifications for entering higher education. The entry requirements of different universities are often varied. In addition to the qualifications of previous study, students also need to provide personal statements and relevant references demonstrating their skills and experience that enable them to succeed at universities. In fact, the selection system determines which learning activities students are mostly involved in and how students spend their out-of-school time to some extent. Students with high pressure of examinations may pay more attention to practice and revision related to various learning resources such as notebooks as mentioned earlier, while if results are not the only standard demonstrating one's learning achievement, students may feel less stressed and spend more time on other learning activities such as participating in practical projects as an apprentice. Therefore, their different beliefs about the pressure of examinations might lead to the variation of students' resource use in many aspects (possibly including the frequency, timing, duration, purposes, and motivations behind using a resource) between the two places.

Furthermore, beliefs about ***the attribution of success and failure*** are related to how students view their performance in mathematics learning as well as examinations, which can be considered as an explanation of their study beyond teachers' instructions and textbooks. In the literature review, Leung summarized that Chinese were more likely to attribute one's successes and failures to controllable factors such as effort and believed that the process of study was an accumulation of hard work rather than enjoyment, while western people emphasize the importance of ability and interests in mathematics learning (Hess, Chang, & McDevitt, 1987; H. W. Stevenson, Chen, & Lee, 1993; Weiner et al., 1987). Chinese attribution deemphasizes individual differences (e.g. ability) in learning, which implies a basic principle of education, namely, to reduce the possible distance among students (Y. Zheng, 2006). They view hardship as a virtue in study and believe that hard work can help them develop concepts, solve difficult tasks, and make up for the lack of natural ability that causes the "distances" among students (J. Li, 2004). The efforts often involve the use of various learning resources possibly including reference books, worksheets, and e-learning systems. On the contrary, western attribution stresses individual differences, which may lead to a greater variation of resource use among English students since their use of learning resources is dependent on individual ability and driven by personal preference in their after-school learning activities.

Overall, every respect of the possible factors (see Figure 10) is constructed to explain the students' use of learning resources with the consideration of local contexts. The factor of out-of-school lessons is about the time devoted to mathematics courses after school. Parental involvement measures the frequency with which parents participate in children's mathematics learning. Teachers' instruction is defined according to the indicators of students' use of learning resources, in which way teachers' instruction is connected to the resource use specifically. Beliefs about the authority of textbooks, doing exercises, the pressure of examinations, and the attribution of success and failure can impact resource use directly or indirectly, which is rooted in cultural background.

Social factor

- *Out-of-school lessons*
  - time spent on math-related classes after school
  - time spent on tutorial
- *Parental involvement in mathematics learning*
  - the frequency of checking/ discussing children's learning progress
  - the frequency of assisting with homework
  - the frequency of providing extra exercises
  - the frequency of buying learning resources

Didactical factor

- *Teachers' mediation*
  - the learning resources that teachers ask students to use during the instruction
  - the frequency and
  - duration with which teachers' instructions incorporate students' use of learning resources
  - the timing in which learning resources are supposed to be used according to teachers' instruction
  - the way students are guided by their teachers to gain access to learning resources
  - the purposes and
  - changes in teachers' instruction involving students' use of learning resources.

Cultural factor

- *Beliefs about the authority of textbooks*
- *Beliefs about doing exercises*
- *Beliefs about the pressure of examination*
- *Beliefs about the attribution of success and failure in study*

Figure 10 Factors that may influence students' use of learning resources

3.2.4 Summary

The construct of "learning resources" stresses the form of presenting information and highlights the learners' perspective by distinguishing the resources for learning from the resources for teaching. Therefore, the classification of various types of learning resources is based on the information carrier, namely, paper/electronic. Specifically, the definition of different paper-based learning resources takes the existing and well-known forms, such as textbooks, into account, while the definition of e-resources is thoroughly based on the forms of presenting information, such as e-books, which present information in the form of a book, instead of the electronic devices.

The construct of resource use is an explanation of the relationship between students and learning resources and the definition of every indicator of the use is about how the interactions are embodied in this study. The use of learning resources is conceptualized based on Activity

Theory and constrained to mathematics at the schooling stage. The indicators include three measures related to time, namely, the frequency, timing, and duration of resource use; two aspects about the reasons of resource use, i.e. purpose and motivation; and three other aspects, including the access to learning resources, the change in resource use compared to the previous academic year, and the influences of resource use on mathematics learning.

The construct of factors that may influence students' use of learning resources in mathematics is a result of the literature review as well as a reorganization and refinement of Rezat and Sträßer's socio-didactical tetrahedron. Specifically, the social, didactical, and cultural factors originate from the model, and are considered as possible explanations of students' use of learning resources here since teachers' mediation, parental involvements, out-of-school lessons, and cultural beliefs are the "external" environment that students are supposed to adapt to in their learning of mathematics; in other words, students' use of learning resources might be shaped by them.

In short, the constructing starts with the conceptualizing of learning resources, followed by a definition of students' use of those resources in their mathematics learning based on Activity Theory, which implies that the *student–learning resource–mathematics* triangle comes into focus. Finally, the factors influencing students' use of learning resources are extracted from the known literature related to mathematics teaching and learning for better understanding students' resource use and the differences and similarities between England and Shanghai. Therefore, the *student–learning resource–mathematics* triangle, surrounded by the possibly contextual influences including didactical, social, and cultural aspects, constitutes the conceptual framework of this study as shown in Figure 11.

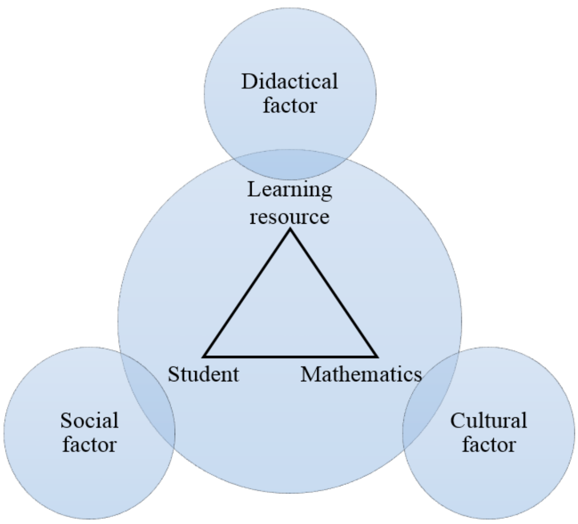


Figure 11 The conceptual framework of this study

Chapter 4 Educational Contexts

Before carrying out the research on students' use of learning resources in Shanghai and England, it is essential to present a description of the educational contexts of the two places based on the emphasis on the close relationship between education and the environment that it takes place in. In the previous chapter of constructs, contexts are considered as the explanatory factors of students' resource use in mathematics, while this chapter discusses the contexts at a broader level, which provides a background for a comparative study on education concerned with mathematics learning between the two places. Specifically, four aspects in regard to the educational environments in Shanghai and England are introduced in this chapter, including geography and demography information, education systems, school systems, and curricula.

4.1 Basic information and statistics

Shanghai

Shanghai is a municipality of China, which is one of the four types of first-level divisions (the other three are province, autonomous region, and special administered region) that are directly administrated by the central government. Located at the mouth of Long River Delta, Shanghai was the centre of the country in terms of cotton textile in the 16th century and was developed as a trading port from the 19th century onwards. Currently, it is the most modern and cosmopolitan city in China, with a population of about 24 million (in 2016) and an area of 6,340 square kilometres composed of 107 townships in 17 administrative counties. As the central trading hub and the financial centre of China (Y. Huang, 2009), Shanghai plays the role of a pioneer in deepening the market-oriented revolutions, in which case it serves as a testing ground in terms of many kinds of reforms, including education, and has become one of the most developed regions in China (Pan, Vayssettes, Fordham, & Yang, 2015). Specifically, its gross domestic product (GDP) in 2015 was nearly 366,000 million US dollars and the product per capita was about 15,120 US dollars, which contributed approximately 3.7% GDP with only 1.75% population in 0.06% area of the whole country (National Bureau of Statistics of China, 2016; Shanghai Bureau of Statistics, 2016).

England

England is a country of the United Kingdom, which is one of the four top-level divisions (the other three countries are Wales, Scotland and Northern Ireland) that have the national government in Westminster and also devolved parliaments, assemblies, and governments in Edinburgh (in Scotland), Cardiff (in Wales) and Belfast (in Northern Ireland). In this case, there is not a devolved administration for England in terms of governance. Separated from continental Europe by the North Sea to the east and the English Channel to the south, England is near France at a distance of only 34 kilometres. It used to be highly industrialized in heavy and manufacturing industry whereas this transformed to a service industry-oriented economy from the 1970s onwards (Reitan, 2003). Nowadays, England is the largest economic entity in the United Kingdom with a population of 53.5 million (in 2016) in an area of 132,938 square kilometres composed of 27 administrative counties and 56 unitary authorities (Kellner & Thomas, 2016), and has about 100 out of Europe's 500 largest corporations in the world's leading financial centre, namely, London (J. Harris, 2015). Specifically, its gross domestic product (GDP) in 2015 was 1,963 billion US dollars and the product per capita was 36,692 US dollars, which contributed about 84% GDP with approximately 84% population in more than half (53.5%) the area of the whole country.

Table 2. Basic statistics of China, Shanghai, UK and England

	Population (2016) (millions)	Area (km^2)	GDP (2015) (millions USD)	GDP per capita (2015) (USD)
China	1,383.7[1]	9,600,000	10,035,858[1]	7,251
Shanghai	24.2[2]	6,340	365,916[2]	15,120
UK	63.7[4]	248,531	2,288,595[3]	35,928
England	53.5[4]	132,938	1,963,000[5]	36,692

1. Source: http://www.stats.gov.cn/tjsj/ndsj/2016/indexch.htm
2. Source: http://www.stats-sh.gov.cn/data/toTjnj.xhtml?y=2016
3. Source: https://www.ons.gov.uk/economy/grossdomesticproductgdp/timeseries/abmi/pgdp
4. Source: http://webarchive.nationalarchives.gov.uk/20160105160709/http://www.ons.gov.uk/ons/guidemethod/geography/beginner-s-guide/administrative/the-countries-of-the-uk/index.html
5. Source: https://en.wikipedia.org/wiki/List_of_country_subdivisions_by_GDP_over_100_billion_US_dollars#cite_note-3

4.2 Education systems in Shanghai and England

Since a formal education system is established or organized by national governments, it is necessary to start introducing the educational systems from political evolution and historical changes with respect to public education in mainland China and the United Kingdom.

China and Shanghai

China, with almost 260 million students and over 15 million teachers in about 508 000 schools excluding graduate institutions, has the largest education system in the world (National Bureau of Statistics of China, 2016). The education system in China is state-run, with little involvement of private sponsors, and is increasingly decentralized (Pan et al., 2015). The local commissions take the responsibility for management and financial issues related to education.

Ancient China had a long history of valuing education and high-stake examinations to select talent for the royal court. The modern education system was set up at the same time as the establishment of the People's Republic of China in 1949, and due to historical and political reasons, it introduced a national curriculum and instructional materials based on the educational system in Soviet (Tan, 2012b). The system carries out pre-school education, primary education, secondary education, and higher education, and enforces free nine-year compulsory education involving primary and junior secondary stages in state-run schools, which means that all the eligible children are supposed to receive primary and junior secondary education for at least nine years, and there should not be entrance examinations or selection in maintained schools at these stages. Moreover, since 2015, the central government has bought textbooks of all the subjects prescribed by the national curriculum for every student studying at state schools in compulsory education. Beyond compulsory education, students can choose to take the senior secondary school entrance examination (i.e. *Zhongkao*) for entering different senior secondary schools (there are general schools and vocational schools), and then the college entrance examination (i.e. *Gaokao*) for entering different colleges and universities. Continuing education and vocational education are included within the system as well. The nation encourages the development of further education and life-long learning.

For schools and institutions, the state and provincial authorities formulate the policies, development plans, and budget allocation, and they directly run most of the higher education institutions. Parents highly trust state-run schools in terms of the quality of education and they scramble for housing around the "famous schools" so that their children can be assigned to the schools, as the entrance principle at the compulsory stage is "proximity" (school-age children are randomly assigned to schools near to their home). This tendency even creates an economic phenomenon in some places called "school district housing" (i.e. *Xue Qu Fang*), with the properties near famous schools always selling at high prices) in the property market. Also, the nation does encourage the public to run schools. In 2015, the proportion of non-state-run schools increased, from primary education to higher education. To be specific, non-state-run schools account for only 3.1% in primary education, 9.1% in junior secondary education, 19.3% in senior secondary education, and approximately 28.7% in higher education (National Bureau of Statistics of China, 2016). Therefore, most schools in compulsory education are run by local governments at various administrative levels under the supervision of the central government.

Therefore, for school types, the distinction between state-run and non-state-run is based on different sponsors of schools; the differentiation between regular/grammar schools and vocational schools in secondary education is to specify the educational content; and there is no need to classify schools with respect to students' gender as all schools in China are mixed schools (Frederick Koon Shing Leung, 1992). However, it is worth mentioning the different types of secondary schools in China in terms of the length of schooling because there is a natural division between lower and higher secondary stages based on compulsory education. Generally, there are five types of secondary schools according to the schooling stages they involve: junior secondary schools only contain lower secondary stage involved in compulsory education, while senior secondary schools only contain the higher stage; complete schools comprise both junior and senior secondary education; nine-year coherent schools include the whole compulsory education; and twelve-year coherent schools consist of the whole elementary education from primary stage to secondary stage.

Shanghai, with about 2.1 million students and 128 thousand teachers in 1,748 schools (Shanghai Bureau of Statistics, 2016), has one of the most developed elementary education systems in China. The Shanghai Education Commission is a provincial-level administrative department directly subordinate to the municipal government. The local responsibility and multi-level administration are the basic management mode as mentioned earlier; thus, there are education commissions at county-level and township-level as well. As the pioneer in the reforming trend, Shanghai is one of the earliest to popularize free nine-year compulsory education and it owns many well-known universities and schools at different education stages (Shanghai Education Commission, 2012).

Specifically, there are 764 primary schools, 790 regular and 98 vocational secondary schools, and 67 institutions of higher education in Shanghai, in which the proportions of non-state-run schools are 22.6% for primary schools, 14.8% for regular secondary schools, 5.1% for vocational secondary schools, and 31.7% for higher institutions. Specifically, at the regular secondary stage, there are 362 junior secondary schools, 141 senior secondary schools, 93 complete schools, 175 nine-year coherent schools, and 19 twelve-year coherent schools (Shanghai Bureau of Statistics, 2016).

UK and England

Unlike China's hierarchical management structure (every administrative level has a sector in charge of educational affairs under the higher authority's regulation.), the United Kingdom has a more decentralized education system at the country level. Overall, it provides five stages of education across the nation: early years, primary education, secondary education, further education, and higher education. Compulsory education covers the primary and secondary stages from the age of 5 (4 in Northern Ireland) to 16 (the Department for Education, n.d.) and is free in state-run schools.

In fact, the "national education system" in the United Kingdom refers to the education system in England, the reason for which can be traced back to the establishment of the nation. The creation of the United Kingdom was a process of cultural amalgamation that took over 400 years (Hamilton & Weiner, 2003). Wales, Scotland, and Ireland were united with England in the 15th century, 17th century, and the beginning of the 19th century, one after the other. However, Ireland was divided into Northern Ireland (remaining in the United Kingdom) and the Irish Free State that was an independent state after the Anglo-Irish Treaty of 1921 (Hamilton & Weiner, 2003). At that time, there existed four educational systems in the British Isles, one each for England, Wales, Scotland, and Northern Ireland (Bell & Grant, 1978). Parliament in London could pass laws for different systems, which were administrated by local interests in Edinburgh, Cardiff, and Belfast (Hamilton & Weiner, 2003). Then due to political reasons, the legislative power of education was diverted from London to Edinburgh and Belfast in the 1990s. In other words, the British Council could no longer determine the curriculum in Scotland and Northern Ireland. Wales did not establish its local parliament until 1999, which means that the national education is statutory in England and Wales, but Wales is independent to some extent (Sun, 2003). This is to say that central government is only responsible for England's education system, which explains why the Department for Education claims that the national curriculum is for all local authority-maintained schools in England, not for any other regions. Thus, when it comes to the education of the United Kingdom at a national level, it indicates that all the relevant issues are only applicable to England.

England, with almost 8.6 million students and 478 thousand teachers in more than 24 thousand schools excluding higher education in the academic year of 2015 to 2016, (UK Government, 2016a) has the most complex school provision, since the types of schools involving different year groups can vary from one local authority to another (Ministry of Defence, 2013). For Early Years education, all three- and four-year-old children are eligible for 15 hours of free nursery education for 38 weeks a year. After that, school-aged children are entitled to a place at state primary schools near their home. The same as primary school admission, children can apply for a secondary school in their local area. Students are qualified by the General Certificate of Secondary Education (GCSE), which was introduced into UK in 1988 to replace O-Level (General Certificate of Education Ordinary Level) and CSE (Certificate of Secondary Education) examinations, and can be seen as the compulsory school-leavers' assessment provided by the government. Based on the results of GCSE and other demonstrations, students may go further to obtain advanced schooling qualifications, such as A-Level (General Certificate of Education Advanced Level) and BTEC (Business and Technology Education Council), in sixth form colleges, which are the fundamental reference for entrance to higher education.

For types of schools in England, there can be numerous methods of categorizing schools according to different criteria, such as if the school provides boarding for students and if the school has a particular religious course. The types of schools discussed here involve three taxonomies: the classification in terms of schools' sponsors, the classification based on whether the school has to follow the national curriculum, and the classification based on whether the school selects students according to their academic ability. Firstly, schools are normally funded by either local councils, the central government, the public (e.g. business, charities, and universities) or are private. In general, grammar schools and community schools are funded by local councils, free schools and academies are directly funded by the government, but some academies have sponsors from the public, and city technology colleges are funded by the public and the central government at the same time; thus, these schools are free for all students, and only private schools have their own operators and charge for tuition fees. Secondly, academies and free schools get money from the government but retain considerable autonomy, which means that they can have their own timetables and school curricula like private schools, while all other schools have to follow the national curriculum. Finally, when it comes to academic selection, only grammar schools and private schools can organize admission tests even at the compulsory stage (UK Government, 2016c).

In 2016, most schools are state-run without regard to the tertiary education institutions. Specifically, there are nearly 6000 academies and more than 10,000 community schools, which account for 60% of schools in England. While only 403 are free schools, 247 are further education colleges and 89 are sixth form colleges, the total proportion of these three types of school is about 3%. Also, there are 2485 private schools with a proportion of approximately 10%. The remainder is constituted of other types of schools, such as voluntary schools (UK Government, 2016a).

4.3 School systems in Shanghai and England

As mentioned earlier, the education system in China has been increasingly decentralized in recent years. Shanghai is one of the particular regions that enjoy great autonomy in education, which has a school system different from the national school system at the compulsory stage. England's system does not have a division between junior and senior stage in secondary education, which results in difficulty comparing the schooling years between England and Shanghai. Also, the two places adopt completely different modes in terms of the length of schooling in post-compulsory education and higher education as well. Therefore, this section briefly sketches the particularity of Shanghai's school system and specifies the schooling period of each education stage in Shanghai and England.

Shanghai

Children usually enter pre-school education at the age of three and four and leave kindergarten at five and six. Then most students in China spend six years in primary schools and three years in junior secondary schools while some places adopt a five-year circle at primary stage and four-year circle at junior secondary stage. Shanghai is one of the few regions that use the "five and four" school system in compulsory education. In fact, Shanghai once implemented the "six and three" system and experienced frequent changes in the school system after the 1970s. In

1985, Shanghai tried to shorten the length of schooling at primary stage in order to cope with the conflict between massive numbers of school-aged children and insufficient places at primary schools. Thus, the period at primary stage was cut down to five years and the sixth year was integrated into junior secondary stage. The “five and four” school system was enforced across the city in the year of 2004 (Shanghai Education Commission, 2004). After finishing compulsory education, students can choose to continue their study in senior secondary schools for three years. The senior secondary schools in China can be simply divided into two categories: one is general senior secondary school and another is vocational senior secondary school; the latter includes technical or specialized secondary schools, adult secondary schools, and craft schools (Pan et al., 2015). Though the senior secondary stage is not included in free education, the Shanghai Education Commission provides free places in selected specialism and schools every year to encourage students’ participation in vocational education (Shanghai Education Commission, 2016). Then the schooling period in higher education can be varied in terms of different disciplines. Normally, students spend four years to obtain bachelor’s degrees, three years in the master’s programme, and another three years in the PhD programme for the highest degree that a student can be awarded.

England

The school system in England starts from pre-school stage at the age of three or four. After staying in nursery for one or two years, children enter primary school at the age of five. England adopts a six-year circle at the primary stage. Children usually leave primary school at the age of 10–11. Then students study in secondary school for five years and end compulsory education at the age of 15–16. There are three choices for 16 to 18-year-old teenagers who finish compulsory education: stay in full-time education, become an apprentice or trainee, or spend 20 hours or more a week working or volunteering while in part-time education or training (UK Government, 2016b). If students choose to stay in full-time education at a college, they will spend two years in an advanced study system, such as A-levels, and take examinations to qualify for studying in different specialisms at universities. Higher education in England includes a three-year undergraduate stage, then a one-year taught master’s programme or two-year research master’s programme, and a four or more-year PhD programme.

Table 3. School system in Shanghai and England

Education stage		Age	Shanghai Grade level	England Year	Education Stage	
--		5-6	--	Year 1	Primary	Compulsory (eleven years)
Compulsory (nine years)	Primary	6-7	Grade 1	Year 2		
		7-8	Grade 2	Year 3		
		8-9	Grade 3	Year 4		
		9-10	Grade 4	Year 5		
		10-11	Grade 5	Year 6		
	Junior secondary	11-12	Grade 6	Year 7	Secondary	
		12-13	Grade 7	Year 8		
		13-14	Grade 8	Year 9		
		14-15	Grade 9	Year 10		
Senior secondary		15-16	Senior 1	Year 11		
		16-17	Senior 2	AS	A-level	
		17-18	Senior 3	A2		
Higher education		18-19	Study for a bachelor's degree	Study for a bachelor's degree	Higher education	
		19-20				
		20-21				
		21-22		Master programme (one or two years)		
		22-23	Master programme			
		23-24		PhD programme (four years or longer)		
		24-25				
		25-26	PhD programme			
		26-27				
		27-28				

4.4 Curriculum

The development of the curriculum in China began with a highly centralized national curriculum that avoided local variation and flexibility. After the national reform and opening up, regional economic disparities gradually increased, hence the central government encouraged contextual diversities in terms of curricula and textbooks under certain standards to meet local economic development. Nowadays, as one of the economic hubs in eastern China, Shanghai has developed a distinctive curriculum that fits its context, which includes a textbook series and a relatively independent examination system. England's education system is in the charge of central government as mentioned earlier, thus most maintained schools (except some academies and free schools) in England are supposed to follow the national curriculum. Therefore, for Shanghai, this section firstly summarizes the curriculum reforms in China and then elaborates Shanghai's situation, whereas for England, only the national curriculum, namely, England's curriculum, is introduced.

China and Shanghai

The new China experienced eight curriculum reforms since its establishment (Qiao, 2012; Xie, Ma, & Zhang, 2013; Yang, 2011; D. Zheng, 2005). With the emergence of a new regime, the government unified the curriculum and all the instructional materials at a national level. Then after disastrous damage during the period of the "Cultural Revolution" (1966–76), the reconstruction of the education system began in the late 1980s and expanded in the following decades. The national economic transition period (since 1986) demanded a high consistency between education and economic development. The following reforms aimed at combining societal needs, student development, and school subjects into an integrated curriculum (Tan, 2012b). Also, the "Compulsory Education Law of the People's Republic of China" (Ministry of Education of the People's Republic of China, 1986) was passed in 1986. Then China enforced compulsory education across the nation and allowed the publication of different teaching materials under a single national curriculum in the year of 1992 (Lianghuo Fan, Wong, & Cai, 2004, p. 41; D. Zheng, 2005). Currently, there are various numbers of textbook series in different subjects approved by the Ministry of Education for local authorities to choose from according to their own contexts.

In the later reforms, the Chinese government intended to cultivate students' innovative spirit and practical ability to improve their international competitiveness (General Office of the Communist Party of China, 1999). The advocacy promoted the development of "quality-oriented education", which held the educational philosophy of "helping students become the new youths who have ideals, knowledge, disciplines and moralities". Therefore, to implement innovation and reform, the state council decided to decentralize the power of curriculum construction and encouraged local governments to develop their own curricula since 2001. In this case, local governments enjoy a greater autonomy but have to pay more money to support their education sectors, which leads to a discrepancy between rich and poor regions. Currently, China employs a three-level curriculum management including national level, provincial level, and school level. At the national level, the Ministry of Education draws up the curriculum plan for primary and secondary education, develops regulations about curriculum management, and produces the national curriculum involving instructional timetables and subject content taught at each education stage. At the provincial level, local authorities either interpret and implement the national curriculum or develop their own curricula based on local situations. All the measures and plans are reviewed by the Ministry of Education and the public successively. At the school level, teachers are encouraged to organize their own courses and research projects while schools and local education sectors are expected to guide and support their work (Pan et al., 2015).

Shanghai was selected in 1997 to have its own curriculum as well as examination system (Lianghuo Fan, Wong, et al., 2004, p. 43). In fact, the "Committee for Reforming the Curriculum and Textbooks at Primary and Secondary Schools" was set up in Shanghai earlier and the local curriculum was proposed in 1991 (R. Huang, 2002). Echoing the tendency of "quality-oriented education", the Shanghai curriculum was revised in 2001, (Curriculum Reform Committee of Primary and Secondary schools in Shanghai, 2001) and publicized in 2005. The curriculum is sorted by education stages, covering primary stage (grade 1 to grade 5), junior secondary (grade 6 to grade 9) stage and senior secondary stage (grade 10 to grade 12), and consists of three types of courses: ordinary courses that present the basic requirements of elementary education, advanced courses that are aimed at cultivating students' learning interests and the ability of self-improving, and research courses that develop students' creative spirit by organizing research activities. The framework comprises eight learning fields: language and literature, mathematics, social science, science, technology, physical education and fitness, art, and comprehensive practice, which involve more than twenty disciplines. Also, the curriculum stipulates lesson hours and periods for each grade and provides a guideline for curriculum implementation, textbook compilation, and curriculum assessment and management.

England

English governments had the awareness about safeguarding the equal education rights of children early (the government passed "Forster Act" for compulsory education in 1870) but published its first national curriculum late, in the year of 1989 (Gillard, 2011; Sun, 2003). Shortly afterwards, people realized its overload in terms of content and structure, especially at primary stage. Therefore, central government adjusted the national curriculum in 1991 by reducing the learning objectives of some disciplines. Then the second simplification happened in the following years and the government issued the second revision of the national curriculum in 1995. With the coming of the new century, central government enacted a new curriculum in 1999 and implemented it in the following year. It further slimmed down the prescribed content and detailed the aims and purposes in an extra handbook for teacher to understand the national curriculum (Children, School and Families Committee, 2009). Then the curricula for the secondary stage and the primary stage were separately reviewed with the aim of cutting down the content and emphasizing cross-curricular themes in 2005 and 2007 one after another. The latest curriculum reform was announced in 2011, which attempted to improve students' international competition based on their performance in PISA 2009. After two formal consultations with its expert panel, central government released finalized national curriculum documents in 2013, which were to be implemented in September 2014 (Roberts, 2016). The government claimed that the new curriculum was not a guide for teachers to teach but a document of the essential knowledge and skills for children to know, in which case teachers were given great freedom to shape and personalize the curriculum to meet their students' needs.

Though the parliaments of the United Kingdom enacted and revised the national curriculum many times since 1989, it never mentioned the issues relating to textbooks; in fact, there have been no official textbooks all the way. The writing, publishing, and use of textbooks do not need any approval from the government, which is a tradition at all ages. It means that anyone can publish textbooks once they gets commercial support from publishers (Sun, 2003).

The current national curriculum covers primary and secondary education from age 5 to age 16, which is organised by blocks of years named "Key stages" as shown in Table 4. The compulsory subjects at key stage 1, 2, and 3 are English, maths, science, design and technology, history, geography, art and design, music, physical education including swimming, computing, and ancient and modern foreign languages (at key stage 2), and citizenship (at key stage 3). Most students at key stage 4 must prepare for the national qualification: GCSE (General Certificate of Secondary Education), thus the compulsory subjects are only English, maths, science, computing, physical education and citizenship; schools usually offer other subjects as supplements according to different contexts. Also, religious education must be provided at all key stages but parents can decide whether their children attend the lessons.

Table 4. Key stages in England national curriculum

	Key stage 1	Key stage 2	Key stage 3	Key stage 4
Age	5-7	7-11	11-14	14-16
Year group	1-2	3-6	7-9	10-11

4.5 Summary

Though differences exist in demography and economic level between Shanghai and England, both of them are in the top-level administrative divisions and are supposed to be or have the most developed region of the country. Thus, they are relatively comparable from the perspective of administrative level and urban development.

For education and school systems, China and the United Kingdom employ a similar structure that involves pre-school stage, compulsory stage, post-compulsory stage (i.e. senior secondary schools in China and sixth form colleges in UK) and higher education, though the school age and schooling period in each stage are slightly different between the two countries; for instance, China runs a nine-year free compulsory education while the UK's is eleven years.

For curricula, the national curriculum in China and the UK have experienced a series of reforms with various purposes, such as to improve students' international competitiveness, since they were first issued and published. Shanghai enacts its own curriculum with an assorted series of textbooks based on the national curriculum framework. Meanwhile, England is the only region that is required to follow the national curriculum in the United Kingdom, and the curriculum is just a basic standard that ensures that students learn the same content rather than a guideline for teaching, in which situation teachers and schools in England enjoy greater freedom in their teaching compared to Shanghai.

Chapter 5 Research Design and Procedures

This chapter introduces how the research is conducted based on the conceptual framework discussed in chapter 3. It includes a rationale and introduction of the whole research design, the descriptions of sampling and research instruments, the explanations of data collection, processing and analysis, and a reflection of the methodology.

5.1 Research methods

Lynn et al. (2009) examined 710 research articles in mathematics education published in six prominent journals from 1995 to 2005 and found that 50% of the studies employed qualitative methods, 21% used quantitative methods, and 29% mixed the two methods. It implies a preference of research methods in mathematics education during the decade, namely, qualitative methods. Nevertheless, the integration of quantitative methods and qualitative methods has become increasingly common in the last decade (Bryman, 2006). Knowing the efficiency of qualitative approaches in interpreting instructional situations, researchers and policymakers have also noticed the advantage of involving quantitative approaches. For example, some significant funding agencies in the United States have been calling for statistics-supported findings that can provide more generalizable results (National Council of Teachers of Mathematics Research Advisory Committee, 2003). This section illustrates why a mixed method is appropriate to achieve the research objectives of this study and how quantitative and qualitative methods are mixed.

Why a mixed method

Tashakkori and Teddlie (2010) emphasized the influence of research aims and questions on the selection of research methods. This study is mainly to portray the way that students use learning resources in mathematics, which is descriptive research in terms of the objectives of a study (Kothari, 2004). In other words, there is not enough information about the reality, and this research aims at drawing a picture of how students from England and Shanghai use learning resources in mathematics. The reasons for employing quantitative methods include, firstly, the fact that resource use as a behaviour can be quantified or standardized to a certain extent; and secondly, the consideration of the generalization of results at a regional level, as it is an international comparative study.

However, reasons behind the similarities and differences in students' resource use may not be straightforward or exhaustively listed in a standardized way. In this case, the involvement of qualitative methods makes up the details and helps the research go beyond the existing information that has been generated as indicators to some unknown areas of the reality, such as the specific relations between the contextual influences and the use of a learning resource.

As Schoenfeld (2002) said in Handbook of International Research in Mathematics Education, "*it is difficult to strive toward both depth and breadth simultaneously. Yes, they are both necessary*" (p. 475). It shows the importance of balancing the two methods for deeply understanding a particular educational phenomenon and for broadly generalizing the findings at the same time. This study tries to make a generalization to investigate students' use of learning resources in Shanghai and England and to go in depth to understand the factors influencing students' resource use, which finally makes a mixed method the best choice.

How they are mixed

Leech and Onwuegbuzie (2009) came up with a three-dimension typology, which classified the mixed method design into eight categories according to three dual sets: *(1) level of mixing (partially mixed versus fully mixed); (2) time orientation (concurrently versus sequentially); (3) emphasis of approaches (equal status versus dominant status)*. With this classification, the research design of this study can be described as a "fully mixed concurrent dominant status design". The design for answering the three research questions is shown in Table 5.

Table 5. Research design

Research Question	Data collection	Data analysis
How do students use learning resources?	QUAN+qual	QUAN+qual
What are the similarities and differences between Shanghai and England?	QUAN	QUAN
What are the factors that influence the use?	QUAN+QUAL	QUAN+qual

Note: "quan" and "qual" stand for quantitative and qualitative respectively. Capitalization indicates a weight or priority on qualitative or qualitative instrument, data, analysis and interpretation in this study.

Quantitative methods dominated the process of measuring the frequency, timing, and duration of resource use, and the documenting of the purpose, motivation, and change in resource use, the access to learning resources, and the influences of students' resource use on their mathematics learning, which reflected the ways, reasons, and results of students interacting with the learning resources from different facets. At this stage, the involvement of qualitative methods was to check the reliability of quantitative data and supplement the details regarding the change in students' resource use. After that, a statistical integration and comparison of the quantitative data collected at the early stage were to address the similarities and differences between Shanghai and England; additionally, to examine whether the defined factors influence students' resource use, the data were collected in both quantitative and qualitative ways. For the purpose of generalization, it is necessary to include quantitative approaches, but the relationship between the contextual factors and students' resource use cannot be simply obtained with numerical data.

Thus, qualitative information was complementary to the quantified data as interpretations and clues to find the association between resource use and the presupposed factors at this stage.

5.2 Sampling

The main subjects of this study are secondary school students from Shanghai and England. To take into account the contextual factors, teachers and parents are also involved in this research. The sampling for collecting data from teachers and parents as well as the sampling for collecting qualitative data are nested in the sampling of main participants, since those are the samplings of additional people and events to create an in-depth understanding of students' interactions with learning resources in different contexts (Onwuegbuzie & Leech, 2007). Therefore, this section firstly introduces the main sampling while the nested samplings are elaborated in the following section along with the specific instruments.

Multi-stage cluster sampling is an efficient way of collecting data when it is either impossible or impractical to compile an exhaustive list of sampling units (Fink, 2003). In this research, it is impractical to list all secondary school students for a random sampling while the sampling units (students) are naturally organized, firstly in classes, and then in schools. The decision of sample size should consider two aspects: one is statistical consideration, such as sampling error and confidence interval, and another is practical feasibility, such as time limits and workload. Buckingham and Saunders (2004, p. 114) provided De Vaus's (2002, p. 81) estimation of sample sizes required to achieve a 95 per cent confidence level with varying degrees of precision (see Table 6).

Table 6. Sample sizes achieving a 95% confidence level with varying degrees of precision

Sampling error (%)[1]	Sample size[2]
1	10,000
2	2,500
3	1,100
4	625
5	400
10	100

1. Two standard errors.
2. This assumes a 50/50 split on the variable.

Given the fact that a class contains about 40 students at most, it seems hard for one researcher to survey more than ten classes in either Shanghai or England. Therefore, this study accepts a sampling error of 10 per cent. In this case, the sample size should be more than 100 so that it is 95 per cent assured that the proportion of students who use learning resources in the way investigated by this research is a certain percentage, plus or minus 10 per cent. About six classes could make up a reasonable workload and guarantee the sample size at the same time, which were arranged in three secondary schools in each place.

The first stage is to sample schools in Shanghai and England. However, different types of schools (e.g. public schools, state-run schools, and private schools) have different ways of operating and different modes of teaching and learning in various degrees, especially in England (UK Government, 2016c). This study only involves state-run/maintained schools, which are funded by the government, since most of them follow general and uniform rules, e.g. admissions and courses, and the national curriculum.

The comparable grade levels are grades 7 and 8 in Shanghai and years 7 and 8 in England, since students at these year levels are in the same age group as mentioned in Chapter 4. Also, grade 6 is often seen as a transitional period between primary and secondary stage and grade 9 is taken as the start of preparing for the senior secondary school entrance examination in Shanghai, which seem less representative of normal teaching and learning practice and therefore are excluded in this study. Accordingly, the population of the first sampling stage was state-funded schools involving grades 7 and 8 in Shanghai and years 7 and 8 in England, and following the unified curriculum, which consisted of 587 secondary schools in Shanghai and 3381 secondary schools in England. The selection of schools was convenience sampling and three schools could make a reasonable sample in each place. The second stage was to select one class at each grade level in the sampled schools depending on teachers' willingness and agenda. The main subjects of this study were all the students in the sampled classes.

5.3 Instruments

This research employs six instruments, including student questionnaire, teacher questionnaire, parent questionnaire, classroom observation, student focus group interview, and teacher interview, to investigate how students use learning resources in mathematics and examine the factors influencing the use in England and Shanghai.

Questionnaire

Based on the conceptual framework and referring to the structure and expressions of background questionnaires in PISA 2012 as well as contextual questionnaires in TIMSS 2011, this study develops self-completed questionnaires for students, teachers, and parents respectively. As shown in Table 7, the student questionnaire includes basic information, uses of learning resources in mathematics, out-of-school study (i.e. out-of-school lessons and parental involvement), and beliefs about learning resources and mathematics learning. The teacher questionnaire consists of three parts: basic information, instructions incorporating students' use of learning resources, and beliefs about learning resources and mathematics learning. The parent questionnaire contains three parts: basic information, involvement in child's mathematics learning, and beliefs about learning resources and mathematics learning.

Table 7. The content of questionnaires

Framework	Student	Teacher	Parent
--	1. Basic information	1. Basic information	1. Basic information
Uses	2. General use, reasons, access, change 3. The influences of resource use on mathematics learning	--	--
Factors	4. Out-of-school study 5. Beliefs	2. Instructions 3. Beliefs	2. Involvement 3. Beliefs

The student questionnaire consisting of 20 questions can be found in Appendix A. To be specific, some basic information, such as schools, gender, and grade level, are needed to identify a response and to make an easy start for students to fill in the questionnaire. In parts 2 and 3, three questions correspond to the frequency, duration, and timing of students' resource use, which measure the time that students spend on learning resources. Two questions ask about the reasons for resource use: one is related to specific activities incorporating learning resources and reflecting the purposes of students' resource use in their learning of mathematics, and another integrates possible motivations for the resource use. Five questions inquire about other aspects of students' resource use: one refers to the way that students gain access to learning resources, one looks into the change in students' use of those resources, and the remaining three questions deal with the influences of using different resources on students' mathematics learning, specifically, corresponding to the helpfulness of the resource use in improving students' mathematics knowledge and skills, reasoning ability, and problem-solving ability respectively. The items and options of these two parts are intervals for the questions regarding the duration of resource use, ordinal for the questions about the frequency and the influence of resource use on mathematics learning, and nominal for all the other questions. It is worth mentioning that the question relating to the change in use contains two sub-questions: one is standardized to inquire whether there is any change in use of learning resources compared to the previous academic year, and another is an open-ended question that asks students to specify the changes and why they made the changes. Additionally, the Likert scale is employed to gather students' opinions about the influences of using different resources on their mathematics learning. The adoption of a five-item scale (e.g. not helpful, slightly helpful, somewhat helpful, helpful, very helpful) is to involve wider variations in terms of opinions compared to a dual scale (i.e. not helpful, helpful).

The fourth part contains two questions querying how many hours students spend on attending out-of-school lessons in mathematics per week, involving the time they spend on attending math-related lessons organized by commercial companies and studying with a private tutor after school, and four questions about parents' involvement in students' mathematics learning in terms of the frequency with which parents check children's learning progress in mathematics, assist with mathematics homework, ask them to do exercises not assigned by their teachers, and buy extra mathematics learning resources for them on their own initiative. All options for this part are ordinal items with time intervals.

The last part of the student questionnaire consists of four questions designed with statements of belief on the authority of textbooks, doing exercises, the pressure of examinations, and the attribution of success and failure in mathematics learning, which are also adopted by the teacher's and parent questionnaire as displayed in Table 7. A four-item scale (i.e. strongly disagree, disagree, agree, strongly agree) is employed to force people to take a stand on the given statements, which avoids the preference of ticking "safe" items by removing the neutral position.

For the teacher questionnaire (see Appendix B), the participants are those who teach mathematics to the sampled classes. In addition to basic information and the same beliefs about learning resources and mathematics learning as the last part in the student questionnaire, another four questions in the teacher questionnaire are to specify teachers' instructions in terms of the frequency, timing, and purpose for which they ask students to use learning resources, and the way they guide students to gain access to the resources.

For parent questionnaire (see Appendix C), the participants are those who have children studying in the sampled classes. Similarly, it contains the section of basic information, the same beliefs about learning resources and mathematics learning as the last part in the student questionnaire, and another four questions with interval items to investigate parental involvement in children's mathematics learning as the verification of students' answers.

Classroom observation

Classroom observation (see Appendix F) was employed to enrich what teachers and students reported in their questionnaires. All the teacher participants were asked if they were available to be observed at least for one lesson. The script focuses on 1) the learning resources that teachers mention during the instruction, 2) the frequency with which teachers' instructions incorporate students' use of each learning resource, 3) the duration with which teachers' instructions incorporate students' use of each learning resource, 4) the timing for which each learning resource is supposed to be used by students according to the teachers' instructions, 5) the ways that students are guided by their teachers to gain access to each learning resource, and 6) the purpose of teachers' instructions involving students' use of each learning resource.

Also, considering the reliability and Rezat's (2009b) criticism of self-completed questionnaires, classroom observation is also used as a triangulation of students' and teachers' reports about resource use in mathematics lessons. However, the data relating to students' use of learning resources after school cannot be observed in practice.

Focus group interview

Focus group interview (see Appendix D) was employed as a supplement to the student questionnaire to provide specific examples in terms of the impact of using different resources on students' mathematics learning, and the factors influencing students' resource use in the two places. All the students completing the questionnaire were asked if they would volunteer to participate in a further interview with the researcher and 5–7 peers. The sample of the focus groups was a random selection of the volunteers, and at least one group was assembled from each sampled class for the interview. Morgan (1996) pointed out that focus groups are particularly useful for orienting oneself to a new field, evaluating different research sites or study populations, and getting participants' interpretation of results from earlier studies. As mentioned previously, using only standardized options may not be enough to obtain a comprehensive view of the contextual factors, especially for the cultural beliefs, since all the given statements are extracted and generated according to literature, while the educational context is interwoven by many "invisible hands", which needs deep insight to dig out people's real thoughts and interpretations. In this case, focus groups can orient the researcher to the details of how the resources help students with their learning of mathematics, and the unknown area of the factors influencing students' resource use. The focus group protocol was developed with eight questions concerning the impact of using different learning resources on students' mathematics learning, parental involvement in children's learning of mathematics, attending out-of-school lessons in mathematics, and beliefs related to learning resources as well as mathematics learning, e.g. "What do you think about doing exercises in mathematics learning? What learning resources do you usually use for doing exercises and how do you use them?" Also, focus groups are more efficient than one-to-one interviews in this study as the subjects can exchange opinions, make comments on others, and negotiate their meanings (Puchta & Potter, 2004), which help young people form a clear view of the topic and encourage them to actively engage in interviews.

One-to-one interview

The participants of one-to-one interviews (see Appendix E) were the mathematics teachers of the sampled classes. As Kerlinger (1970) suggested, interviews are usually used to validate other methods, and to go deeper into respondents' reasons for their behaviours and views. In this study, teacher interviews are used as verification and are complementary to the questionnaire, which includes some overall perceptions (based on the class's performance) of the role of those resources in students' mathematics learning, e.g. "Overall, what do you feel about the importance of learning resources?", and teaching practice incorporating students' use of learning resources, e.g. "How did you teach mathematics last term? Compared to that, are there any changes this term in terms of the resources you ask students to use according to your instructions?", and the beliefs about learning resources as well as mathematics learning from teachers' viewpoints.

Validity and reliability

This design is based on the relevant literature, the researcher's knowledge about learning resources and the use of them, and two classroom observations in Beijing. The initial instruments were firstly reviewed by a colleague with the purpose of a language check, and then the main instrument (i.e. student questionnaire) was tested with nine Chinese students and one Chinese teacher to collect some basic opinions about how it could be improved and operated. Also, a more formal pilot was implemented during 17th July to 11th August 2017 to refine the instruments, which were conducted with five secondary school students and four mathematics teachers from Shanghai and England for testing the validity of the student and teacher questionnaires and interview protocols. It aimed to check whether the participants could understand every sentence and item, whether their understanding was exactly the same as it was supposed to be, and whether there were any inappropriate statements or descriptions in terms of the defined learning resources, measures, and reasons as well as other aspects of resource use, and the factors. The pilot took place in real life in England, involving two students and two mathematics teachers from four different secondary schools; all the students and teachers completed the questionnaires and participated in a one-to-one interview, and one student interview was audio taped. In Shanghai, the questionnaires including the questions relating to their understanding and opinions were sent to two teachers from the same school by email, and one of the teachers further helped me to find two volunteers in her class to complete the student part; moreover, one more student from another school was interviewed via FaceTime.

According to the results of the pilot, the learning resources posed in questionnaires were slightly different between the Shanghai and England surveys since all the teachers and students from England said that they did not have commercial workbooks (i.e. a book containing tasks and questions used by students for doing exercises, which is compiled and published by commercial companies). Instead, English teachers pose questions on the blackboard and their students write the questions down in a book with blank or ruled pages, which is called an "exercise book" in English. In other words, the "exercise book" used by English students is actually the book for both taking notes and doing exercises. Hence, there was no "workbook" and "notebook" in English questionnaires since they were integrated into one and called an "exercise book", while Chinese questionnaires still had "notebook" and "workbook" as they were different in Chinese understanding.

A research design with good reliability provides consistent results. Kothari (2004) specifies the two aspects of reliability, i.e. stability and equivalence. Stability is concerned with the repeatability of the same research instrument. It can be improved by standardizing the conditions under which the measurement takes place (p. 75). Equivalence is to consider the differences in research results caused by different investigators or samples. It can be improved by employing trained investigators and increasing the sample size (p. 75). In this study, the sample size has been maximized under the finite time and financial support, and the researcher is trained academically, which guarantees the equivalence to some extent. Also, multiple instruments adopted by this study, as the triangulation and complement to each other, are also aimed at improving research reliability.

5.4 Research ethics

Informed by the BERA (British Educational Research Association) 2011 ethical guidelines and the ethics policy of the University of Southampton, this study was registered on the University's Ethics and Research Governance Online (ERGO) system (with ethics number 27678) and the research design and all instruments were reviewed and approved by the committee. Access to participants was negotiated (Cohen, Manion, & Morrison, 2011) with schools, including headteachers, the mathematics departments, and mathematics teachers. Since the main participants in this study were students under 18 years old, the researcher's Disclosure and Barring Service (DBS) check relating to childcare was presented to schools at the first visit, and, as suggested by Diener and Crandall (1978), the teachers involved helped with explaining the research process printed on information sheets and consent forms to their students, so that they understood their role in the survey and recognized their voluntary role and their right to withdraw from the research.

Questionnaires along with information sheets and consent forms were distributed in envelopes and the participants' information collected by questionnaires were coded and identified solely by numbers so that anonymity could be assured.

Nevertheless, complete anonymity is not possible for interviews, since the participants would know each other in face-to-face interviews. Particularly, in focus group interviews, the participants were given paper to write down the information that they might not want to share, and told in advance that there were no right/wrong answers and if they felt worried about their answers, they could talk to the researcher privately later. The interviewees' information was also coded and identified solely by numbers so that no-one could be identified even by the researcher.

For classroom observation, the researcher and camera (where permitted) were set in the back of classrooms so that no students' faces were recorded. For anonymity purposes, participants' names (for instance, a teacher called students' names during a class) were deleted in transcripts.

The original video/audio records were stored securely in a password-protected hard drive and all paper-based data were kept in a locked drawer for confidentiality.

5.5 Data collection

In Shanghai, data were collected from 161 students studying in 6 classes in 3 state-funded secondary schools, 6 mathematics teachers who were in charge of teaching the sampled students, and those students' parents. The students contributed 144 valid responses (75 in grade 7 and 69 in grade 8) to questionnaires, and boys and girls were roughly even in the sample (73 girls, 69 boys and 2 unidentified). All the 6 teachers (3 were teaching in grade 7 and 3 in grade 8) completed questionnaires, of whom there were 4 female teachers and 2 male teachers. The parents contributed 152 valid responses including 89 replies from mothers or female guardians, 44 from fathers or male guardians, and 19 from those who did not indicate their gender. The details are summarized in Table 8.

Table 8. Numbers of valid questionnaires collected from Shanghai schools

School	School A		School B		School C		Total
Grade	Grade 7	Grade 8	Grade 7	Grade 8	Grade 7	Grade 8	
Student	19	19	41	34	15	16	144
Teacher	1	1	1	1	1	1	6
Parent	26	22	38	31	18	17	152

The three schools sampled in Shanghai are junior secondary schools only covering the grade level from 6 to 9 and located in urban areas. Since the schools were chosen by convenience sampling, two of the schools were introduced by a teaching research fellow working for a district-level education department in Shanghai, in which case the fieldwork was taken as a part of her school inspections so that the classroom observations, questionnaire surveys (involving teachers and students), student focus groups, and teacher interviews were arranged and implemented within one day as the teaching research fellow inspected each school (mid-September 2017); parent questionnaires were distributed on the same day but collected on the following days after the inspection; also, the classroom observations were videotaped and the interviews were audio taped. The other school was contacted via a personal relationship and unfortunately, the headteacher only approved questionnaire surveys and teacher interviews without any audiotape; hence, the interviews were recorded by taking notes and no classroom observations and student focus group interviews were conducted in this school. The numbers of classroom observations and valid interviews collected from those schools are presented in Table 9.

Table 9. Numbers of classroom observations and valid interviews collected from Shanghai schools

School	School A		School B		School C	
Grade	Grade 7	Grade 8	Grade 7	Grade 8	Grade 7	Grade 8
CO	1(31)	1(24)	--	--	1(26)	1(17)
StFG	1(0g2b)	1(3g3b)	--	--	1(3g4b)	1(3g4b)
TI	1	1	1	1	1	1

CO: classroom observation. The figures in brackets indicate the number of students in the classes that were observed.
StFG: student focus group interview. The figures and letters in brackets indicate the number of girls and boys participating in the focus group interview, e.g. 3g4b means 3 girls and 4 boys participated in the focus group interview.
TI: teacher interview.

In England, data were collected from 206 students studying in 8 classes (3 in year 7 and 5 in year 8) in 3 maintained secondary schools, 6 mathematics teachers who were in charge of teaching the sampled students, and those students' parents. A total of 178 students (70 in year 7 and 108 in year 8) provided valid responses to questionnaires and the number of boys was slightly more than girls in the sample (83 girls, 92 boys, and 3 unknown). All the 6 teachers (they were teaching multiple year levels including years 7 and 8) participated in the questionnaire survey, of whom there were 3 female teachers and 3 male teachers. The parents contributed 74 valid responses to questionnaires including 56 replies from mothers or female guardians, 16 from fathers or male guardians, and 2 from those who did not indicate their gender.

It is worth mentioning that the method of distributing student questionnaires in England was slightly different from Shanghai. According to the result of the pilot, all the English teachers and students thought that the student questionnaire was too long and the workload was not reasonable for children at those ages. Therefore, to improve the quality of the response, the original questionnaire was divided into two sections, which were distributed to the same students twice in a week in schools A and B, while to different classes within one day in school C due to their arrangements for my visit. The first section consists of the basic information and 7 questions in regard to the use of learning resources, while the second section consists of 13 questions including the influence of resource use on mathematics learning, the student's out-of-school study, and beliefs. Accordingly, the 206 students from England provided 177 responses to section 1 and 157 responses to section 2, of which there were 150 and 139 valid responses to the two sections respectively, from 178 students in total. The details are presented in Table 10.

Table 10. Numbers of valid questionnaires collected from England schools

School		School A		School B			School C			T
Year level		7	8	7	8		7	8		
Class		C1	C2	C1	C1	C2	C1	C1	C2	
St	Sec.1	24	7	31	24	28	15	21	--	150
	Sec.2	22	7	30	24	28	--	--	28	139
Teacher		1		1			4			6
Parent		14	0	17	32		2	9		74

C1: class 1, C2: class 2.
St: student.
Sec: section of student questionnaire.
T: total

Since the schools were chosen by convenience sampling, the selected schools in England were the first three that granted my request via email and located in the south-west. Two of the schools were secondary level as well as sixth form, while the other one only covered secondary level. In school A, the data collection was spread across three days within one week (end of November 2017). One class in year 7 and one in year 8 taught by the same mathematics teacher were observed twice on two days; the first section of the student questionnaire and parent questionnaire were distributed to those classes on the first observation day, in which case students were asked to complete their questionnaires in class and take home the parent questionnaire; the second section of the student questionnaire and teacher questionnaire were distributed and collected on the second observation day; and the student focus group interviews and teacher interviews were conducted and parent questionnaires were collected on the third day.

In school B, the data collection was spread across two days within one week (beginning of December 2017). One class in year 7 and two in year 8 taught by the same mathematics teacher were observed twice; the first day in school B was the same as school A, while on the other day, the teacher questionnaire and the second part of the student questionnaire were distributed and collected from the three classes, parent responses were recalled, and all the interviews were implemented as well.

In school C, the data collection was spread across two days in two weeks (mid-January 2018). Two classes in year 7 and two in year 8 taught by four different mathematics teachers were observed once on the first day, three of which participated in the questionnaire survey. The first section of the student questionnaire was distributed to one year 7 class and one year 8 class, while the second part was distributed to the other class in year 8; in the meantime, parent questionnaires were also sent to the three classes taking part in the student survey; and then in the following week, parent responses were collected, and two of the teachers, as well as twelve students from other classes at the two year levels, were interviewed.

The numbers of classroom observations and valid interviews collected from those schools are presented in Table 11.

Table 11. Numbers of classroom observations and valid interviews collected from England schools

School	School A		School B			School C			
Year	7	8	7	8		7		8	
Class	C1	C2	C1	C1	C2	C1	C2	C1	C2
CO	2(28/26)	2(20/18)	2(32/30)	2(24/25)	2(31/30)	1(30)	1(18)	1(24)	1(28)
StFG	1(2g3b)	1(2g2b)	--	--	1(3g3b)	1(3g3b)*		1(3g3b)*	
TI	1		1			1	--	1	--

Year: year level.
C1: class 1, C2: class 2.
CO: classroom observation. The figures in brackets indicate the number of students in the classes that were observed each time.

StFG: student focus group interview. The figures and letters in brackets indicate the number of girls and boys participating in the focus group interview, e.g. 3g4b means 3 girls and 4 boys participated in the focus group interview.
TI: teacher interview.
*. The students were not from the observed classes.

5.6 Data processing and analysis

All the collected data were coded and typed into a password-locked personal computer with a Windows 10 system and analysed using Microsoft Excel, SPSS, and NVIvo. The criteria for filtrating the valid responses of student questionnaires included: firstly, more than 50% of questions were completed, and secondly, the answers were not the same (or in the same "pattern") for different questions in every part. Similarly, the criteria for filtrating teacher and parent questionnaires were: firstly, more than 2/3 boxes were ticked since there were fewer questions in their questionnaires, and secondly, the answers were not the same for different questions relating to beliefs about learning resources and mathematics learning.

Data analysis in this study has four stages as shown in Figure 12. Quantitative data for portraying students' use of learning resources and the possible factors influencing the resource use were organized and presented with descriptive statistics to show the distributions numerically and graphically, followed by a comparison of the use between Shanghai and England by Chi-square tests. After that, the constructed factors were combined with the data measuring students' resource use, to examine whether associations existed between those factors and the resource use in Shanghai and England by Chi-square tests and t-tests.

The qualitative data collected from student and teacher interviews and classroom observation were firstly transcribed and categorized according to different learning resources, and then were coded and generated with different indicators of interactions between students and learning resources as well as the factors influencing their resource use. Finally, they were organized and interpreted in the thesis when necessary to enrich the content about students' resource use in their learning of mathematics and teachers' instructions incorporating learning resources, and to provide more details of their out-of-school study and the beliefs about learning resources and mathematics learning. Particularly, the qualitative data revealed specific relationships between their beliefs and resource use since the statistical associations cannot conclude a causality, and it is often the participants themselves who identify what the causes of their behaviours are, though the researcher needs to be careful about the conclusions given by the participants as they have reasons not to tell the real causes or may make mistakes (Cohen et al., 2011, p. 65).

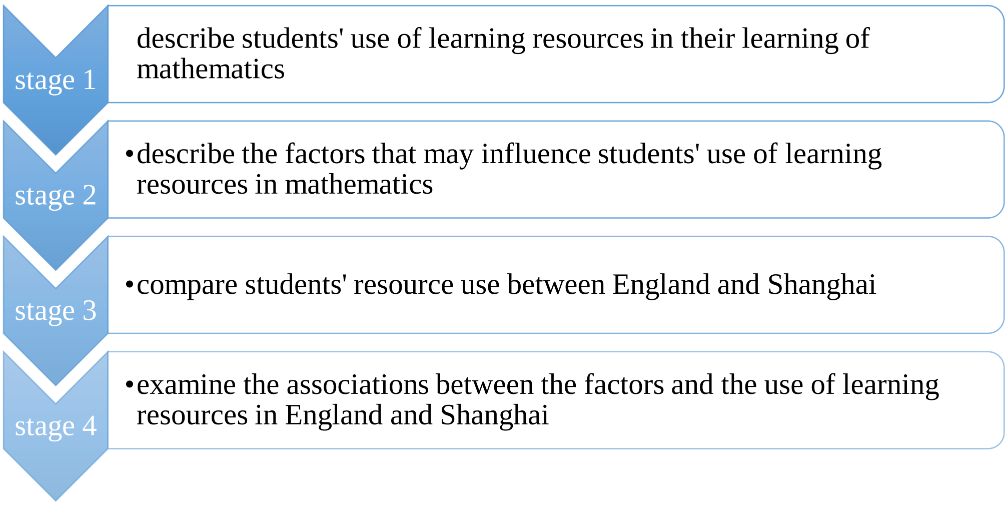


Figure 12 The process of data analysis

Stage 1

The data revealing students' resource use in mathematics were mainly collected from student questionnaires and triangulated by classroom observation. The frequency of use, duration, and the influence of students' resource use on their learning of mathematics were ordinal variables measuring the dominance and importance of the resources in students' mathematics learning, while the timing, purposes, motivations, change in resource use, and the access to those resources were nominal variables describing different aspects of the interactions between students and learning resources in mathematics. Descriptive statistics, such as frequencies, means, and percentages, were helpful to see the distributions of these variables. The data of different regions were analysed and presented separately to obtain a detailed description of students' resource use in Shanghai and England respectively.

Stage 2

The data relating to the factors influencing students' resource use in mathematics learning were primarily collected from student and teacher questionnaires, verified by parent questionnaire and classroom observation, and further explained in teacher interview. Similar to the analysis of students' resource use, descriptive statistics were employed to see the distribution of these variables; additionally, the observation and interview records were summarized and presented where necessary. The data of different regions were also analysed separately to obtain an overview of teachers' instruction, parental involvement, out-of-school lessons, and people's beliefs about the use of learning resources and mathematics learning.

Stage 3

The technique for comparing students' resource use in mathematics between Shanghai and England is easily understood. The population of the test was state-funded secondary school students in grades 7 and 8 in Shanghai and years 7 and 8 in England. Chi-square tests were employed to examine the relationship between how students used learning resources and where they came from. The hypotheses can be roughly stated here as:

H_0: In the population, there is no association between the use of a learning resource (e.g. the frequency of using textbooks) in mathematics and regions (i.e. England and Shanghai).

H_A: In the population, there exists an association between the use of a learning resource in mathematics and regions.

If the test rejected H_0, then it would matter whether students studied in Shanghai or England, and how they usually used a resource in their mathematics learning. Moreover, the direction of the association was revealed by combining descriptive statistics presented at stage 1.

Stage 4

The descriptive statistics displayed at stage 2 actually also revealed some differences in the didactical, social, and cultural situations between England and Shanghai, which could be linked to students' use of learning resources according to the details provided in interviews; for instance, students clarified the resources they used in out-of-school lessons in interviews, and then their attendance of the lessons and use of the resources were examined to see if there existed significant associations. Chi-square tests were employed to detect the relationship between social as well as didactical factors and the resource use, while t-tests were applied to cultural factors, since the four-item Likert scale was valued from 1 to 4 so that it became a scale variable by adding up the scores on five statements reflecting students' opinions about each belief. The hypotheses for Chi-square tests are:

H_0: In the population, there is no association between the factor (e.g. the frequency with which parents assigned extra exercises to their children) and students' use of a learning resource (e.g. the purpose of using reference books) in mathematics.

H_A: In the population, there exists an association between the factor and students' use of a learning resource in mathematics.

And the hypotheses for t-tests in this study can be summarized here as:

H_0: In the population, there is no difference in the mean scores of a belief (e.g. beliefs about the authority of textbooks) between students who use a learning resource in different ways (e.g. whether they use textbooks for a preview).

H_A: In the population, there exists a difference in the mean scores on a belief between students who use a learning resource in different ways.

If the test rejected H_0, then the factor could be an explanation of how students use a learning resource in a certain way.

5.7 Limitations

For various reasons, such as time and financial issues, this study has its limitations. The sample of participants just comes from three state-funded schools that are accessible to the researcher in each place, which may cause some representative problem. In this case, the results cannot really stand for all the situations of students' use of learning resources in Shanghai and England, since the reality may be different from unban district to suburban counties in Shanghai, and from one administrative county to others in England. However, it still is one step closer to the truth and provides some insights into students' resource use in their mathematics learning in the two places, though the results should not be overgeneralized.

Moreover, the research instruments used in this study mainly collect self-reported information, in which situation the data may have some bias, since the participants are likely to present a positive image of their behaviours, could be willing or unwilling to tell the truth, or might forget some details of their learning experiences. To minimize those effects, this study employs various research tools and involves the relevant parties to triangulate the data.

5.8 Summary

The primary question of this study is, How do secondary students use learning resources in mathematics in Shanghai and England? To address this question, students' resource use was mainly measured quantitatively, and 161 students in 6 classes from three state-funded secondary schools in Shanghai and 206 students in 8 classes from three maintained secondary schools in south-west England were sampled by conveniently clustered sampling. To take into consideration the contextual factors, the teachers and parents of the sampled students also got involved. Also, qualitative approaches were employed to complement and triangulate the self-completed quantified data in the study.

Six instruments were designed based on the conceptual framework to collect the data:

<u>Student questionnaire</u>: consisting of 20 questions, this was the dominant instrument collecting all the information measuring students' resource use and the contextual factors except for teachers' instruction, which is constructed as the didactical factor in chapter 3. The valid response rates are 89.4% and 86.4% from Shanghai and English students respectively.

<u>Teacher questionnaire</u>: containing 8 questions, this was developed and administrated to 6 teachers in each place to collect the data revealing teacher instructions incorporating students' resource use in mathematics and their beliefs about learning resources and mathematics learning. All the 12 participants gave valid responses back.

Parent questionnaire: designed with 8 questions, this was employed to collect the data reflecting parental involvement and beliefs about learning resources and mathematics learning from parents' perspectives, which were used as the triangulation of students' answers. All the sampled students were supposed to take home the parent questionnaire and bring back the replies to schools in the following few days. There were response rates of 94.4% from Shanghai parents and 36.0% from English parents.

Classroom observation: this was adopted by this study as the supplement and triangulation of teachers' and students' interactions with learning resources in class. In all, 4 mathematics lessons delivered by four of the sampled teachers and their students were observed in Shanghai while 14 mathematics lessons conducted by the six sampled teachers with sampled classes were observed in England.

Student focus group interview: this was designed to mainly obtain the details of attending out-of-school lessons, studying with parents, and students' beliefs about learning resources and mathematics learning, which were used to identify the relation between the factors and students' resource use in mathematics. A total of 22 Shanghai students grouped in four sets and 27 English students divided into 5 groups were interviewed one after another.

Teacher interview: this was employed to enrich the data collected from the teacher questionnaire in terms of teaching practice incorporating students' resource use and their beliefs about learning resources and mathematics learning. All the sampled teachers from Shanghai and 4 of the sampled teachers from England were interviewed in real life.

The quantitative approaches were applied to the data collected from questionnaires to obtain a general picture of how students use learning resources in mathematics as well as the contextual factors for their use, and to compare the resource use between Shanghai and England. The qualitative methods were mainly used on the data collected from interviews and classroom observations to form an in-depth understanding of how students use the resources and whether the factors could be associated with students' resource use in the two different contexts.

Chapter 6 Findings of the Shanghai Study

6.1 How Shanghai students use learning resources in mathematics

Generally speaking, in the 144 valid responses from students, only one pointed out that he had paper-based and e-learning materials bought from out-of-school classes and he could not classify those into any of the resources conceptualized by this study, thus the category of "other paper-based resources" and "other e-resources" are omitted to provide a concise result.

Moreover, there was only one who did not use textbooks at all in mathematics (the student ticked "N.A." (not applicable) for textbook as the answer to every question. Four did not use workbooks, seven did not use worksheets and ten did not have notebooks, which means that most of the students owned and used mathematics textbooks, workbooks, worksheets, and notebooks in their study. However, 36.2% of the students replied that they did not use any reference books in mathematics and most of the students did not use e-resources in their learning of mathematics, the proportions of which were 80.6% for e-books, 68.8% for teaching videos and 64.6% for e-learning systems.

How frequently?

Students participants were supposed to indicate the frequency of using the defined resources in their mathematics learning by choosing from "N.A" (not applicable), "1 day per week", "2–3 days per week", "4–5 days per week", and "6–7 days per week". Figure 13 shows the weekly frequency (including weekends) of using the eight learning resources defined for Shanghai students.

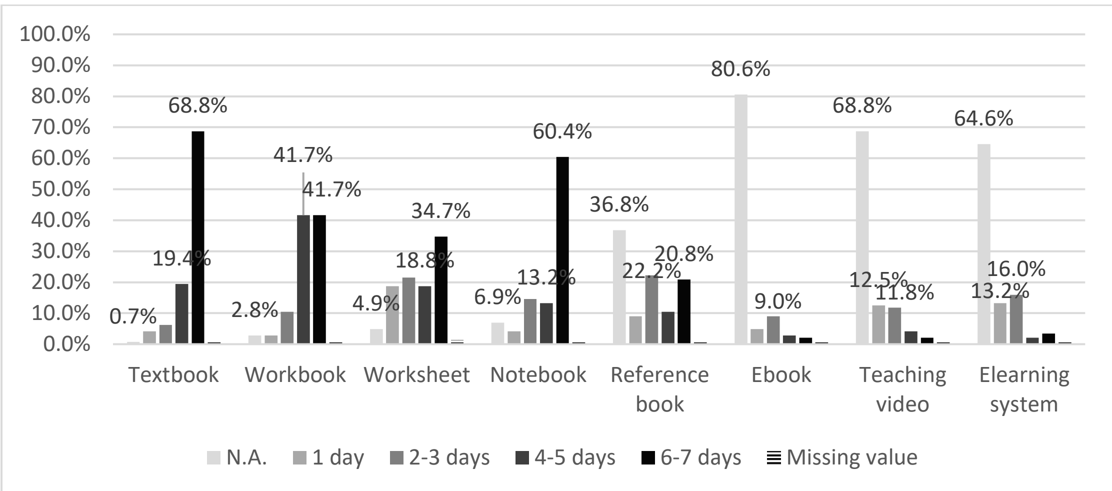


Figure 13 Percentage distribution of Shanghai students who used learning resources at different frequencies

According to the legend, the darker colour of the bars shows the more frequently the learning resource was used, which presents a preference for using paper-based resources, especially textbooks. To be specific, a majority of the students used mathematics textbooks (68.8%) and notebooks (60.4%) almost every day including weekends. The percentage of those who used workbooks more than 4 days a week (83.3%) was almost the same as the percentage for textbooks (88.2%). Compared to those three resources, the frequency of using worksheets and reference books was distributed rather evenly at different intervals. Also, e-resources seemed not particularly popular among students in mathematics learning. Only about 20% of the students said that they used e-books and around one-third of the students got teaching videos or e-learning systems involved in their learning of mathematics, most of which indicated that they used the e-resources less than 3 days a week.

Since there is a natural order of using frequency from "N.A." for "I don't use it", to "6–7 days" for "I use it almost every day", the frequencies were assigned values from 1 to 5 to make it scalable from the lowest frequency to the highest one, so that the mean of the scale can show an average frequency of using those learning resources. The details are shown below:

Table 12. Average frequency of using different learning resources in mathematics (Shanghai)

Using frequency	Textbook	Workbook	Notebook	Worksheet	Reference book	Elearning system	Teaching video	Ebook
Mean	4.52	4.17	4.17	3.61	2.69	1.66	1.57	1.4
N[1]	(n=143)	(n=143)	(n=143)	(n=142)	(n=143)	(n=143)	(n=143)	(n=143)

1. N stands for the number of valid responses excluding the missing values.

Table 12 presenting the average frequencies of using learning resources in descending order makes it clear that the dominant resources used by Shanghai students in their learning of mathematics were textbooks, workbooks, and notebooks while the three e-learning resources seemed not popular to them.

For what length of time?

Since some resources were used every day, while some were used less frequently in a week, it is better to know more details, such as how much time students usually spend on different resources in a normal school day, which is a step further on from knowing how frequently students use different resources in mathematics learning. Student participants were asked to indicate the duration of using the defined resources in a normal school day by choosing from "N.A. (not applicable)", "<15 minutes", "15–30 minutes", "30–45 minutes" and ">45 minutes". Figure 14 presents a rough shape of the time spent on each learning resource with five bars. It takes students less time where the shape skews to lighter colours, hence obviously, students hardly spent much time on the three e-learning resources, while it seems that they spent much time working with worksheets.

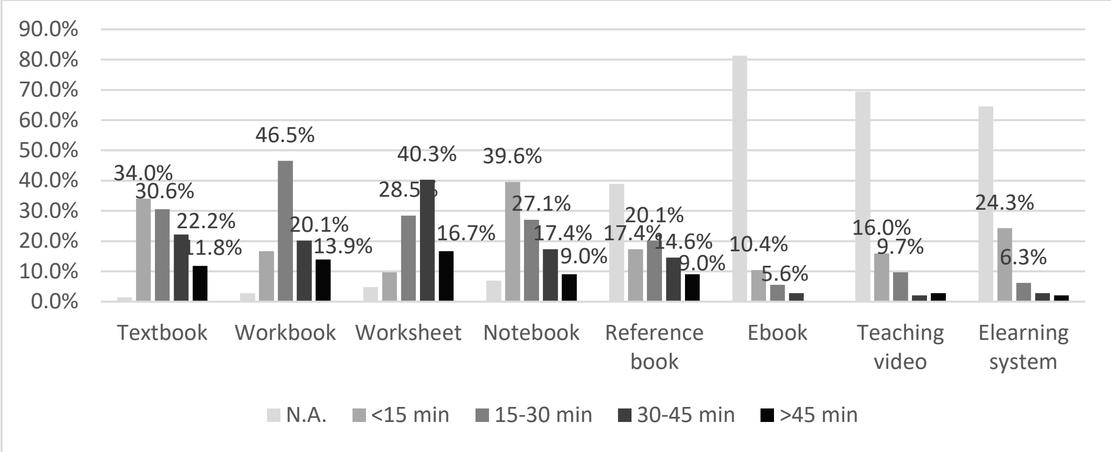


Figure 14 Percentage distribution of Shanghai students who used learning resources for different time lengths in a school day that they have mathematics lessons

Moreover, the five time-intervals shown in the legend were assigned values from 1 for "N.A." to 5 for ">45 min" to provide an average time spent on each resource. As sorted in ascending order in Table 13, the worksheet was the resource that Shanghai students spent most of their time with; specifically, over half (57%) of the students spent more than 30 minutes working on worksheets in a normal school day with mathematics lessons. Combined with the spread shown in Figure 15, the average time spent on workbook and textbook goes beyond the interval of "15–30 min"; in fact, about one third (34%) of the students indicated that it took them more than 30 minutes to work with the two books in a normal school day. Also, the other two paper-based resources, namely, reference book and notebook, were used with an average time between "<15 minutes" and "15–30 minutes" while all the e-learning resources were used less than 15 minutes per day according to students' answers.

Table 13. Average scores of the duration of using different learning resources in a day that Shanghai students have mathematics lessons

Duration	Ebook	Teaching video	Elearning system	Reference book	Notebook	Textbook	Workbook	Worksheet
Mean	1.30	1.53	1.53	2.38	2.82	3.09	3.26	3.54
N[1]	(n=144)	(n=144)	(n=144)	(n=144)	(n=144)	(n=144)	(n=144)	(n=144)

1. N stands for the number of valid responses.

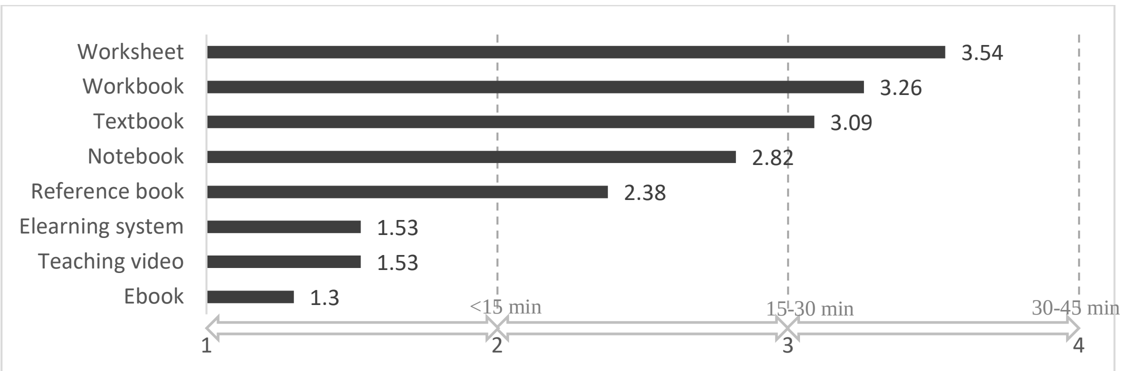


Figure 15 Average scores of the duration of using different learning resources in a day that Shanghai students have mathematics lessons

When to use?

Figure 16 provides a distribution of Shanghai students who used the defined learning resources with different timings. A total of 47.2% of the students said that they used textbooks in class while another 47.9% indicated that they used textbooks both in and after class, which accounted for 95.1% of all valid responses. Notebooks were more likely to be used only in class (50.7%), and worksheets and workbooks were used both in and after class with the proportion of 50% and 56.3% respectively. Reference books were not treated the same way as other paper-based learning resources: nearly one-third of the students did not use them (labelled as "N.A." in the legend) to learn mathematics and 44.4% of them stated that they only used them after class. As mentioned before, not many students used the three e-learning resources in mathematics and most of the users stated that they only used them after class, the proportions of which were 15.3% for e-books, 22.9% for teaching videos, and 29.9% for e-learning systems.

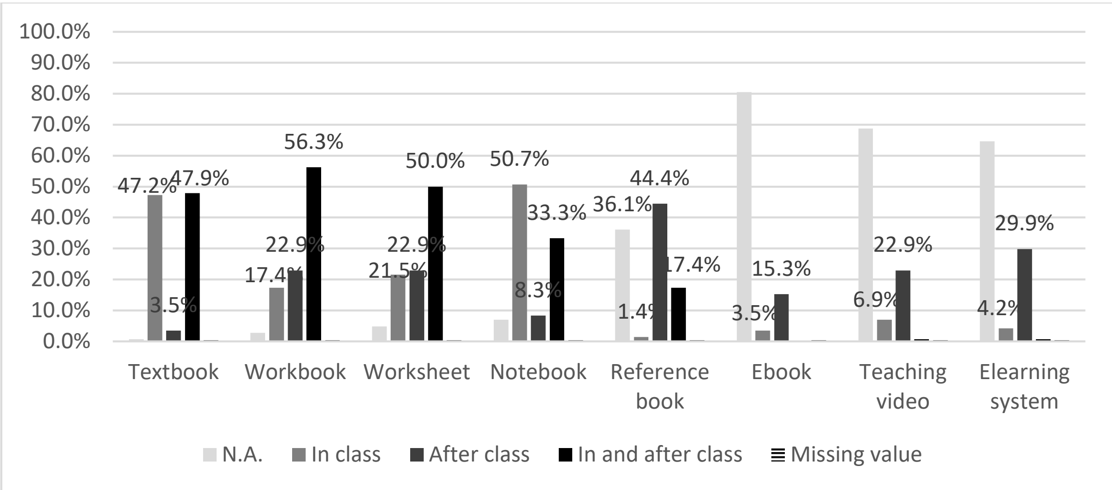


Figure 16 Percentage distribution of Shanghai students who used learning resources in different timings

For what reasons?

To draw a picture of the interaction between students and learning resources, it is important to investigate how students incorporate different resources in various learning activities, which is an in-depth understanding of the timing of using those resources. Based on the constructs in Chapter 3, this study provided eight situations, or purposes, for students to choose from, including "N.A."(not applicable), "preview", "in-class learning and exercise", "revision", "looking up definitions, theorems, and formulas", "looking up examples, answers, and references", "doing homework", and "doing extra exercises". Figure 17 presents the results of students' multiple choices of the purposes of using different learning resources (students can choose more than one option to answer what they usually use a certain resource for).

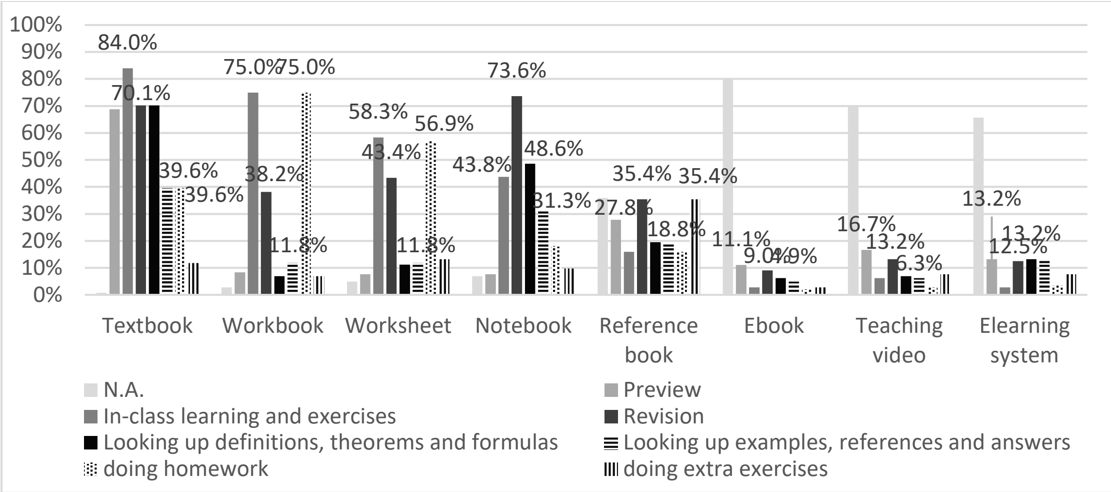


Figure 17 Percentage distribution of Shanghai students who used learning resources for different purposes

Firstly, it is clear that mathematics textbooks were widely used in many situations. A large percentage (84%) of the students used textbooks for in-class learning and exercises. Around 70% of the students used textbooks when they previewed new lessons, prepared for examinations, and looked up definitions, theorems, and formulas. Four-tenths of the students needed textbooks when they did homework and inquired about examples, references, and answers. Also, only 11.8% said that they used textbooks for doing exercises that were not assigned by their teacher.

Secondly, the use of workbooks seemed to have a more explicit purpose. The two main situations for using mathematics workbooks were in-class learning and exercises and doing homework, both of which accounted for three-fourths of the whole. Then 38.2% of the students used workbooks for revision, about 12% needed them for looking up examples, references, and answers, and no more than 10% used workbooks for the other three purposes. The use of worksheets had a similar distribution. The two main purposes of using worksheets were doing homework (56.9%) and in-class learning and exercises (58.3%). Then 43.4% of the students used them for reviewing what they had learned and around 10% incorporated worksheets in the other four learning activities respectively.

Also, notebooks were mostly used by students for revision (73.6%) that might mainly refer to studying for examinations. A total of 43.8% of the students took notes for in-class learning and exercises. Nearly a half (48.6%) read notebooks to look up definitions, theorems, and formulas, and around one third (31.3%) used notebooks for reviewing examples, references, and answers. A total of 18.1% of the students used notebooks when they did homework. The proportion of those who used notebooks to do exercises not assigned by their teacher was 9.7% and those who used notebooks to obtain the knowledge they had not been taught (preview) was only 7.6%.

Also, reference books were more likely to be used for self-learning such as revision (35.4%) and doing additional exercises (35.4%). In all, 27.8% of the students used reference books to preview new knowledge. About one-fifth of the students referred to the books for definitions, theorems, and formulas (19.4%) as well as for examples, references, and answers (18.8%), while both the proportions of those who incorporated reference book in classroom learning and those who used reference books for doing homework were 16%.

For e-learning resources, the main situations of using e-books, teaching videos and e-learning systems were the same, namely, to preview what they were about to learn before class, the percentages of which were 11.1%, 16.7%, and 13.2% respectively. Then 13.2% of the students said that they used teaching videos for revision, while the proportions for e-books and e-learning systems were 9% and 12.5%. Another major application of e-learning systems was to obtain instant information: both the percentage of those who gained access to e-learning systems for finding definitions, theorem, and formulas, and those who looked for examples, references, and answers were 13.2%, which were the second largest groups of the students who incorporated e-learning systems in their learning of mathematics. Moreover, 7.6% of the students used either teaching videos or e-learning systems for doing extra exercises, whereas the proportion for e-books in the same situation was only 2.8%.

As explained in Chapter 3, the reasons for using the resources may not be related to any specific learning activities and even have no relation to learning. Hence, some reasons are constructed as "motivations" for students' use of different learning resources in this study. According to the structure shown in Figure 9, there was one item in the questionnaire reflecting "enjoyment", and one corresponding to "challenge", as the intrinsic motivations. Two options referred to "external regulation", including teacher mediation and parent-supervision, and another two statements corresponded to "self-regulation", which were constructed as extrinsic motivations. The final one item applied only to e-learning resources was classified as other extrinsic motivation. No other reasons were illustrated by the participants in the blank. The details of the options listed under the question, In general, what is the reason for you to use the learning resource in mathematics learning? are presented below.

Table 14. The motivations for using learning resources in mathematics

Motivations		Options in student questionnaire
Intrinsic motivation	Enjoyment	There are many **interesting things** so it is enjoyable for me to use it.
	Challenge	I always feel **fulfilled** when I solve some difficult problems in it.
Extrinsic motivation	External-regulation	My **teacher** usually asks me to use it according to his/her instructions.
		My **parent** usually asks me to use it when I study with him/her.
	Self-regulation	I keenly know that it can **improve my mathematics mark**.
		I think it can help me **better understand** mathematics knowledge and skills, and **enhance my mathematical abilities**.
	other	It is the **fastest way** to get the information I need.

Figure 18 shows the results of students' responses to why they incorporated paper-based resources in their learning of mathematics. Self-regulation and teacher mediation were the two major motivations for using those learning resources. Specifically, two thirds of the students thought that the use of textbooks could help them better understand mathematics knowledge and skills, and enhance their mathematical abilities, which was the main reason for students' textbook use, over half of them (54.2%) used textbooks because their teacher required them to do so, and 44.4% of them deemed that textbooks could improve their mathematics marks.

Moreover, a large percentage of students identified the relevance between the use of workbooks (63.2%) and worksheets (61.8%) and the improvement of mathematics marks, which were the largest groups of those who incorporated workbooks and worksheets in their learning of mathematics respectively. The use of workbooks seemed more likely to be led by teacher instructions (56.3%) compared to the use of worksheets (45.1%). Then more than half of the students believed that the use of workbooks (53.5%) and worksheets (54.2%) had positive influences on their understanding of mathematics and mathematical abilities.

For notebooks, the statement corresponding to "enjoyment", an intrinsic motivation, was addressed as "It is enjoyable for me to take notes in mathematics lessons", which was ticked by nearly half of the students (45.1%) as the reason for using notebooks. Another main reason was consistent with the other paper-based resources, namely, self-regulation including the improvement of marks (55.6%) and mathematics knowledge as well as abilities (56.3%). Also, about one-third of the students indicated that their use of notebooks was teacher-led.

For reference books, 43.1% of the students used them because they wanted to improve their performance in mathematics and 41% aimed at the enhancement of mathematics knowledge and skills. In addition to self-regulation, approximately one-fifth of students (18.9%) thought it made them feel fulfilled when solving some difficult problems in those books, which was the third largest group of those who used reference books in mathematics.

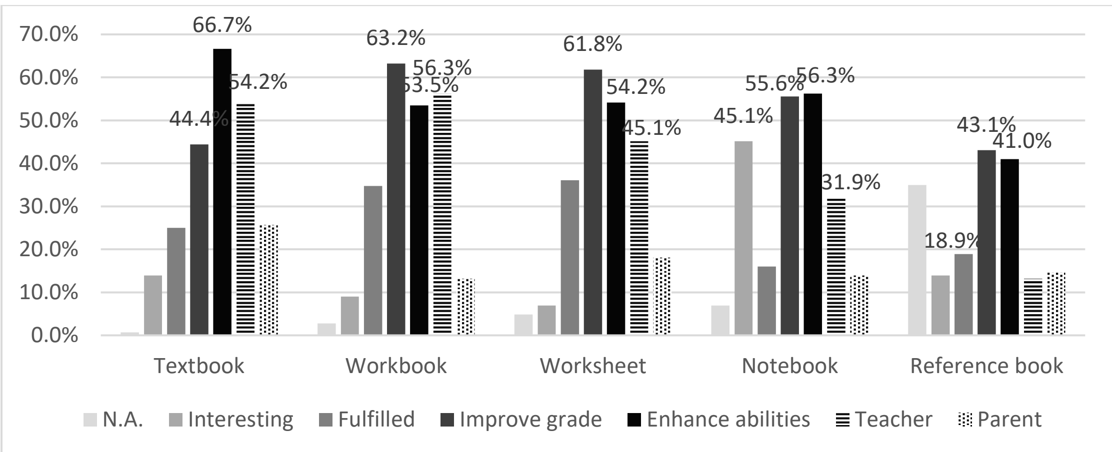


Figure 18 Percentage distribution of Shanghai students who used paper-based resources out of different motivations

When it comes to e-learning resources, the main reasons for using e-books involved self-regulation and parent-supervision. To be specific, 7.6% of the students used e-books for improving mathematics knowledge and skills, 6.9% of them deemed that e-books were helpful to their mathematics marks, and 5.6% used e-books as their parents asked them to do so, while the primary reasons for using teaching videos and e-learning systems were self-regulation and enjoyment. In all, 14.6% of the students found it interesting to watch teaching videos, which was the second largest group next to those who incorporated teaching videos in their learning of mathematics for better understanding the knowledge and skills (17.4%) and higher than the proportion of those who sought better marks (11.1%). Then over one fifth of the students (20.8%) used e-learning systems because the resource benefited them in terms of the understanding of mathematics and relevant abilities, 12.5% of them gained access to e-learning systems since they thought it could help them perform well in examinations, and 10.4% of the students found that it was interesting to interact with software, e-learning platforms, programmes, and systems. Finally, a few students (5.6%) agreed that it was the fastest way to get instant information via e-learning systems; for instance, they could get the result immediately when searching for a formula with a computer-based application to solve problems in homework.

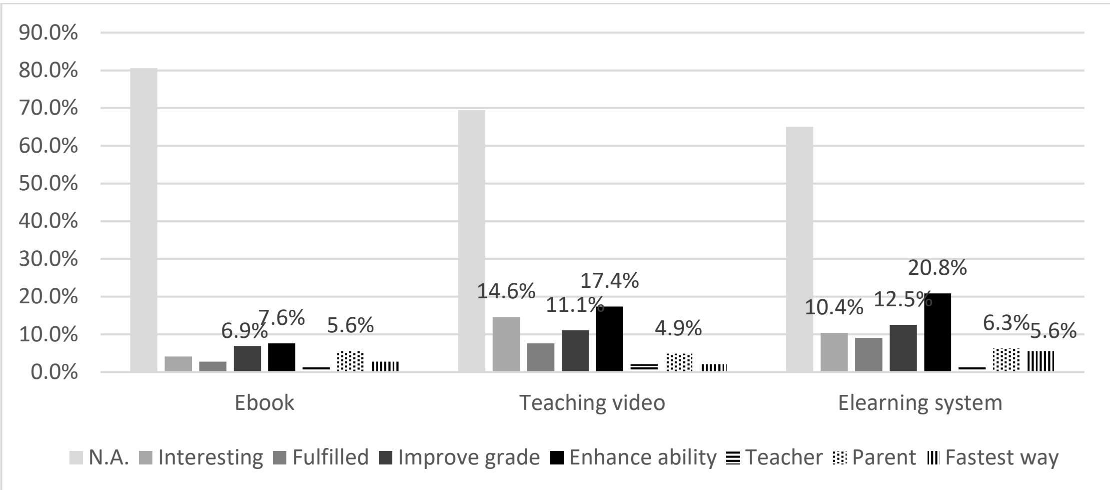


Figure 19 Percentage distribution of Shanghai students who used e-resources out of different motivations

How to access?

Based on the above preliminary analysis of how various resources accompany students in their learning of mathematics, it is natural to ask where those resources come from, or in other words, how students usually gain access to the learning resources. In the questionnaire, students were asked to indicate the way that they got those resources by choosing from “N.A.”, “parents buy for me” “school or other sponsors buy for me”, “borrow from library”, “borrow from classroom”, “teacher makes for me”, and “borrow from peers”, for the paper-based resources, and “N.A.”, “parents buy for me”, “google them directly or search on the publisher’s website”, “access through school website” “it is an accessory to the other resource”, “teacher makes for me”, and “borrow from peers”, for e-learning resources.

Figure 20 shows the way that students obtained different paper-based resources except for notebooks, because in Shanghai, students always buy their own books with blank or ruled pages for taking notes. It is obvious that textbooks and workbooks were commonly free to students. According to classroom observation and teachers’ interviews, Shanghai’s government buys students a set of books that includes a series of textbooks and workbooks for every subject; additionally, the local department, namely, district education departments, and schools also issue their own mathematics workbooks for students; hence, in total, students can have three free workbooks. For worksheets, most students (81.3%) said that they obtained them for free and some of them (25.7%) clearly knew that it was their teacher who made the worksheets for them. As a complement to the textbook, reference books were bought by parents in most cases when the students needed them to learn mathematics (58.3%).

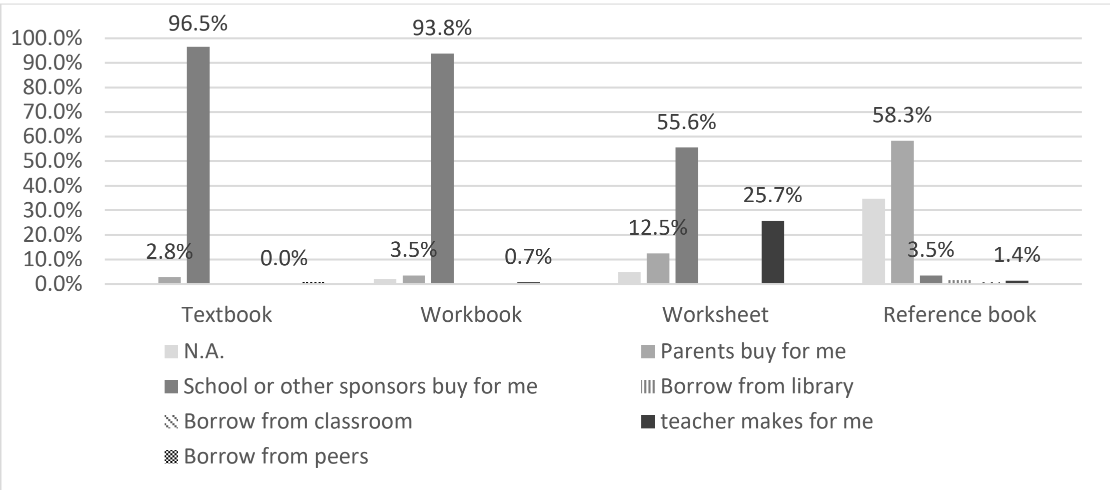


Figure 20 Percentage distribution of Shanghai students who gained access to paper-based learning resources in different ways

For e-learning resources, apart from those who did not use them at all, a large percentage of students (10.4%) gained access to e-books by purchasing themselves a copy, while for teaching videos and e-learning systems, students were more likely to either just choose one of the results given by search engines (e.g. Google) or directly went to the publishers’ website (14.6% and 21.5%).

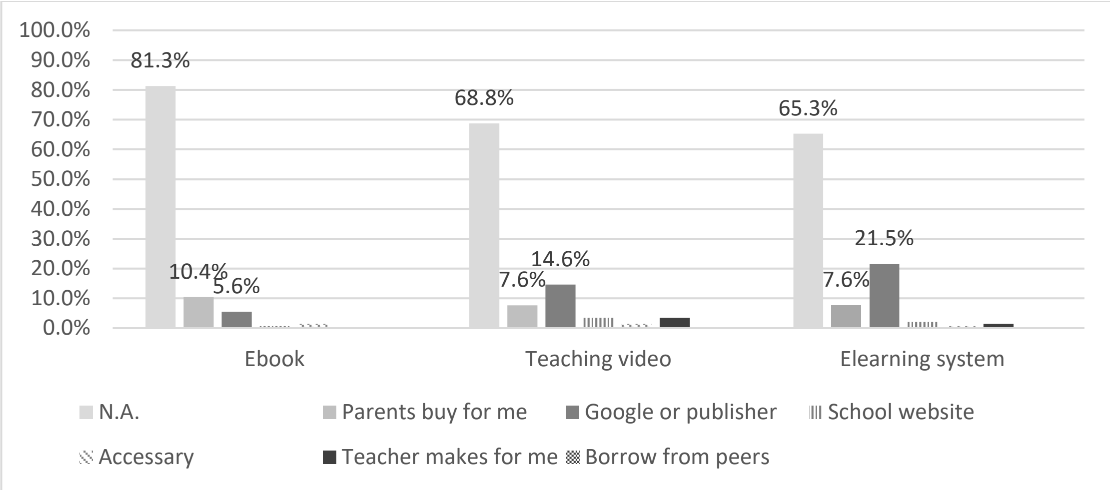


Figure 21 Percentage distribution of Shanghai students who gained access to e-learning resources in different ways

Does the use help with learning?

In the questionnaire, students were asked to evaluate the helpfulness of different learning resources in improving their mathematics knowledge and skills, their ability in mathematical reasoning, and their ability in problem-solving with a five-item scale. The items were assigned values from 1 for “not helpful” to 5 for “very helpful” while there was still an item “N.A.” assigned with 0 for students to tick in the case of not using the corresponding resource. Table 15 shows the average degrees of the influence of different learning resources on mathematics knowledge and skills. Since it is not reasonable for those who did not use some of the resources to judge how useful the resources were in their learning of mathematics, the computation excluded the number of those who ticked “N.A.” for the resources. As the neutral value is 3, it seemed that all resources positively influenced students’ learning of mathematics knowledge and skills; particularly, the use of worksheets, reference books, notebooks, and workbooks helped more than the use of textbooks and e-learning resources in students’ views.

Table 15. Mean scores of the influence of using learning resources on mathematics knowledge and skills (Shanghai)

Learning resources	Worksheet	Reference book	Notebook	Workbook	Textbook	Teaching video	Elearning system	Ebook
Mean	4.34	4.26	4.14	4.09	3.98	3.73	3.49	3.35
N[1]	(n=137)	(n=92)	(n=134)	(n=140)	(n=143)	(n=41)	(n=47)	(n=23)

1. N stands for the number of valid responses excluding the number of those who ticked “N.A.”.

Table 16 presents the average degrees of how the use of different resources helped Shanghai students improve their ability in mathematical reasoning. It seems that the use of worksheets and reference books contributed to the students’ reasoning ability the most. Then the helpfulness of notebooks and workbooks were regarded as almost the same and ranked after the two resources mentioned above. The degrees of how the use of textbooks and teaching videos enhanced the reasoning ability were at the same magnitude, 3.6, positioned in third place, while the other two e-resources, e-learning systems and e-books, had the lowest degree of helpfulness.

Table 16. Mean scores of the influence of using learning resources on the ability of mathematics reasoning (Shanghai)

Learning resources	Worksheet	Reference book	Notebook	Workbook	Textbook	Teaching video	Elearning system	Ebook
Mean	4.11	4.09	3.97	3.96	3.69	3.63	3.42	3.42
N[1]	(n=137)	(n=92)	(n=134)	(n=140)	(n=143)	(n=43)	(n=48)	(n=24)

1. N stands for the number of valid responses excluding the number of those who ticked "N.A.".

Table 17 displays the average degrees of the impact of using different learning resources on students' ability in problem-solving. Similar to the two results shown above, worksheets and reference books were valued as the two most helpful resources. There were two differences compared to the result relating to mathematics knowledge and skills as well as the reasoning ability. One was that the degree to which the use of textbooks and teaching videos enhanced ability in problem-solving had a larger difference; another one was that e-learning systems helped more than teaching videos to boost students' ability to solve problems, which switched the places of the two resources in descending order.

Table 17. Mean scores of the influence of using learning resources on ability in problem-solving (Shanghai)

Learning resources	Worksheet	Reference book	Notebook	Workbook	Textbook	Elearning system	Teaching video	Ebook
Mean	4.20	4.11	3.97	3.94	3.87	3.48	3.43	3.14
N[1]	(n=133)	(n=90)	(n=131)	(n=136)	(n=139)	(n=46)	(n=40)	(n=22)

1. N stands for the number of valid responses excluding the number of those who ticked "N.A.".

Since the three results of how using different resources influences students' mathematics learning have a similar order, there could be some relationship between the impact of the same learning resources on different aspects of mathematics learning. The examination of the correlations verified that point. As shown in Table 18, significantly positive correlations were found between almost all pairs of the impact of resource use on different aspects of mathematics learning at 0.01 level with Pearson coefficients, especially for the relationship between the influence of resource use on mathematics knowledge and skills and the impact on ability in mathematical reasoning (see the row of "KS-MR")

Table 18. The Pearson coefficients and the significance of the correlations between different aspects of mathematics learning (Shanghai)

	Textbook	Workbook	Worksheet	Notebook	Reference book	Ebook	Teaching video	Elearning system
	(N=143)	(N=140)	(N=137)	(N=134)	(N=92)	(N=23)	(N=41)	(N=47)
KS-MR	0.647**	0.679**	0.667**	0.696**	0.711**	0.710**	0.644**	0.665**
KS-PS	0.578**	0.596**	0.549**	0.566**	0.591**	0.475*	0.437**	0.383**
MR-PS	0.583**	0.632**	0.636**	0.605**	0.649**	0.201	0.515**	0.500**

KS: mathematics Knowledge and Skills, MR: ability in Mathematical Reasoning, PS: ability in Problem-Solving.

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Any changes compared to the previous academic year?

Finally, the only semi-open ended question in the student questionnaire was to inquire whether they had changed their use of each resource in the learning of mathematics compared to the previous academic year, what the changes were, and why that happened. Figure 22 presents the results of whether they changed the way of using different learning resources. The computation excluded the number of those who ticked “N.A.” for the resources indicating that they did not incorporate the corresponding resources in their learning of mathematics. The figures suggest that there were not many changes. A majority of the students used textbooks, workbooks, worksheets, and teaching videos in the same way as before. Though a larger percentage of the students made some changes in using notebooks, reference books, e-books, and e-learning systems, over 70% of them still remained the same in terms of using those four resources in mathematics as the lower grade.

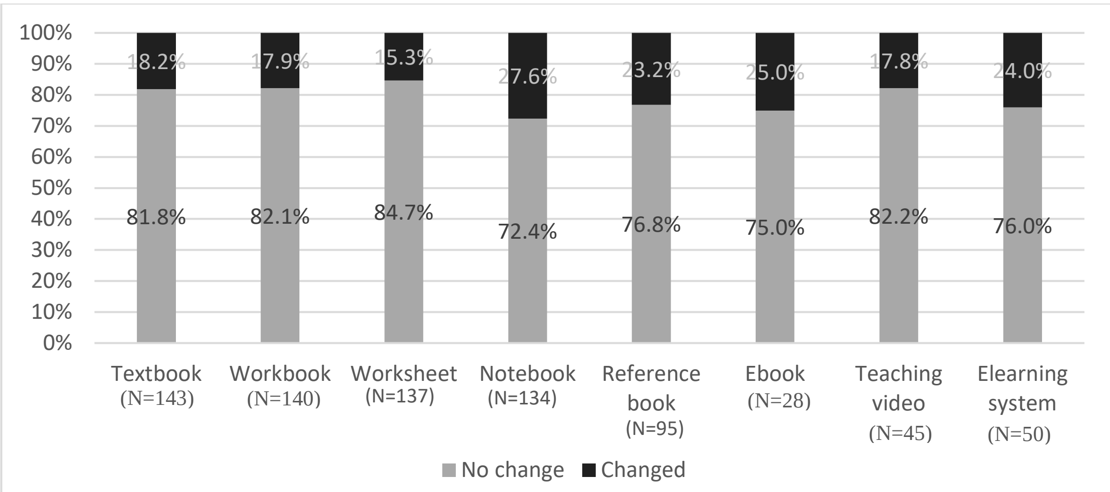


Figure 22 Percentage distribution of Shanghai students who indicated whether they changed their way of using the resources compared to the previous academic year

Also, Chi-square tests were employed to examine the differences between grade 7 and grade 8 students’ change in using learning resources in mathematics. To refine the results given by Chi-square tests, Fisher–Freeman–Halton tests were used to examine the difference when the cross-tables had low expected frequencies (<5) (Freeman & Halton, 1951).

Table 19. Results of the Chi-square test of differences between grade 7 and grade 8 students’ changes in using learning resources in mathematics

Chi	Textbook	Workbook	Worksheet	Notebook	Reference book	Ebook	Teaching video	Elearning system
	(N=143)	(N=140)	(N=137)	(N=134)	(N=92)	(N=23)	(N=41)	(N=47)
χ^2	0.398	2.547	3.397	0.264	1.667	--	--	0.018
df	1	1	1	1	1	--	--	1
Sig.[1]	0.528	0.110	0.065	0.607	0.197	--	--	0.892
F-F-H[2]	--	--	--	--	--	0.646	0.705	--

1. Asymptotic significance (2-sided).
2. Exact significance (2-sided) of Fisher–Freeman–Halton test.

Table 19 suggests that no significant differences were found between the two grade levels in terms of the change in using those resources in mathematics learning except for worksheets, which slightly missed the significance at the 0.05 level. Specifically, 90% of the grade 7 students responded that they did not change the use of worksheets compared to grade 6 while the proportion for grade 8 was 79%, which implied that students were more likely to change their ways of using worksheets when they started studying at a higher year level.

When it comes to how they changed the use of different learning resources in mathematics, 56 students specified the details: 29 of them referred to notebooks, 22 of them mentioned textbooks, 19 responses were related to workbooks, 15 talked about reference books, 14 mentioned worksheets, and 8, 4, and 3 of them specified the changes in using e-learning systems, e-books, and teaching videos respectively. Based on the results of content analysis, their changes tended to mean that they spent more time working with those resources compared to their previous academic year, especially for paper-based resources, since most students who mentioned the change in the frequency and duration of the resource use suggested increases in the time of using them.

Table 20. The numbers about how Shanghai students changed the way of using different learning resources in mathematics

How	Textbook	Workbook	Worksheet	Notebook	Reference book	Ebook	Teaching video	Elearning system	Total
Freq[1] ↑[3]	6	6	4	8	8	2	3	5	42
Freq ↓[4]	1	1	4	3	2	2	0	2	15
Dura[2] ↑	7	6	5	6	9	0	1	1	35
Dura ↓	0	2	2	0	0	0	0	2	6
Timing	1	1	0	3	0	0	0	0	5
Purpose	8	4	4	4	6	0	1	0	27
Motive	6	0	4	2	1	0	0	0	13
Influence	1	1	2	5	2	0	0	0	11
Others	0	2	0	2	1	0	0	0	5
Total	30	23	25	33	29	4	5	10	159

1. Freq: frequency.
2. Dura: duration.
3. ↑ : increase (in the frequency or duration of using learning resources).
4. ↓ : decrease (in the frequency or duration of using learning resources).

Then, five answers referred to the timing of using textbooks (1), workbooks (1), and notebooks (3). One described the change as “I used to read the textbook *only during lessons*, but now I read it both *in and after class*”, one said “I use workbooks *at home* for self-training now”, two of them indicated that they used notebooks *at home* for revision, while the other one stated that s/he had started to take notes *in mathematics lessons* since the new academic year.

Furthermore, eight responses were related to the change in the purpose of using textbooks: some mentioned that they used textbooks more frequently for *preview*, some stated that textbooks were incorporated more often in *revision*, and others explained the changes from the perspective of taking textbooks as references in their learning of mathematics, including *looking up concepts, definitions, examples, and other content* in textbooks. All the responses relating to workbooks and worksheets suggested that they used either workbooks or worksheets for *doing more exercises*, and all the changes with regard to notebooks showed that they used them more for *reviewing* the knowledge. The six responses reflecting a change in the purpose of using reference books all conveyed that they needed to find *more exercises* from those books to train themselves, which was not required by their teachers. One more answer said that "teaching videos were used for *preview* this term, I will understand the knowledge faster and more deeply when the teacher explains it if I know some in advance."

Also, thirteen responses mentioned the motivation for using the resources when illustrating the changes in using textbooks (6), worksheets (4), notebooks (2), and reference books (1). For textbooks, two of them identified the relation between textbook use and the improvement of their *mathematics marks*, the other four indicated the changes in their *teachers' instructions* incorporating textbook use, such as "last term, my teacher mainly used PPT during the lessons and did not use the textbook frequently, while this term, the new teacher always starts a lesson with revision of the knowledge we learned in the previous lesson and then introduces the new concepts posed in the textbook, hence (we) use (the textbook) more often". For worksheets, two of them suggested that their changes were based on *teachers' instructions*, one came to realize that the use of worksheets could improve *mathematics marks*, and the other one noticed the relationship between the use of worksheets and *the enhancement of mathematics knowledge*. For notebooks, one claimed that the *teacher* changed the way of teaching while the other one detailed the change as "(I) hardly used notebooks before, but now I can always solve some difficult problems by using notebooks", which implied that the *challenge* moved him/her to incorporate the resource in mathematics learning. For reference books, one student became aware of the usefulness of reference books in consolidating *mathematics knowledge*.

Additionally, eleven responses involved the influence of using different resources on mathematics learning when elaborating the changes in using paper-based resources. All of them pointed out the helpfulness of using the resources in learning *mathematics knowledge*; for instance, "it (the notebook) helped me to remember the knowledge that the teacher taught me in class", and then one further claimed that the use of workbooks could make him/her solve problems faster, which suggested an improvement in *mathematics skills*, such as calculating.

Lastly, when exploring the reasons why the changes happened, 10 keywords were extracted from 55 responses that either included the words "because (yin wei[4])", "since (you yu[5])", "for (wei le[6])", "reason (yuan yin[7])" and "as (yin[8])" clearly, or they existed as explanations in addition

4 The translation of "because" in Chinese.
5 The translation of "since" in Chinese.
6 The translation of "for" in Chinese.
7 The translation of "reason" in Chinese.
8 The translation of "as" in Chinese.

to the specified changes. As shown in Table 21, the 6 reasons were sorted in ascending order of occurrence. Two students indicated their changes in using notebooks (one started to notice the influence of using it on the enhancement of basic knowledge while the other did not clarify the change) was because they took it as a supplement to what they learned in class.

Five responses indicated that the frequency of decrease in using textbooks (1), workbooks (1), notebooks (2), and e-books (1) was due to the use of alternative materials; for instance, one student stated the reason as "I rely more on textbooks, hence do not use e-books that much (this term)." Meanwhile another five responses implied that the changes in using textbooks (one student started to use the textbook for preview), workbooks (one did not clarify the change), notebooks (one student began to use the notebook after class) and e-learning systems (one student used e-learning systems more often in the new term while the other one did not clarify the change) were on account of students' wishes to improve their learning of mathematics.

Table 21. The occurrence of the reasons behind the change in resource use (Shanghai)

Reasons	Textbook	Workbook	Worksheet	Notebook	Reference book	Ebook	Teaching video	Elearning system	To tal
Supplement	0	0	0	2	0	0	0	0	2
Alternative	1	1	0	2	0	1	0	0	5
Improvement	1	1	0	1	0	0	0	2	5
Teaching	4	0	2	2	1	0	0	0	9
Workload	2	4	1	2	0	1	0	0	10
Difficulty	1	2	1	1	5	1	1	2	14
Others	0	0	1	1	0	0	0	2	4
Total	10	8	6	13	8	3	1	6	54

More students attributed the changes in using the resources to the teacher's instruction. Specifically, nine responses clearly pointed out that teacher's teaching was the reason for the changes: four of them were related to the frequency of using the textbook, two were about the frequency of using worksheets, two referred to the use of notebooks but did not specify the change, and one mentioned the frequency decrease of using reference book (e.g. "the teacher helps me to remember the knowledge in class, hence I use the reference book less frequently"). In the meantime, another ten responses explained the changes in using those learning resources with increasing workload at the new year level: two of them were related to the increase in the time of using textbooks, four explained that the changes in using workbooks involved the changes in time duration (e.g. "I use workbooks for a longer time since the school assigned one more book for homework, I have more homework"), and the change of purpose and frequency (e.g. "I used to do nothing but now I use it for doing more exercises"), one referred to the increase of the time of using worksheets while another one was the decrease of frequency of using e-books, and two of the responses mentioned that the students relied more on notebooks as "there are more things that need to be written in the notebook."

The most cited reason for the change in resource use was students' awareness of the difficulty of learning mathematics at a higher year level. The fourteen responses spreading over all the eight resources were related to the increase of time and frequency of using those resources; for example, “since I’ve been at a higher year level, there is an increase in difficulty (of learning mathematics), I use reference books, e-books, teaching videos, and e-learning systems more frequently” and “there are many questions that I cannot solve so I need to find more exercises from reference books.”

6.2 The factors that may influence students’ use of learning resources in mathematics

According to the conceptual framework, this study takes into account two social aspects, including out-of-school lessons and parental involvement, one didactical aspect, namely, teacher instruction, and four cultural aspects, involving beliefs about the authority of textbooks, beliefs about doing exercises, beliefs about the pressure of examinations, and beliefs about the attribution of success and failure in mathematics learning, as the factors that may have some impact on students’ use of different resources in their learning of mathematics. This section is to depict an image of the context regarding those factors in Shanghai. The associations between the factors and students’ resource use will be presented in Chapter 8.

Out-of-school lessons

The survey inquired whether students had out-of-school lessons organised by commercial companies, which could be called “cram schools”, or studied with private tutors, and for what length of time per week in that academic year.

In Shanghai, as shown in Figure 23, two-thirds of the students attended out-of-school lessons organized by commercial companies in their after-school time, and half of them spent more than 1.5 hours every week. Moreover, nearly 30% of the students indicated that they have a private tutor for mathematics, while 17.3% spent more than 1.5 hours with their tutors on mathematics learning every week.

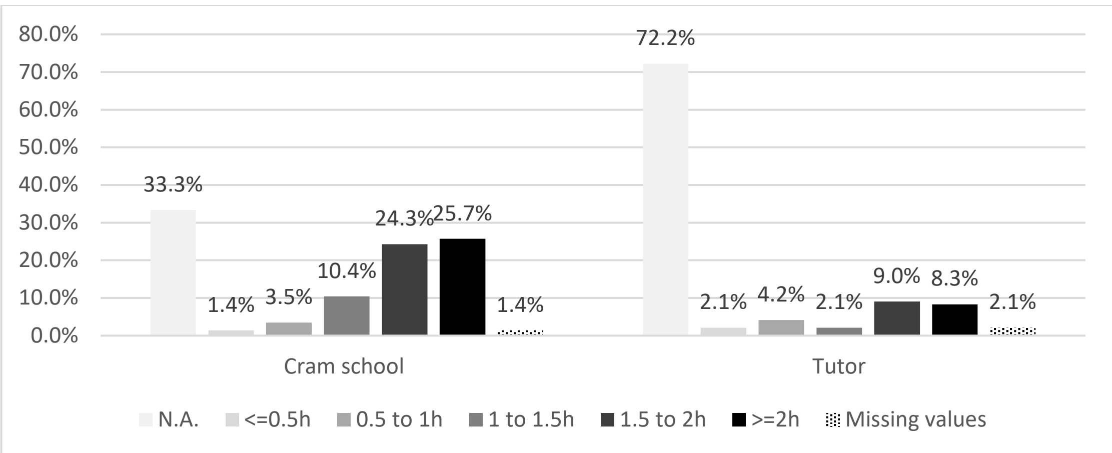


Figure 23 Percentage distribution of Shanghai students who attended out-of-school lessons

Parental involvement

Figure 24 presents the results of the data collected from 144 Shanghai students. About 90% of the students indicated that their parents checked their learning progress in mathematics and more than one-fourth stated that the frequency was higher than 5 times a week. In all, 62.5% of the students said that their parents did help with mathematics homework, most of which were at the frequency of 2–3 times a week. Around 80% of the students pointed out that their parents asked them to do "non-school-related" exercises in mathematics; specifically, 38.9% did the extra practice at the frequency of once a week or less, 18.8% were at the frequency at 2–3 times a week, and 20.8% of them did them 4–5 times a week or more. Moreover, nearly 82% of the students indicated that their parents bought them resources to learn mathematics that term, which mostly happened less than once a month (36.1%).

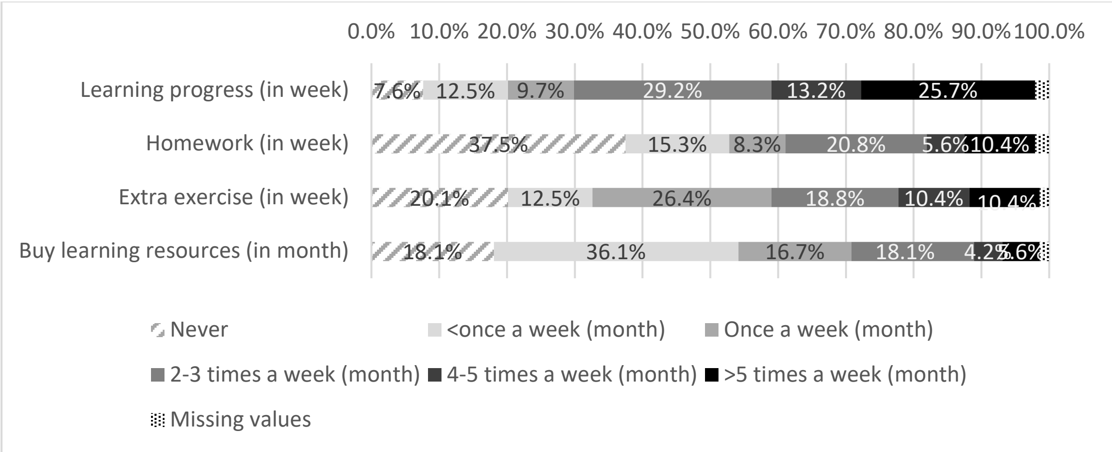


Figure 24 Percentage distribution of Shanghai's parents who got involved in their children's mathematics learning at different frequencies (student survey)

For the purpose of triangulation, the same questions were asked in the parent questionnaire as well. Figure 25 presents the result of 152 parents' responses. Compared to Figure 24, the distributions from parent survey have some similar "key features"; for instance, more than 90% of the parents indicated that they were concerned about children's learning progress in mathematics, the most common frequency of checking the progress was at 2–3 times a week, around 10% of the parents said that they helped with children's mathematics homework more than 5 times a week, and not many parents (fewer than 5%) bought resources for their children to learn mathematics very frequently (4–5 times a month or more), which are the examples proving that a coherence exists between parents' and students' responses.

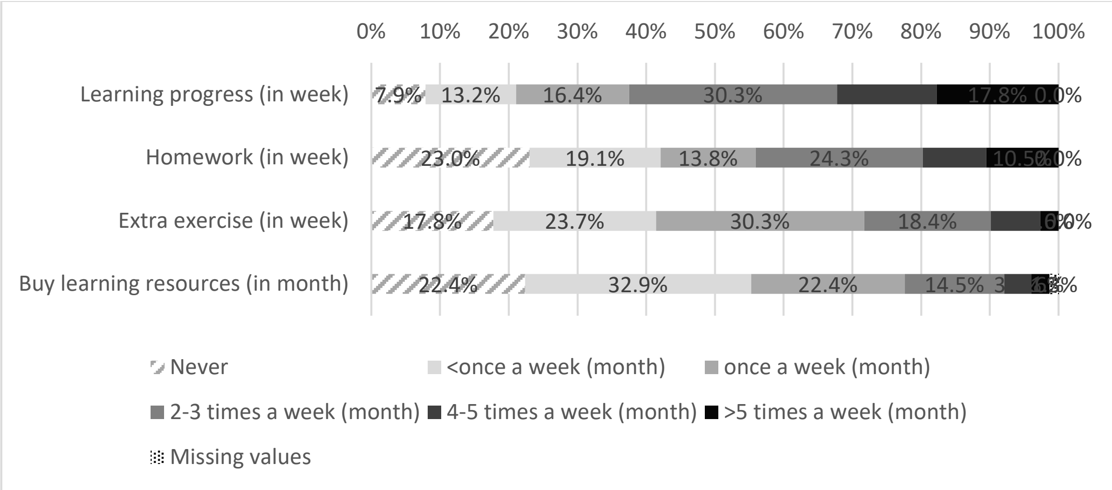


Figure 25 Percentage distribution of Shanghai's parents who got involved in their children's mathematics learning at different frequencies (parent survey)

Chi-square tests further confirmed that there was no significant difference between students' and parents' answers in terms of how often parents checked children's learning progress in mathematics, how often parents helped with children's mathematics homework, and how often parents bought learning resources for children to learn mathematics. However, when it came to parental involvement by assigning extra exercises to children, there were some different voices from students and their parents. Compared to students' responses, more parents thought that they did not often ask children to do additional practice. The results showed that the difference was significant at the 0.05 level (2-sided).

Table 22. Results of Chi-square test of the difference between students' and parents' responses to parental involvement in mathematics learning

	Learning progress	Homework	Extra exercise	Buy learning resources
χ^2	4.809	9.472	13.511	4.281
df	5	5	5	5
Sig.[1]	0.440	0.092	0.019	0.510
N[2]	293	293	294	292

1. Asymptotic significance (2-sided).
2. Number of students' and parents' responses excluding the missing values.

Teacher mediation

The teacher questionnaire collected the data in regard to the frequency, timing, purpose, and access with which the teacher instructions incorporated students' use of learning resources in mathematics. According to teachers' responses, the main learning resources used by students under teacher instruction in mathematics were paper-based resources including workbooks, textbooks, notebooks, and worksheets, which corresponds to a great extent with students' reports.

Specifically, all the six teachers said that their students were required to use workbooks almost every school day per week, four of them from schools A and B stated that workbooks were used by students both in and after class while teachers from school C only asked students to use workbooks after class. For textbooks, teachers from schools A and C indicated that they asked students to use mathematics textbooks more than 4 days per week, but teachers from school A instructed their students to use them both in and after class teachers from school C only asked students to use them in class, and teachers from school B pointed out that their students were supposed to use textbooks at the frequency of 2–3 days per week in class. Also, teachers from school B said that they asked students to use notebooks 4–5 days per week in class, teachers from school A stated that they asked students to use notebooks in and after class almost every day including weekends, while teachers from school C showed that notebooks were not necessary in their classrooms but they instructed students to use worksheets in class very frequently (6–7 days per week) including weekends.

When it came to worksheets, teachers from schools A and B used them in their classroom just 2–3 days a week, and the grade 8 teachers asked students to use them both in and after class while the grade 7 teachers just guided students' work on them in class. Moreover, teachers from school A and one teacher from school C stated that they suggested students use reference books after class at the frequency of 2–3 days a week. For e-learning resources, only one teacher from school A said that he sometimes asked students to use e-learning systems after class, and no other teachers explained that they required students to use any e-resources in mathematics learning.

Furthermore, all the teachers required their students to use workbooks mainly for in-class learning and exercises (not the case for teachers from school C), revision, and doing homework. For textbooks, teachers from schools A and C indicated that they asked students to use textbooks for preview, in-class learning and exercises, and revision, and some of them also encouraged their students to look up definitions and examples in mathematics textbooks and assigned homework from textbooks. Teachers from school B responded that they only asked students to use textbooks for in-class learning and exercises. For worksheets, all the teachers asked their students to use them for revision; particularly, teachers from school C also asked students to use them for in-class learning, and looking up definitions, theorems, and formulas; one of them additionally required students to use worksheets for preview and looking up examples, and teachers from school A used worksheets for assigning homework in the meantime. For notebooks, teachers from school C indicated that their students were not required to have them in mathematics learning, teachers from school B only asked their students to use notebooks for in-class learning and exercises, while teachers from school A applied notebooks widely to mathematics learning, including preview, in-class learning and exercises, revision, and looking up definitions, theorems, formulas, examples, and answers. For reference books, three of the teachers (two from school A and one from school C) stated that the students were only supposed to use them for revision. For e-learning systems, the teacher from school A said that he asked students to use them for preview, revision, and looking up definition, theorems, and formulas.

When asked how their students usually gained access to the learning resources, all the teachers indicated that schools bought students textbooks and workbooks, and four of them implied that schools also provided worksheets for students while the other two teachers made worksheets themselves. It is natural for students to buy their own notebooks in Shanghai and teachers from school A indicated that students also bought themselves reference books, while one of the teachers from school C said that her school provided students reference books for free. Also, the teacher from school A who had students using an e-learning system pointed out that they just directly went to the publisher's website for using the resource, which was free.

For interviews and classroom observations, Table 23 summarizes the information of the participants so that the results can be presented according to the codes of the teachers.

Table 23. Information of Shanghai teachers involving in interviews and classroom observations

Teacher[1]	School	Grade	Gender	Year of teaching	Topic of the observed lessons
T1	A	7	Male	10	Like Terms
T2	A	8	Female	17	Quadratic Equation
T3	B	7	Female	18	--
T4	B	8	Male	10	--
T5	C	7	Female	3	$a^m \cdot a^n = a^{m+n}$
T6	C	8	Female	4	Quadratic Equation

1. Ti, i=1, 2 … 6, is the code of different teachers.

Lesson and interview of T1

This lesson was the second lesson to deliver the concept of "like terms". Students were supposed to recognize like terms in an expression and be able to do the relevant calculations after the lesson. During the observation, many of the students put the textbook on their desks but did not use it and even the teacher did not mention it during the lesson. T1 explained:

> *…actually it's their habit in primary school, they did not need to use their textbooks in primary school so they are not yet used to using them though I really encourage them to do so. Even if they don't open it in class, I often ask them to put it on the desk and use the textbook after class or when doing homework…*

Almost all the students used notebooks to write exercises in as their teacher asked them to do so and some of them also took down some key points that they thought important. T1 also talked about his opinion of using notebooks:

> *…I require them to take notes in my lessons because students can really think about the question while writing and review what they learn by taking the book back home. I know there are other teachers who think that taking notes takes a lot of time for some students and they may not follow the lesson if they write things more slowly than others. So every teacher has his own consideration of whether to ask students to use notebooks.*

It is worth mentioning that when doing in-class exercises, the teacher firstly left enough time for students to think about the question, and then asked one student to solve it on the blackboard, finally corrected the student's work, and demonstrated or summarized the whole procedure, which was actually a teacher-led activity.

When asked about the resources used for homework, T1 answered:

> *…students have three workbooks, one is the accessory of the textbook, which we seldom use for homework, sometimes we may use it as in-class exercises or the exercises that students are supposed to complete at mid-day breaktime. The other two are provided by our school and the local authority respectively. The one provided by the local authority is the resource used daily for assigning homework.*

When asked about the use of worksheets, T1 mentioned:

> *…we don't use worksheets very often since those (workbooks) are enough…sometimes worksheets are used for tests, and when preparing for the final examination, we usually give them worksheets to do more exercises and revision…*

Also, T1 explained his thought about the influence of using the paper-based resources on the improvement of students' mathematics learning:

> *…textbooks are very important in learning mathematics since there are knowledge and concepts. Students cannot always remember everything they learned in the lesson, so they need to use textbooks if they forget. We require them to memorize some important concepts as there will be questions like "which concept is wrong?" in examinations…if students cannot solve the problems in homework, they also can refer to the examples in textbooks, which demonstrate the normal solutions.*
>
> *…textbooks are the origin and provide basic things, then you need to enrich them with exercises…sometimes students cannot understand some complicated concepts though we have explained many times, but they can gradually understand them by doing exercises in workbooks.*
>
> *…textbooks also demonstrate the format and procedures of solutions related to reasoning problems…*

In T1's lesson, notebooks were the resource mostly used for in-class learning and exercises, workbooks were used for homework, and textbooks and worksheets usually were used after class for revision, according to his instruction and interview. In T1's opinion, textbook use positively influenced students' learning of mathematics knowledge and the improvement of reasoning ability, and the use of workbooks also helped students better understand the knowledge.

<u>Lesson and interview of T2</u>

This lesson was the first lesson to introduce the concept of quadratic function. Students were supposed to explore and understand what quadratic function is, normalize quadratic functions, know the coefficient of every term in a quadratic function, understand the meaning of root, decide whether a number is the root of a function, know the differences in root between linear function and quadratic function, and know the features of a quadratic function with one root of 0, 1, or -1. During the observation, students put the textbook on their desks but not many opened it in the lesson. T2 explained:

> *…actually I often ask them to open textbooks in revision lessons, but just for concepts instead of exercises. The examples and exercises used in lessons are normally not just from textbooks.*

In fact, many of the in-class exercises were simple so students could answer immediately without any paperwork, but when they could not, some students opened textbooks to look up answers. The teacher also required students to write some exercises down in their notebooks, left time for them to solve by themselves, and asked several students to do the exercises on the blackboard, and marked and commented on their work on the blackboard. In the interview, T2 gave more details of that:

> *…and I require them to preview the knowledge with textbooks and finish relevant exercises posed in textbooks at home before I give the lesson, so they can easily answer many questions when they come to the lesson.*
>
> *…I do not require them to write down every single word of what I write on blackboard, but I think they can take notes on something not in textbooks or emphasized by the teacher.*

Similar to T1's responses, the workbook provided by the local authority was usually used for assigning homework and the other two workbooks were mostly used in revision lessons. When asked about worksheets, T2 explained:

> *Sometimes we will distribute worksheets to the class in revision lessons for saving time in copying questions.*

Also, T2 also talked about reference books:

> *… last year, parents asked me to recommend reference books as a supplement resource so that they could buy for their children.*

When asked about the influence of using different resources on students' mathematics learning, T2 said:

> *…workbooks help them make their knowledge base solid and improve the fluency of calculating...textbooks show them the normal process of reasoning.*

Therefore, in T2's lessons, notebooks were mostly used by students for in-class learning and exercises, workbooks were mainly used for assigning homework, and textbooks and worksheets usually were used beyond the classroom for preview and revision according to her instruction and interview. In T2's opinion, the use of workbooks positively influenced students' learning of mathematics knowledge and skills while textbook use helped with the improvement of reasoning ability.

Interview of T3

T3 gave some different perceptions of textbook use in mathematics learning:

> *I do explain examples posed in textbooks in my lessons, but they are relatively simple and basic. I must add other examples and exercises, which are integrated into my slides so I do not require students to open their books in my lessons. Actually, textbooks seem to be not that useful to students, they are simple.*

When asked about the resources that students usually used in her lessons, she explained:

> *…they use notebooks, but I don't ask them to write down concepts since those are printed in their books, I often ask them to take notes of examples and my solutions.*

Also, workbooks were mainly used for assigning homework while worksheets were mostly used for revision before end-of-term examinations according to her responses.

T3 also talked about the reasons why reference books and e-resources were hardly used by students in her class:

> *…I am not allowed by the school to recommend any reference books to my students unless parents contact me privately and ask for my recommendation…*

> *…on the one hand, we don't have time to produce any self-made e-resources, and on the other hand, the school doesn't provide such opportunities for students to use them.*

Interview of T4

Similar to T3, T4 also asked students to take notes in his lessons, assigned homework with workbooks, distributed worksheets to students as preparing for examinations, and could not suggest any reference books unless parents asked for that privately. When it comes to textbook use, T4 explained:

> *All contents in textbooks will be used in my lessons…generally, I put examples and exercises on slides so they (students) don't need to open their books in class.*

Furthermore, he mentioned that students in his school have two workbooks: one is associated with textbooks while another is edited and provided by the school.

Lesson and interview of T5

This lesson was the first lesson to introduce the multiplication of powers with the same bases. Students were supposed to understand the concept, explore the rule of multiplication of powers with same bases, master and apply the rule of the multiplication, and experience the mathematical thinking from specific examples to general rules. During the observation, students had textbooks on their desks and a few of them read the books when the teacher was demonstrating her slides.

The teacher distributed worksheets to every student as the class began and asked them to do the well-structured exercises printed on the sheets according to her teaching process, hence students did not use their notebooks in the lesson. It is worth mentioning that T5's instructions for using worksheets were very explicit, such as: "*…write down this concept in the blank*", and "*…now complete example 2 on your worksheet*". T5 provided more details in the interview:

> *…we prepare the worksheets together with all other teachers at the same grade level…we have to consider that students need to copy the question before solving it. The content in this lesson seems fine, but when it comes to other topics including application questions, it may take lots of time to copy questions. Therefore, worksheets seem better, we can leave blanks for students to take notes and get the questions ready to save time at the same time. That is the reason why we don't use notebooks…*

Thus, most of the students did not use other resources in addition to worksheets in class. As T5 mentioned, those worksheets were produced by a group of teachers and nicely adapted to their teaching processes, which usually contained an abstract of the lesson, statements of concepts and knowledge with blanks to be filled in, and plenty of selective exercises. In this lesson, T5 did not have enough time to let students finish all exercises posed on the sheet, which seemed to be a common situation:

> *…yes, students were asked to complete all the exercises left on their worksheet in school. So they usually do that during lunch break and bring it to me, I mark the papers and give them feedback before they go home…they also can use the worksheets for revision.*

The facts that only a few students used textbooks and the teacher did not incorporate textbooks in her teaching during the observation were explained:

> *I ask them to use textbooks before lessons, to preview what we are going to learn, read the texts, mark the concepts, and complete the exercises in textbooks; actually, they always refer to textbooks when they get stuck in homework, which is the main situation for incorporating textbooks.*

Though they rarely used textbooks in class, T5 mentioned the helpfulness of textbooks in improving students' mathematics knowledge and incorporated them in after-school study. Also, the workbook provided by the local authority was used daily to assign homework, which positively influenced students' mathematical abilities according to T5's response.

In short, in T5's class, textbooks were supposed to be used beyond lessons for preview and helping with homework, worksheets were the main resources used for in-class learning and exercises as well as revision purposes, and workbooks were used for assigning homework.

<u>Lesson and interview of T6</u>

This lesson was also the first lesson to deliver the topic quadratic equations, which set teaching objectives which were almost the same as T2's lesson. During the observation, students put textbooks and workbooks on their desks but they hardly opened those books during the lesson. Similar to T5's class, students received the teacher-made well-structured worksheets at the beginning of the lesson, which were the only resource that students worked with in that lesson, and the teacher also gave explicit instructions when she asked students to use the worksheets: "*you have 30 seconds to write down the coefficient names of every term in a general quadratic function on your sheet*". Moreover, T6 was in the same situation as T5 in terms of why they used worksheets instead of notebooks in lessons, who made the worksheets, and how to incorporate them into students' mathematics learning.

Workbooks were also used to assign homework. T6 provided details of textbook use and emphasized the importance of textbooks in mathematics learning:

> *T6: …I think textbooks are more important to students compared to workbooks.*
>
> *Interviewer: But you did not let students use them in your lesson, did you?*
>
> *T6: …did not use them today because I did not have enough time in the end. I often ask them to open the book and help them mark key concepts in ordinary lessons since some students pay much more attention to exercises compared to knowledge and concepts. For example, $a \neq 0$ is a very important condition to the concept of quadratic equations in today's topic, some students may ignore it while it is mentioned in textbooks…I also expect them to use textbooks when they're doing homework.*

Therefore, in T6's class, textbooks were supposed to be used both in and after class for looking up definitions, worksheets were the dominant resources for in-class learning and exercises as well as revision, and workbooks were mostly used to assign homework, just as T5 did in her lessons.

Beliefs

In questionnaires, the cultural factor that may influence students' resource use refers to some relevant beliefs embodied in twenty statements in questionnaires. Abstracted from different literature, some statements were in favour of Chinese views and some reflected the beliefs from western or English perspectives as shown in Table 24. Participants were asked to choose from "strongly disagree", "disagree", "agree", and "strongly agree" to represent their attitudes towards the statements.

Table 24. Statements describing different attitudes of the beliefs

Beliefs about the authority of textbooks in mathematics learning		
1.1	Textbooks always present the most elegant and simplest, namely, the best way to solve problems.	C[1]
1.2	Textbooks always present the right things, therefore, they are trustworthy.	C

1.3	Textbooks always follow essentially the curriculum, which is a guideline for passing examinations.	C
1.4	The teacher seems unreliable if she/he always follows the instructions posed in textbooks.	E[2]
1.5	Textbooks are just a source of exercises, I do not care about what textbooks say about mathematics in other parts.	E
	Beliefs about doing exercises in mathematics	
2.1	Doing maths exercises is boring.	E
2.2	Doing exercises is just a repeat of practice with fixed steps.	E
2.3	Doing exercises is an efficient way that helps me better understand mathematics knowledge.	C
2.4	Practice makes perfect.	C
2.5	Doing exercises is not good for developing creativity.	E
	Beliefs about the pressure of examination	
3.1	I have to work hard because there are lots of examinations ahead of me.	C
3.2	Achieving good marks is the most important thing of learning mathematics in schools.	C
3.3	It will upset me very much if I do not do well in mathematics examinations.	C
3.4	A good mark is the only way to a bright future.	C
3.5	Others (e.g. peers, teachers, and parents) are likely to judge me with my examination performance.	C
	Beliefs about the attribution of success and failure in mathematics learning	
4.1	Hard work can make up the lack of natural ability in mathematics.	C
4.2	Everyone is born with different gift and talent, so it seems fine if mathematics is not one of the things that I am good at.	E
4.3	A success or failure in the learning of mathematics mainly depends on how hard one works.	C
4.4	A success or failure in the learning of mathematics mainly depends on one's ability and interests.	E
4.5	The most important thing in schools is to develop one's gift and talent rather than to focus on the things that I am not good at.	E

1. In favour of Chinese views
2. In favour of English or western views.

As depicted in Figure 26, the result of whether the 144 students agreed with the statements provides evidence for the belief about the crucial role of textbooks in mathematics learning from Chinese perspectives. For the three statements in favour of Chinese views (1.1–1.3), a large percentage of the students chose the positive side, most of them (79.9%) agreed that textbooks always present the most elegant and simplest way in solving problems, 64.6% of the students thought textbooks were trustworthy, and 86.8% of the students believed that textbooks adhered to the national curriculum, which were helpful for passing examinations. For the other two statements, almost all the Shanghai students (90.2%) disagreed or strongly disagreed that textbooks were "only a source of exercises", whereas they seemed much less determined when it came to the other statement: 54.8% chose the negative side while 44.4% were on the positive side agreeing that the teacher seemed unreliable if she/he always followed what textbooks said.

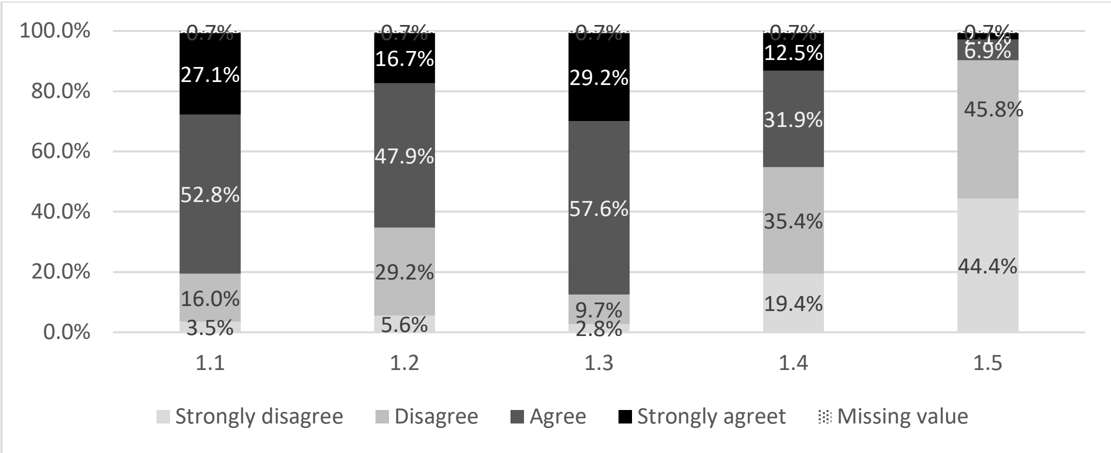


Figure 26 Percentage distribution of Shanghai students' beliefs about the authority of textbooks in mathematics learning

For doing mathematics exercises, the responses from Shanghai students confirmed what the literature summarized about practice and doing exercises in mathematics to a great extent (see Figure 27). For the three statements in favour of western views (2.1, 2.2, and 2.5), 80.6% of the students disagreed or strongly disagreed that "doing maths exercises is boring", 64.6% of them did not support the idea that "doing exercises is just a repeat of practice with fixed steps", and 76.3% disagreed or strongly disagreed that "doing exercises is not good for developing creativity", while for the two statements in favour of Chinese views, almost all the students (95.2%) agreed that "doing exercises is an efficient way that helps me better understand mathematics knowledge" and 89.6% of the students accepted that "practice makes perfect" in their learning of mathematics.

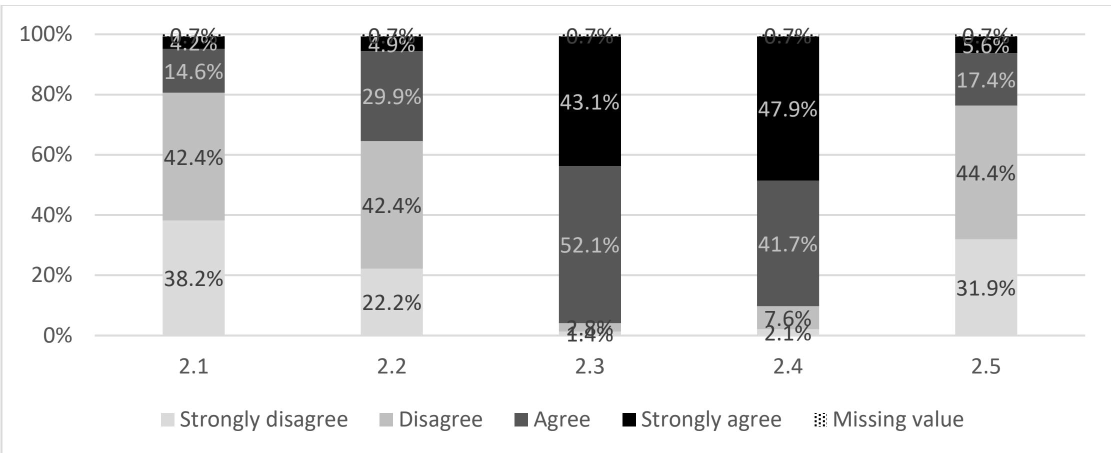


Figure 27 Percentage distribution of Shanghai students' beliefs about doing mathematics exercises

Regarding the pressure of examinations, as depicted in Figure 28, 62.5% of the students agreed or strongly agreed that “I have to work hard because there are lots of examinations ahead of me”, more than 70% of the students believed that “achieving good marks is the most important thing of learning mathematics in schools”, nearly 80% of the students were in favour of the statement “it will upset me very much if I do not do well in mathematics examinations”, and 57.7% of them did think that other people such as their peers, teachers, and parents are likely to judge them by their performance in examinations. However, only a half of the students accepted that “a good mark is the only way to a bright future” though it still accounted for a slightly larger proportion compared to those who disagreed and strongly disagreed with the statement (47.9%).

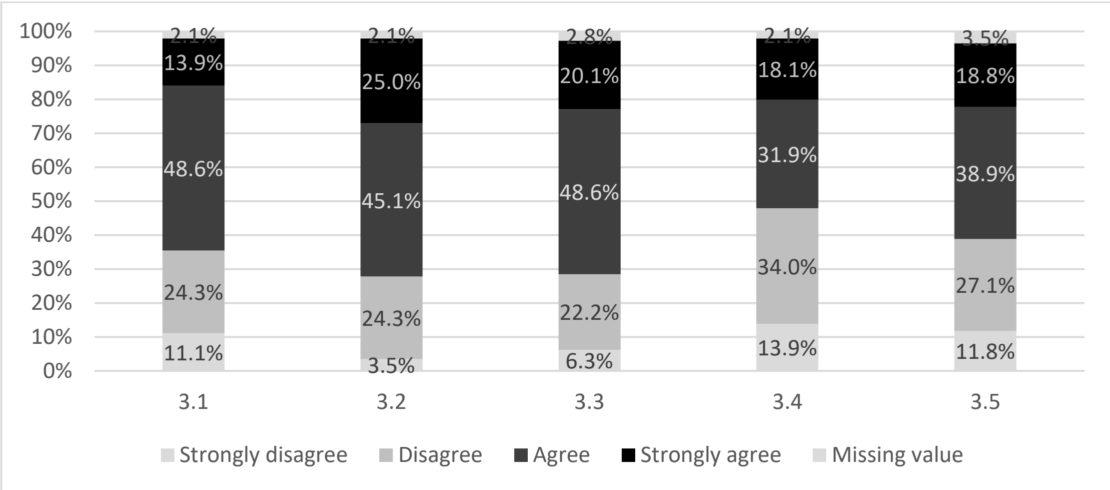


Figure 28 Percentage distribution of Shanghai students’ beliefs about the pressure of examinations

Finally, the result of Shanghai students’ beliefs about why they succeed or fail in the learning of mathematics brings some different voices compared to the literature, as depicted in Figure 29. For the two statements in favour of Chinese views (4.1 and 4.3), 85.4% of the students agreed or strongly agreed that “hard work can make up for the lack of natural ability in mathematics”, and 82% of the students supported the view that “success or failure in the learning of mathematics mainly depends on how hard one works.” For the other three statements, two-thirds of Shanghai students disagreed or strongly disagreed that “the most important thing in school is to develop one’s gift and talent rather than to focus on the things that I am not good at”; however, a large percentage of them (79.2%) accepted individual differences in terms of talent in mathematics learning and (77.1%) also believed that “success or failure in the learning of mathematics mainly depends on one’s ability and interests”, which broke the impression that Chinese de-emphasized individual differences and paid little attention to individual abilities and interests in education.

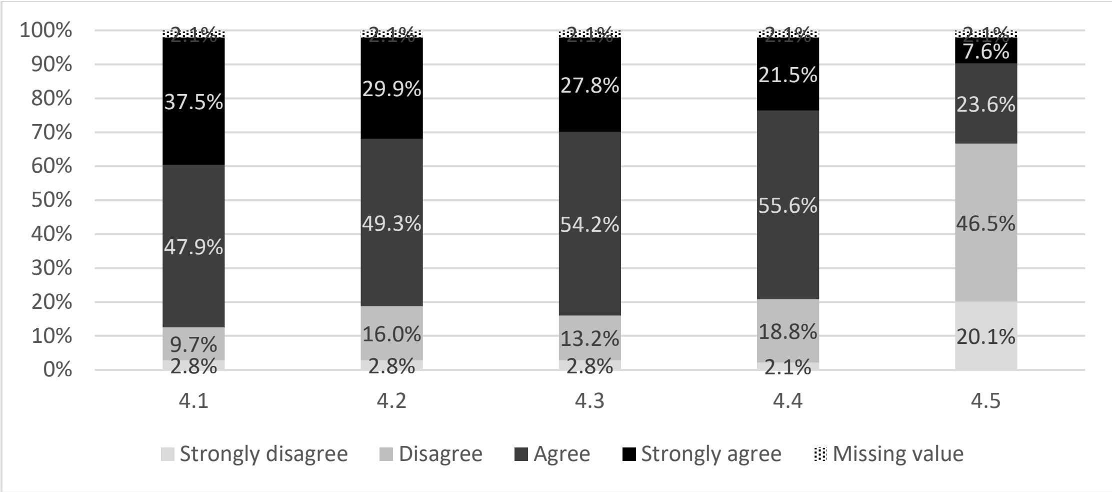


Figure 29 Percentage distribution of Shanghai students' beliefs about the attribution of success and failure in the learning of mathematics

Also, their mathematics teachers' and parents' opinions about the four beliefs involving 20 statements were collected from questionnaires, which were highly consistent with students' responses, especially for the beliefs about the authority of textbooks and doing exercises in mathematics.

6.3 Summary

This chapter reports the findings of how Shanghai students used learning resources in mathematics and the contextual factors that may influence their resource use. Generally speaking, Shanghai students relied heavily on paper-based resources in their mathematics learning, and findings related to the factors to a great extent confirmed the concerns of social, didactical, and cultural contexts mentioned in the literature review.

1. The most-used resources were workbooks, textbooks, notebooks, and worksheets in terms of frequency of use and duration, and these were mainly provided by schools, the local government, and teachers, except for notebooks.

2. Textbooks, workbooks, and worksheets were more likely to be used not only within but also beyond the classroom, while notebooks tended to be used only in class, and reference books were incorporated by a large percentage of students only after class.

3. Textbooks were used the most widely in many learning activities, including preview, revision, in-class learning and exercises, and looking up information. Workbooks and worksheets seemed to have a similar function in terms of the situations they were used for (mainly for in-class learning and exercises and doing homework). Notebooks were mostly used for revision, and reference books were mostly used for doing extra exercises.

4. Students had a strong sense of self-regulation since “it can improve my mark” and “it can help me better understand the knowledge and enhance my mathematics ability” were the most cited motivations for using the resources. Teacher instruction incorporating the use of resources was the second most-quoted motivation for using textbooks, workbooks and worksheets. It is worth mentioning that a large percentage of students used notebooks of their own accord.

5. Students treated the influence of using the resources for their mathematics optimistically (mean scores are all larger than 3); particularly, students seemed to benefit greatly from using reference books.

6. There were not many changes of resource use compared to the previous academic year. The changes mentioned indicated more increases than decreases in frequency of use and duration and alterations of reasons for students’ resource use. The main causes of the changes included students’ awareness of the difficulty of learning mathematics, the increase of the workload, and teachers’ different teaching strategies at a higher year level.

7. A large proportion of students had out-of-school lessons in mathematics, and attending after-school class organized by commercial companies seemed more common among the students, compared to studying with tutors at home.

8. Assisting with homework was not the major way to participate in children’s mathematics learning in addition to checking or discussing learning progress; instead, parents were more likely to be involved in assigning extra exercises and buying learning resources.

9. Teachers had their own ideas of which resources should be used by students in mathematics learning, but workbooks, worksheets, textbooks, and notebooks were still the main choices.

10. Most students trusted their textbooks very much and positively viewed doing exercises in mathematics. Many of them did bear the stress of examinations, and the majority believed that both efforts and talent were important in mathematics learning. The parents’ and teachers’ responses were to a great extent consistent with students’ results.

Chapter 7 Findings of the England Study

7.1 How English students use learning resources in mathematics

In the 150 valid responses to the first section of the student questionnaire, only one pointed out that he used paper-based resources that he could not classify into any of the resources conceptualized by this study, and six of them indicated that they also used some e-resources that did not fit into a well-organized form for mathematics learning, such as Google Images and Wikipedia items. Thus, the category of "other paper-based resources" and "other e-resources" are omitted to provide a concise result.

In general, 70% of the students did not use textbooks at all in mathematics (the students ticked "N.A." for textbook as the answer to every question.) and 87.3% of the students replied that they did not use any reference books. However, all the students incorporated exercise books and worksheets in mathematics learning. For e-learning resources, though most of the students (92%) did not use e-books, a large percentage of them used teaching videos and e-learning systems, with a proportion of 72.7% and 62.7% respectively.

Also, it is worth remembering that though the same structure and content were applied to English questionnaires, there were no "workbook" and "notebook" in the English version since they were integrated and called "exercise book" in English, as explained in Chapter 5.

How frequently?

Figure 30 shows the weekly frequency (including weekends) of using the seven learning resources defined for English students.

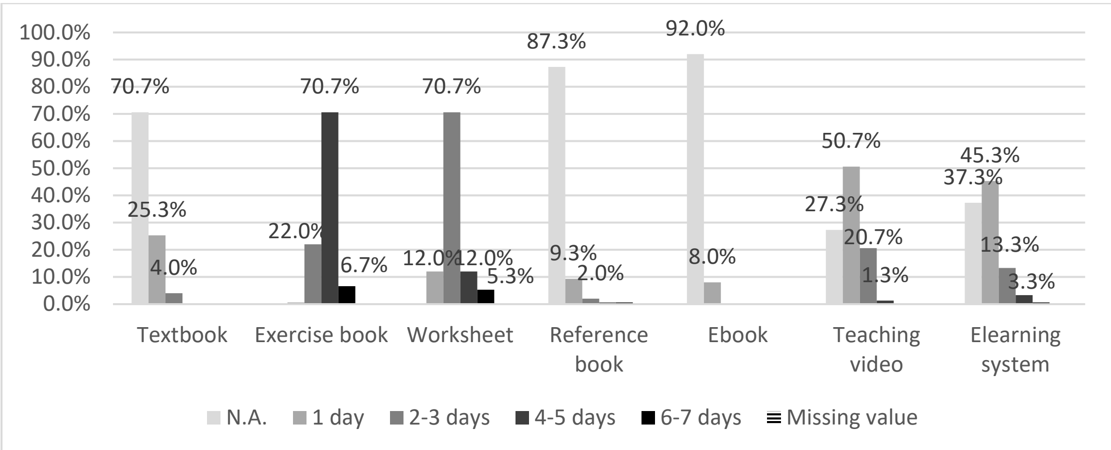


Figure 30 Percentage distribution of English students who used learning resources at different frequencies

According to the legend, the darker colour of the bars shows the more frequently the learning resource was used, which presents a preference for using exercise books and worksheets. To be specific, most of the students (77.4%) indicated that they used exercise books almost every school day and even more. In all, 70.7% of the students used worksheets 2–3 days in a week and 17.3% said that they used them more than 4 days per week. For textbooks, reference books, and e-books, as mentioned above, a large percentage of the students did not use them in mathematics learning. About one-fourth of the students used textbooks 1 day per week, and only a few (4%) used textbooks 2–3 days of a week. The majority of the students used reference books and e-books at the lowest frequency (i.e. 1 day every week). Moreover, the frequencies of using teaching videos and e-learning systems are close: the largest proportion of students (50.7% for teaching videos and 45.3% for e-learning systems) said that they used the two e-resources once a week, some (20.7% and 13.3%) used them more with a frequency of 2–3 days a week, and a few of the students (1.3% and 3.3%) used them almost every school day.

Also, the frequencies were assigned values from 1 to 5 to make them scalable, from the lowest frequency to the highest one so that the mean of the scale can show an average frequency for using those learning resources. The details are shown below:

Table 25. Average frequency of using different learning resources in mathematics (England)

Using frequency	Exercise book	Worksheet	Teaching video	Elearning system	Textbook	Reference book	Ebook
Mean	3.83	3.11	1.96	1.85	1.33	1.18	1.08
N[1]	(n=150)	(n=150)	(n=150)	(n=150)	(n=150)	(n=150)	(n=150)

1. N stands for the number of valid responses excluding the missing values.

Table 25 presenting the average frequency in descending order shows that the dominant resources used by English students in their learning of mathematics were exercise books and worksheets, while reference books and e-books were rarely mentioned by them.

For what length of time?

To know how much time the students spent on different learning resources is to further confirm their preference for the defined resources in mathematics learning. Figure 31 depicts a rough shape of the time spent on each learning resource with five bars. It takes students less time when the shape skews to lighter colours; accordingly, students hardly spent much time on reference books and e-books, while they did spend much time on exercise books.

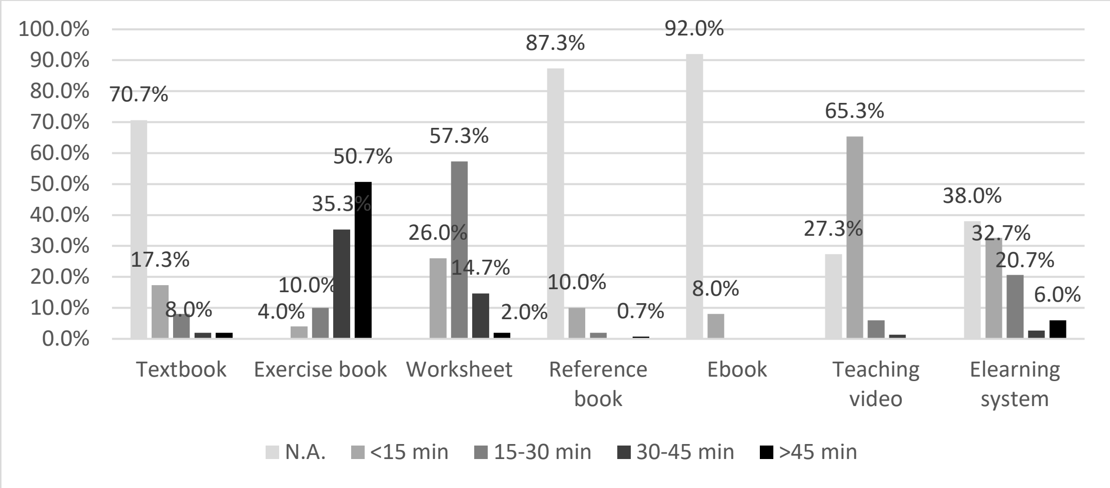


Figure 31 Percentage distribution of English students who used learning resources for different time lengths in a school day that they have mathematics lessons

Moreover, the five time-intervals were assigned values from 1 for "N.A." to 5 for ">45 min", so that an average time spent on each resource can be presented (see Table 26 and Figure 32). The results indicate that exercise books were the resource that English students spent most of their time on; specifically, over half (50.7%) of the students spent more than 45 minutes working in exercise books in a normal school day in mathematics lessons, and the average time spent in exercise books was about to reach the interval of ">45 min". The second most used resource was worksheets, which scored 2.93 on the five-point scale. In fact, the largest percentage (57.3%) of students indicated that it took them 15–30 minutes in an ordinary school day to study mathematics with worksheets. Though the average scores of e-learning systems and teaching videos were close (2.06 and 1.81), most (65.3%) of the students used teaching videos for less than 15 minutes, whereas the proportion for e-learning systems was only 32.7% and many students used the systems more than 15 minutes in a school day according to Figure 31. Also, since textbooks, reference books, and e-books were not commonly used by students in mathematics, their scores fell into the lower set below the interval "<15 min".

Table 26. Average scores of the duration of using different learning resources in a day that English students have mathematics lessons

Duration	Ebook	Reference book	Textbook	Teaching video	E-learning system	Worksheet	Exercise book
Mean	1.08	1.17	1.47	1.81	2.06	2.93	4.33
N[1]	(n=150)	(n=150)	(n=150)	(n=150)	(n=150)	(n=150)	(n=150)

1. N stands for the number of valid responses.

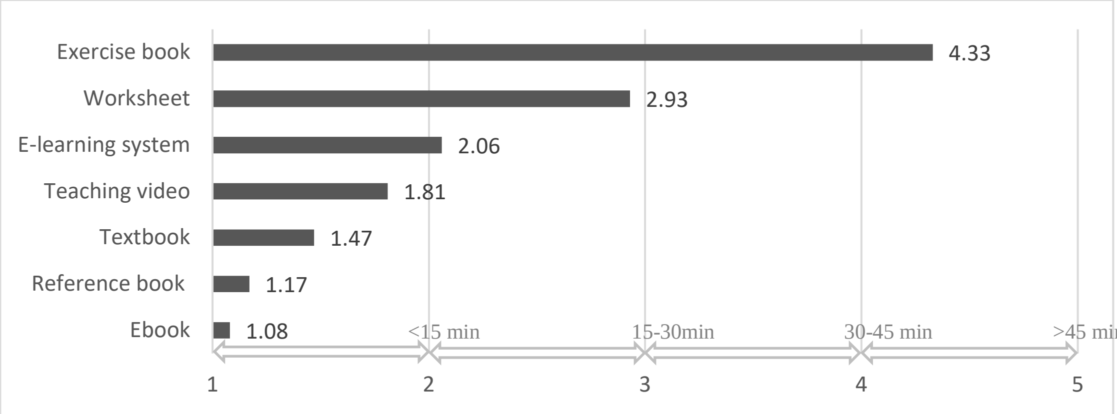


Figure 32 Average scores of the duration of using different learning resources in a day that English students have mathematics lessons

When to use?

Figure 33 shows the distribution of English students who used the defined learning resources at different timings. It is clear that mathematics textbooks were used by students only in class, and the majority (78%) of the students indicated that they used their exercise book only in class as well, while 21.3% used exercise books both in and after class. For worksheets, nearly a half (46%) of the students said that they used them only in class, the other half (47.3%) used them both in and after class and a few used worksheets only after class. The distribution of students who used reference books is more scattered compared to the other paper-based resources: 5.3% of all only used reference books in class, 4.7% used them only after class and 2.7% used both in and after class. When it comes to e-learning resources, the largest proportion (62.7%) of students stated that they used teaching videos only in class while a few of them used videos either after class (4%) or both in and after class (6%); similarly, a larger percentage (30%) of students said that they used e-learning systems only in class while some used them either after class (17.3%) or both in and after class (15.3%). Moreover, a few (4.7%) students incorporated e-books only in class and fewer (3.3%) used them only after class.

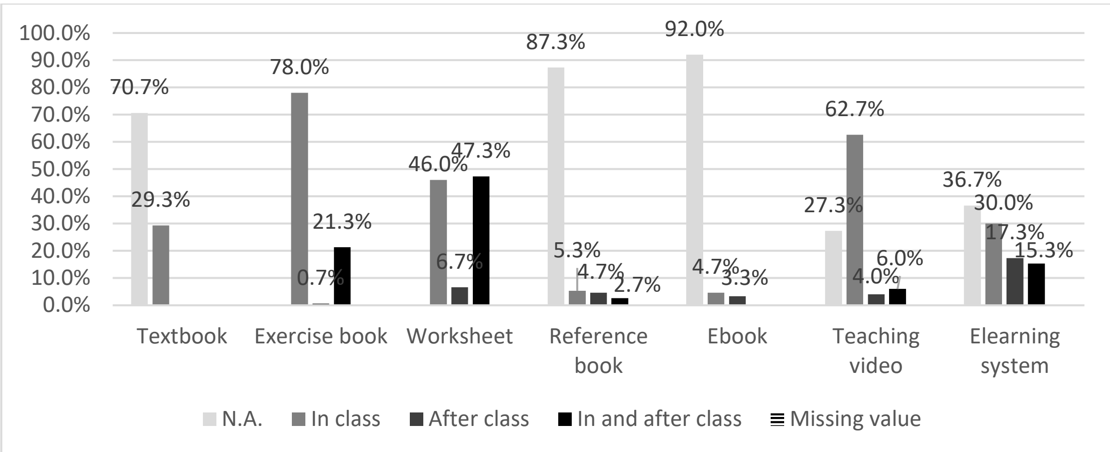


Figure 33 Percentage distribution of English students who used learning resources in different timings

For what reasons?

Figure 34 presents the results of how English students used different resources in mathematics for different purposes constructed by this study, which allowed students to choose more than one option when answering what they usually use a certain resource for.

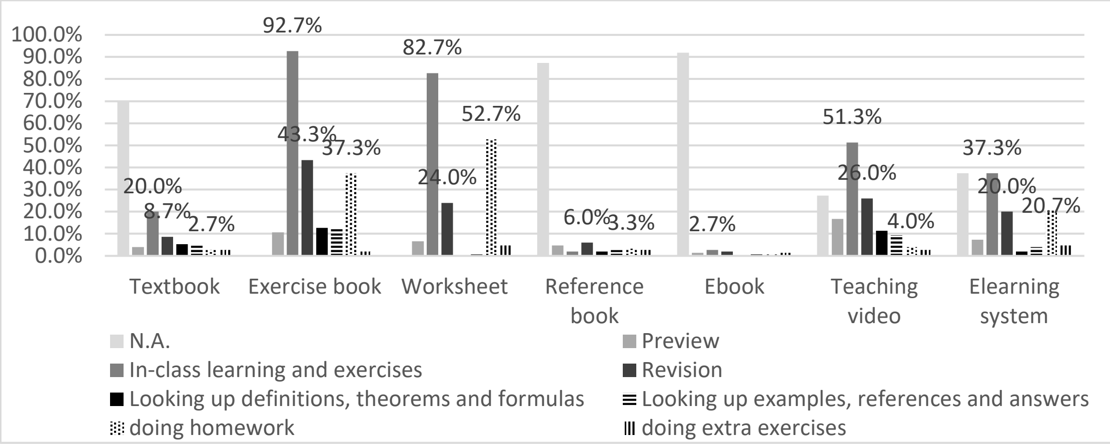


Figure 34 Percentage distribution of English students who used learning resources for different purposes

Firstly, the main activity incorporating mathematics textbooks was in-class learning and exercises, which was agreed by one-fifth of all the student participants in England. Then, some of the students (8.7%) indicated that they also used textbooks for revision, and fewer used textbooks for all the other purposes.

Secondly, the majority (92.7%) of the students used exercise books for in-class learning and exercises, and the other two main activities incorporating exercise books were revision and doing homework, which was affirmed by 43.3% and 37.3% of the students respectively. Additionally, around 12% of the students used exercise books for looking up definitions, theorems, and formulas; meanwhile, the same proportion of them used the books for looking up examples, references, and answers. Comparably, worksheets and e-learning systems were mainly used in similar situations. The largest percentage (82.7% and 37.3%) of students used them for in-class learning and exercises, and the other two main purposes of using the two resources were revision and doing homework, though students were more likely to use worksheets for doing homework compared to revision, since the proportion of the former (52.7%) was over twice as much as the latter (24%).

Also, 6% of the students indicated that they used reference books for revision and 2.7% of the students expressed that they used e-books for in-class learning and exercises, which accounted for the largest proportion of those who did incorporate the two resources in their learning of mathematics.

Additionally, more than half (51.3%) of the students used teaching videos for in-class learning and exercises and 26% used videos when they did revision, which were the largest two proportions of those who used teaching videos to learn mathematics. In all, 16.7% of the students pointed out that they watched the videos for preview, namely, to obtain knowledge before lessons, which was a purpose rarely mentioned by the students for using other resources. Moreover, a few (approximately 10%) students also used the videos for looking up information such as theorems and examples, and fewer (6%) used them for all the other purposes.

When it comes to the motivations interpreting the non-activity-related reasons of students' resource use in mathematics learning, the options listed in Table 14 covered all the possible answers since no other motivations were raised by the participants. Figure 35 shows the results of English students' responses to what drove them to use the defined paper-based resources in their learning of mathematics. It seems that teacher mediation was the major motivation for using textbooks, exercise books, and worksheets, which were mainly provided by schools. Specifically, over half of the students said that they used exercise books (58.7%) and worksheets (51.3%) because their teachers asked them to do so, and the students using textbooks for the same reason accounted for 14%, which was the largest proportion of those who did use textbooks in mathematics learning.

Self-regulation was another important reason for using those resources. Around one-fourth of the students used exercise books and worksheets to better understand mathematics knowledge and skills and to enhance their mathematical abilities, while for textbooks and reference books, the proportion dropped to approximately 9% and 4% respectively, since not many students incorporated these two resources in their learning of mathematics. Similar to that, the percentages of students who identified the relationship between the use of exercise books, worksheets textbooks, and reference books and the improvement of their mathematics marks were 25.3%, 22.7%, 8.7%, and 3.3%.

Moreover, some of the students used exercise books and worksheets because they thought it made them fulfilled when solving some difficult problems in those resources, which accounted for 19.3% and 16% respectively, and some (12%) deemed that the tasks in worksheets seemed interesting so they were glad to work out the solutions. It is worth mentioning that parent-led use was seldom mentioned by the students according to their answers relating to paper-based resources.

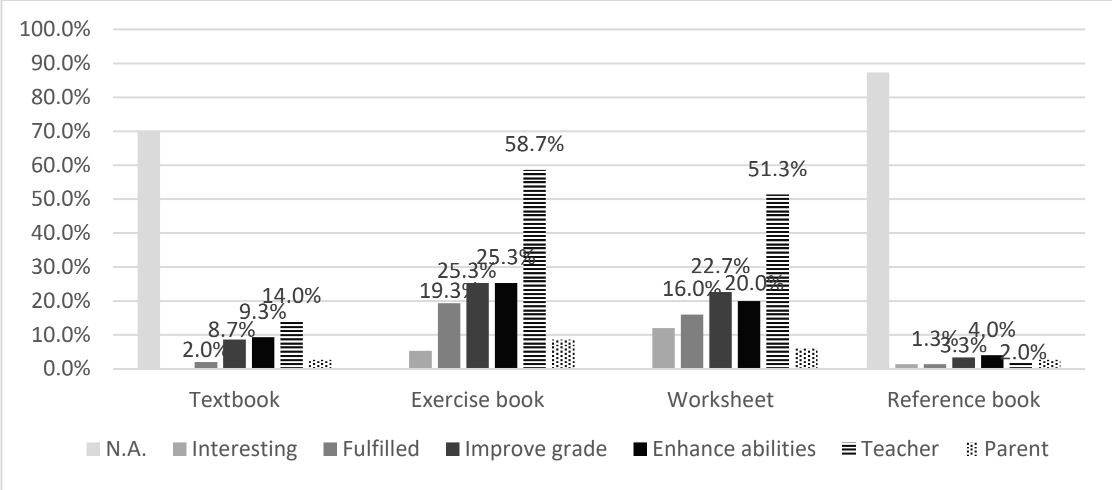


Figure 35 Percentage distribution of English students who used paper-based resources out of different motivations

For e-learning resources, the main motivations for using e-books involved self-regulation and enjoyment. To be specific, 4% of the students used e-books for improving mathematics marks, and 3.3% found it interesting to read e-books, while the primary reasons for using teaching videos were self-regulation and teacher mediation. A total of 26.7% of the students watched teaching videos under their teacher's guidance, 20% of the students incorporated teaching videos in their learning of mathematics for better understanding the knowledge and skills, which was slightly lower than the proportion of those who sought better marks (21.3%). Then the main motivations for the use of e-learning systems were teacher mediation, self-regulation, enjoyment, and parent-supervision, which seem more scattered compared to other resources as the proportions of many of the items were close to each other. In total, 20.7% of the students used e-learning resources under their teachers' instruction, which accounted for the largest proportion of those who incorporated e-learning systems in mathematics. A total of 16% of the students used e-learning systems because the resource benefited them in terms of marks, 11.3% of them used e-learning systems since they thought it could help them better understand the knowledge and enhance mathematical abilities, the same percentage of the students found that it was interesting to interact with software, e-learning platforms, programmes, and systems, and 10% of the students said that their use of e-learning systems was parent-led.

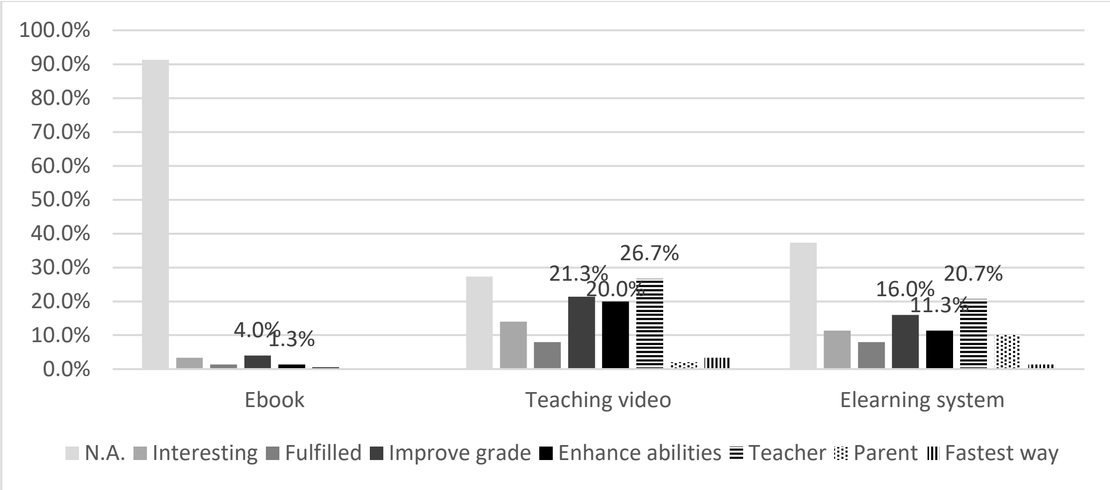


Figure 36 Percentage distribution of English students who used e-resources out of different motivations

How to access?

Figures 37 and 38 show how English students gained access to the paper-based resources and e-learning resources respectively. It seems that the students usually owned free exercise books and worksheets, which were commonly bought by their schools or made by teachers. Specifically, almost all (97.3%) the students pointed out that their schools (or the sponsors) bought them exercise books, a large percentage (61.3%) of the students said their schools also bought them worksheets, some (27.3%) clearly knew that it was their teachers who made the worksheets for them, and some (9.3%) said that the worksheets came from both the schools and their teachers. For textbooks, most (24%) students who did use textbooks in mathematics learning said that they often borrowed them from the classroom, which means that they could not take them home and write anything on the books. According to classroom observation and teachers' interviews, schools normally provided exercise books instead of textbooks because textbooks were so expensive that they could not afford them for every student. Moreover, exercise books were usually kept in classrooms and teachers would allocate them to students when they attended lessons and collect them back when a lesson finished, in which case the students hardly brought exercise books home. While a complement to the textbook, reference books were bought by parents in most cases when the students used them to learn mathematics (6%).

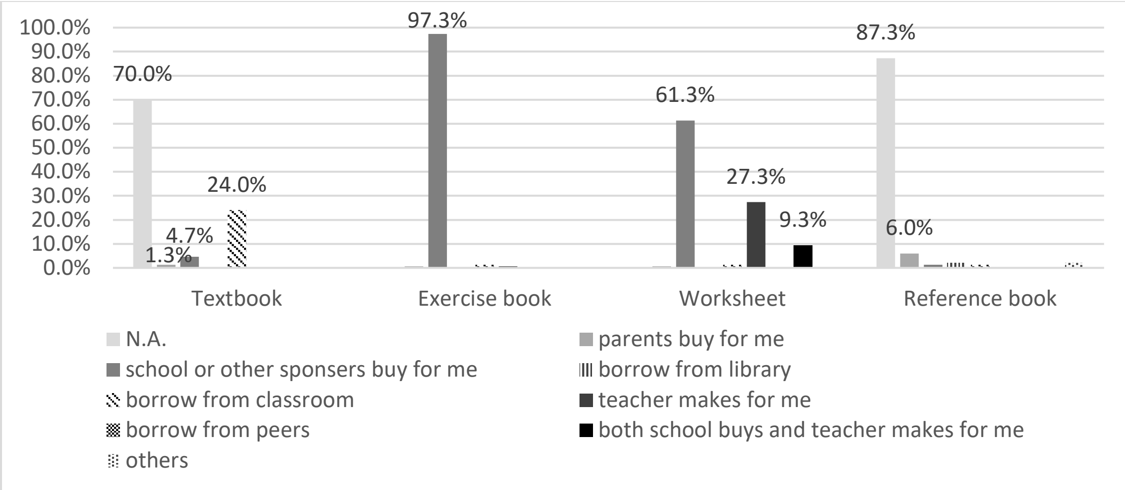


Figure 37 Percentage distribution of English students who gained access to paper-based learning resources in different ways

When it comes to e-learning resources, English students often gained access to teaching videos by searching on Google and going directly to publishers' websites (26.7%), or used what teachers prepared for them (25.3%), while others (12%) used the school website to watch the videos. For e-learning systems, the largest proportion of students (25.3%) who incorporated the resources in mathematics learning indicated that they entered e-learning systems through the school website, a smaller proportion of the students (24%) used Google or the publishers' websites to get into the systems, while a few (6%) said their teachers made the resources for them. Based on classroom observations in school A and teacher interview in school C, the schools did buy access to some e-learning systems and platforms, such as "MyMaths", for their students to learn mathematics online every two weeks in a classroom set up with computers, and the teachers sometimes assigned homework from the systems, which could help them with marking and knowing students' progress better. Also, in the case not many of the students using e-books in mathematics learning, the school website was the main access for them to read the books (4%).

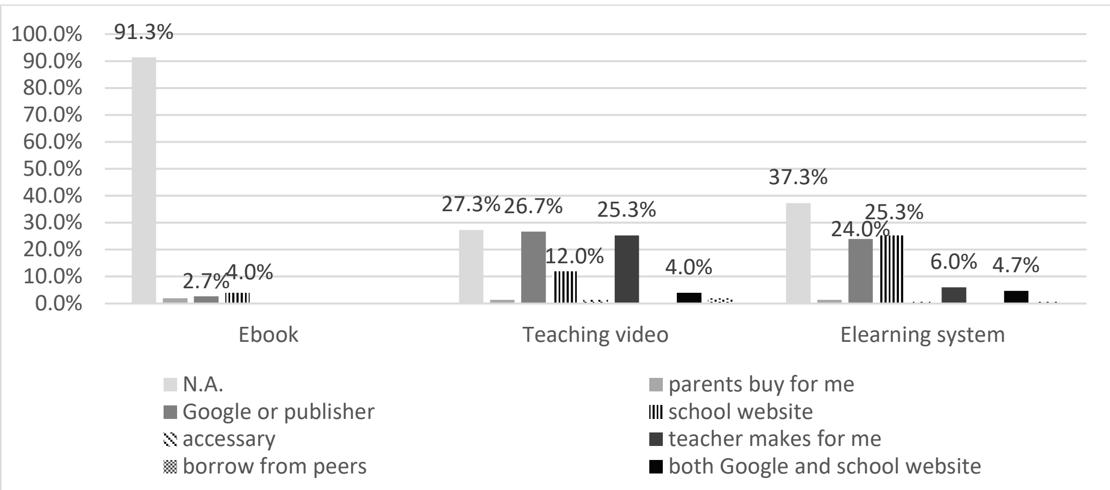


Figure 38 Percentage distribution of English students who gained access to e-learning resources in different ways

Does the use help with learning?

As mentioned earlier, students were asked to evaluate the helpfulness of different learning resources in improving their mathematics knowledge and skills, ability in mathematical reasoning, and ability in problem-solving with a five-item scale in the questionnaire. The items were assigned values of "0" for "N.A." and from 1 for "not helpful" to 5 for "very helpful" in order to obtain average degrees of the influence of different learning resources on mathematics learning. Table 27 presents the mean scores of the helpfulness ratings of the resources in descending order in terms of improving students' mathematics knowledge and skills. It seemed that exercise books were the most helpful resource in the students' view. In addition, worksheets, reference books, and teaching videos positively influenced students' learning of mathematics knowledge and skills, as the mean scores were larger than the neutral position at the value of 3, while the other three resources, textbooks, e-learning systems, and e-books, were less helpful in the students' opinion. Also, it is worth mentioning that the numbers of valid responses to the helpfulness rating of reference books and e-books were less than 15, which might not have the same representation as others.

Table 27. Mean scores of influence of using learning resources on mathematics knowledge and skills (England)

Learning resources	Exercise book	Worksheet	Reference book	Teaching video	Textbook	Elearning system	Ebook
Mean	4.15	3.40	3.14	3.12	2.94	2.85	2.69
N[1]	(n=139)	(n=139)	(n=14)	(n=108)	(n=47)	(n=95)	(n=13)

1. N stands for the number of valid responses excluding the number of those who ticked "N.A.".

Table 28 presents the average degrees in descending order of how the use of different resources helped English students improve their ability in mathematical reasoning. Apparently, the use of exercise books and worksheets contributed to reasoning ability the most in the students' opinion. Then reference books still seemed to play a positive role in improving the ability of reasoning, while the use of teaching videos did not positively influence the students as the mean score was lower than 3. Moreover, the use of textbooks and e-books was regarded as almost the same and scored lower than 3 as well, and e-learning systems had the lowest degree of helpfulness in improving ability in reasoning. Still, it might be more convincing to have more students using reference books and e-books in the samples.

Table 28. Mean scores of influence of using learning resources on the ability of mathematics reasoning (England)

Learning resources	Exercise book	Worksheet	Reference book	Teaching video	Textbook	Ebook	Elearning system
Mean	3.78	3.22	3.14	2.91	2.76	2.75	2.57
N[1]	(n=139)	(n=139)	(n=14)	(n=106)	(n=46)	(n=12)	(n=94)

1. N stands for the number of valid responses excluding the number of those who ticked "N.A.".

Table 29 displays the average degrees in descending order of the impact of using different learning resources on students' ability in problem-solving. Though all the paper-based resources ranked higher than the e-resources, only exercise books were helpful in improving their ability in problem-solving in the students' view, as the ratings of textbooks, worksheets, and reference books were all lower than 3. There were two big differences compared to the result relating to mathematics knowledge and skills as well as reasoning ability: one was that the ratings of worksheets and reference books turned to be on the negative side, and another one was that textbooks ranked second place, which seemed to be more helpful than other resources except for exercise books to boost students' ability to solve problems. However, it still had the same limitation in terms of the size of the sample using reference books and e-books.

Table 29. Mean scores of influence of using learning resources on ability in problem-solving (England)

Learning resources	Exercise book	Textbook	Worksheet	Reference book	E-learning system	Teaching video	Ebook
Mean	3.39	2.93	2.85	2.79	2.66	2.65	2.54
N[1]	(n=138)	(n=46)	(n=137)	(n=14)	(n=94)	(n=106)	(n=13)

1. N stands for the number of valid responses excluding the number of those who ticked "N.A.".

Since the three results of how using different resources influences students' mathematics learning have some similar features, such as exercise books always contributing the most to the three aspects of mathematics learning from the students' perspective, there could be some relationship between the impact of the resources on different aspects of mathematics learning. The correlation examinations verified that point. As shown in Table 30, significantly positive correlations were found between most of the pairs of the impact of resource use on different aspects of mathematics learning with Pearson coefficients.

Table 30. The Pearson coefficients and the significance of the correlations between different aspects of mathematics learning (England)

	Textbook	Exercise book	Worksheet	Reference book	Ebook	Teaching video	Elearning system
	(N=47)	(N=139)	(N=139)	(N=14)	(N=13)	(N=108)	(N=95)
KS-MR	0.563**	0.578**	0.685**	0.751**	-0.004	0.448**	0.566**
KS-PS	0.366*	0.516**	0.440**	0.534*	0.664*	0.422**	0.452**
MR-PS	0.474**	0.467**	0.411**	0.723**	0.411	0.614**	0.393**

KS: mathematics Knowledge and Skills, MR: ability in Mathematical Reasoning, PS: ability in Problem-Solving.
**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Any changes compared to the previous academic year?

Finally, the semi-open question in the student questionnaire investigated whether English students had changed their way of using the resources in mathematics learning compared to the previous academic year, what the changes were, and why the changes happened. Firstly, Figure 39 presents the results of whether they changed their way of using different learning resources.

The computation for each resource excluded the number of those who did not incorporate the corresponding resources in their learning of mathematics. The figure suggests different degrees of the change in students' resource use in mathematics learning. A majority (71.4%) of the students changed their ways of using e-books in the new academic year, and more than half (57.1%) of the students used textbooks in different ways compared to their lower year level. Moreover, around 40% of the students made some changes when they watched teaching videos (46.7%), interacted with e-learning systems (39.1%), and read reference books (38.9%). A smaller percentage of the students indicated that they used exercise books (25.2%) and worksheets (30.9%) differently this academic year.

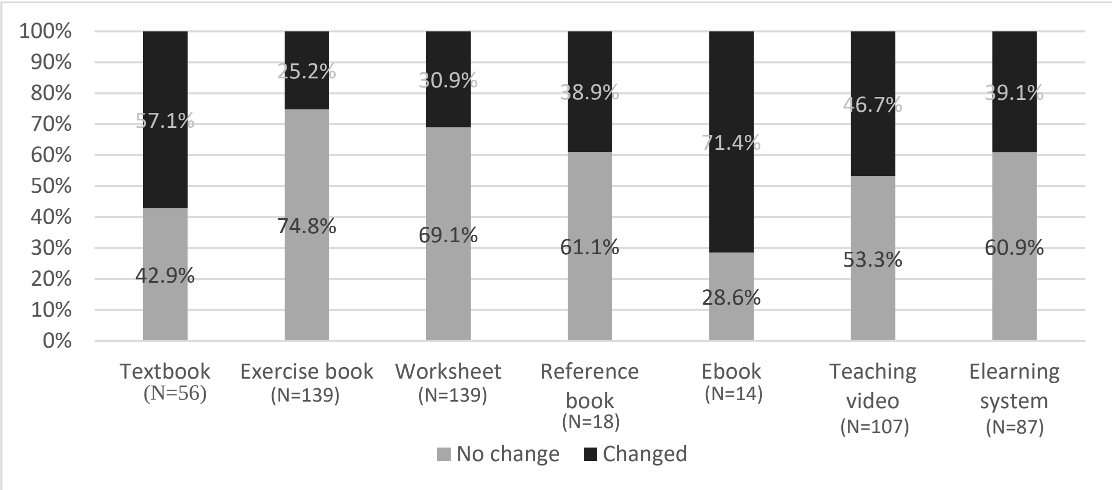


Figure 39 Percentage distribution of English students who indicated whether they changed the way of using the resources compared to the previous academic year

Also, Chi-square tests were applied to examine the differences in whether English students changed their resource use between year 7 and year 8. The Fisher–Freeman–Halton method was employed when the cross-tables had low expected frequencies (<5) (Freeman & Halton, 1951).

Table 31. Results of the Chi-square test of differences between year 7 and year 8 students' changes in using learning resources in mathematics

Chi	Textbook	Exercise book	Worksheet	Reference book	Ebook	Teaching video	Elearning system
	(N=56)	(N=139)	(N=139)	(N=18)	(N=14)	(N=107)	(N=87)
χ^2	11.200	1.081	3.598	--	--	4.588	6.508
df	1	1	1	--	--	1	1
Sig.[1]	0.001	0.298	0.058	--	--	0.032	0.011
F-F-H[2]	--	--	--	0.627	0.505	--	--

1. Asymptotic significance (2-sided).
2. Exact significance (2-sided) of Fisher–Freeman–Halton test.

The results in Table 31 suggest that some significant differences existed between the two year levels in terms of the change in using textbooks, teaching videos, and e-learning systems in mathematics. Specifically, the difference in the change in textbook use was significant at the 0.01 level; almost all (18 out of 21) the year 7 students pointed out that some changes existed compared to their year 6 in primary school, while 60% of the students in year 8 did not change the way they used textbooks compared to their previous year level. Then, the difference of the change in using teaching videos in mathematics learning was significant at the 0.05 level. Nearly 60% of the students in year 7 indicated that there were changes in using teaching videos compared to year 6, while most of the year 8 students (62%) did not have any change in terms of watching teaching videos in mathematics learning compared to year 7. Finally, the difference in the change in using e-learning systems between the two year levels was significant at the 0.05 level as well. For year 7, the percentage of students who changed their way of using the systems was almost the same as those who did not change, whereas most of the year 8 students (74%) indicated that there was not any change compared to the previous academic year.

When it comes to how they changed their use of different learning resources in mathematics, 75 students specified the details: 34 of them mentioned teaching videos, 23 of them referred to textbooks, 20 responses were related to e-learning systems, 19 talked about worksheets, 15 mentioned exercise books, and 7 and 6 of them specified the changes in using e-books and reference books respectively. As shown in Table 32, based on the results of content analysis, almost all the students indicated increases in the frequency and duration of using paper-based resources except for textbooks, which had equal numbers of students on the two sides in terms of the change in using duration, and an opposite result in terms of the change in using frequency. It seemed that students were likely to rely on textbooks at their lower year levels, while they turned to exercise books, worksheets, and reference books when the higher year level started. In fact, many of the students who used textbooks less frequently said that they used to use textbooks in year 6 (primary school) but did not use them any more in year 7 (secondary school). Additionally, the number of students who suggested increases in the frequency of using the e-resources was more than those who used them less frequently.

Table 32. The numbers about how English students changed the way of using different learning resources in mathematics

How	Textbook	Exercise book	Worksheet	Reference book	Ebook	Teaching video	Elearning system	Total
Freq[1] ↑ [3]	2	12	11	5	4	16	9	59
Freq ↓ [4]	16	0	1	0	2	10	7	36
Dura[2] ↑	1	3	2	0	0	0	0	6
Dura ↓	1	0	0	0	0	0	0	1
Timing	0	0	0	0	0	1	0	1
Purpose	0	1	2	0	0	2	1	6
Motivation	0	0	0	1	0	2	1	4
Influence	0	1	0	0	0	2	0	3
Unidentified	2	0	2	0	0	0	1	6
Total	22	17	18	6	6	33	19	121

1. Freq: frequency.
2. Dura: duration.
3. ↑ : increase (in the frequency or duration of using learning resources).
4. ↓ : decrease (in the frequency or duration of using learning resources).

Then one answer referred to the timing of using teaching videos: "we use them *in lessons* to learn from". Six responses were related to the change in purpose of using the resources: two of them mentioned that they used worksheets more often for *homework*, another two specified the change in using teaching videos (one used them for *preview* and the other used them more for *revision*), one used exercise books a lot more for *revision* and making notes, and one used e-learning systems for *homework* and online tasks.

Furthermore, four responses mentioned the motivation for using the resources when illustrating the changes. Two of them identified the relation between the *enhancement of mathematics knowledge* and the use of teaching videos and reference books respectively, while one noticed the relation between the *improvement of their mathematics mark* and the use of e-learning system, and one indicated the changes in *teachers' instruction* incorporating teaching videos: “we go into more depth about the video…as our teacher usually tells us that”.

Additionally, three responses involved the influence of using different resources on mathematics learning when elaborating the changes. One of them pointed out the helpfulness of using exercise books in learning *mathematics knowledge*: “I have more definitions in it to help me”, and the other two claimed that the use of teaching videos in mathematics helped them better understand what they needed to do when doing practice, which suggested an improvement of *mathematics skills*, such as calculating.

Lastly, when exploring the reasons why the changes happened, 2 keywords were extracted from 13 responses that either included the words “because”, “since”, “for”, “reason” and “as”, or existed as explanations in addition to the specified changes. As shown in Table 33, the main reason for the change in resource use was students' awareness of the difficulty of learning mathematics at a higher year level. In all, 11 responses covered all the resources and reflected the reason for the increases of using frequency of the resources; for instance, “I use it (an e-learning system) more because the maths in high (secondary) school has got harder.” Also, two responses explained the decrease of the frequency of using teaching videos and e-learning systems as “different teacher”, which attributed the change to teachers' instructions.

Table 33. The occurrence of the reasons behind the change in using learning resources (England)

Reasons	Textbook	Exercise book	Worksheet	Reference book	Ebook	Teaching video	Elearning system	Total
Teaching	0	0	0	0	0	1	1	2
Difficulty	1	2	3	1	1	1	2	11
Total	1	2	3	1	1	2	3	13

Also, one student later provided some details of the change in textbook use:

Student 1: Um, we use the textbooks a bit more in eight. We use the ***textbooks more*** *than we did in year seven.*

Interviewer: So you weren't in Andrew's class last year?

Student 1: No, we were just in different groups last year because that was our first year. So they changed us into normal groups. So they saw our ability in maths and divided us and grouped us. At the end of year seven, we were in *this group, and then we stayed in the group.*

Interviewer: Ok, so your maths teacher was also Andrew's last year?

Student 2: …I was actually in, the label said I was in Mr Ash trees. And ***we didn't use like textbooks****, we mostly used like um, something on the computer called ten quick questions …*

It suggests that teacher mediation influences students' resource use to a certain extent, which will be further discussed in the following section.

7.2 The factors that may influence students' use of learning resources in mathematics

This section is to give an image of the context regarding the defined factors in England. The associations between the factors and students' resource use will be presented in Chapter 8.

Out-of-school lessons

The student questionnaire enquired how much time students spent on out-of-school lessons every week, including attending lessons organized by commercial companies (cram school) and studying with private tutors.

In England, as shown in Figure 40 (n=139), nearly 90% and 95% of the students did not attend any after-school lessons for learning mathematics. A total of 4.3% of the students had some lessons organized by commercial schools for 0.5 to 1 hour every week and fewer spent more than 1 hour per week on those lessons. In the meanwhile, no more than 3% of the students had private tutors helping with mathematics for 0.5 to 1 hour per week and only 1.4% of them spent 1 to 1.5 hours on mathematics with their tutors every week in that academic year.

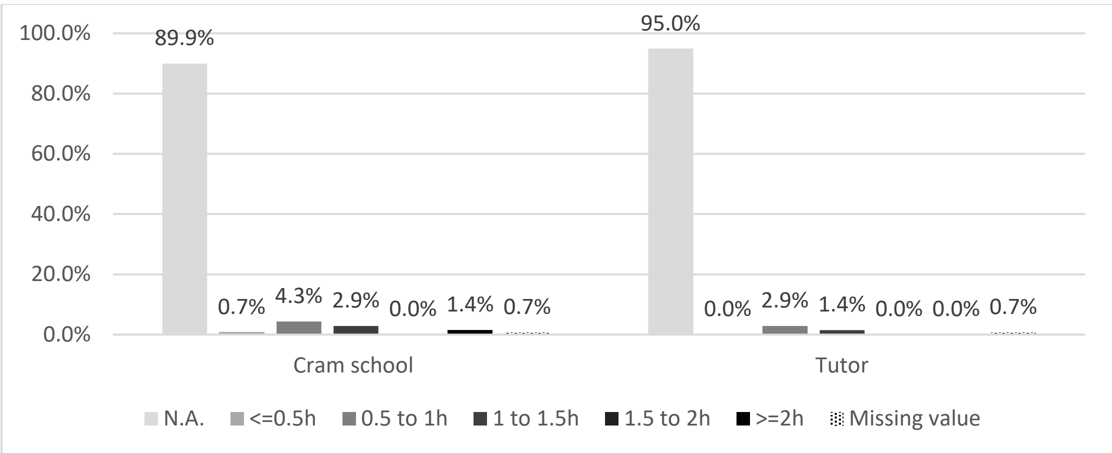


Figure 40 Percentage distribution of English students who attended out-of-school lessons

Parental involvement

Figure 41 presents the results based on data collected from 139 England students. About 80% of the students indicated that their parents checked their learning progress in mathematics, most of which were at the frequency of once a week and less, and nearly 20% of the students said that their parents usually did it 2–3 times a week. Similarly, 75% of the students stated that their parents assisted them in doing mathematics homework, most of which were at the frequency of once a week and less, and around 16% of the students said that their parents helped them with the homework at the frequency of 2–3 times a week. Moreover, 41% of the students pointed out that their parents asked them to do exercises not assigned by school teachers; specifically, 32.4% did those exercises at the frequency of once a week and less, 2.2% were at the frequency at 2–3 times a week, and 5.7% of them did them 4–5 times a week or more. Also, more than half (53.2%) of the students indicated that their parents bought resources for them to learn mathematics that academic year, which mostly happened less than once a month (31.7%), and 14.4% of the students received learning resources from parents at the frequency of once a month, while only approximately 6% of the students got the resources at the frequency of 2–3 times a month and more.

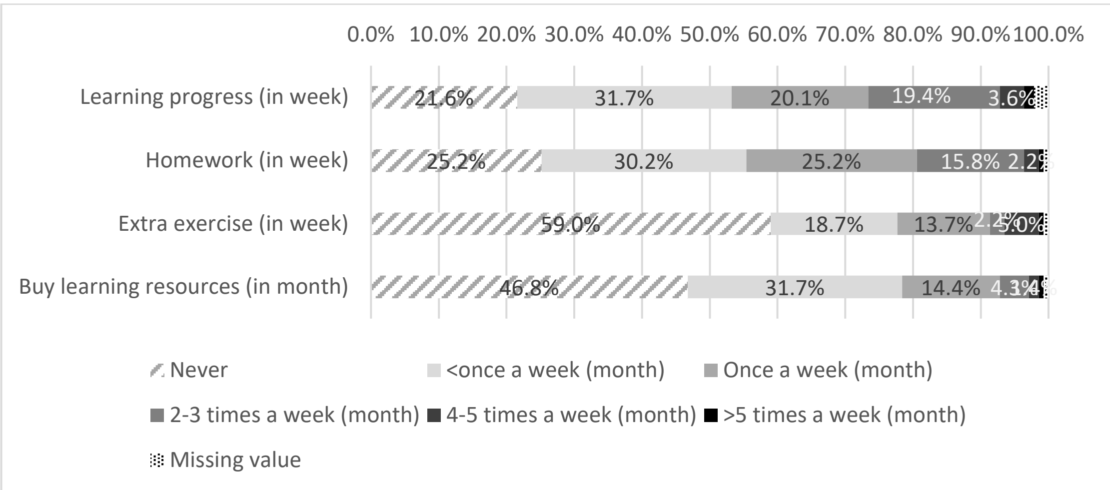


Figure 41 Percentage distribution of England's parents who got involved in their children's mathematics learning at different frequencies (student survey)

Figure 42 presents the results based on data collected from 74 parents. Compared to Figure 41, the distribution of parent responses have some similar "key features"; for instance, nearly 75% of the parents said that they helped with children's mathematics homework, most of which were at the frequency of once a week and less, no more than a half (45.9%) of the parents assigned additional exercises to their children, most of which were at the frequency of less than once a week, and not many (9.5%) parents regularly bought learning resources for their children.

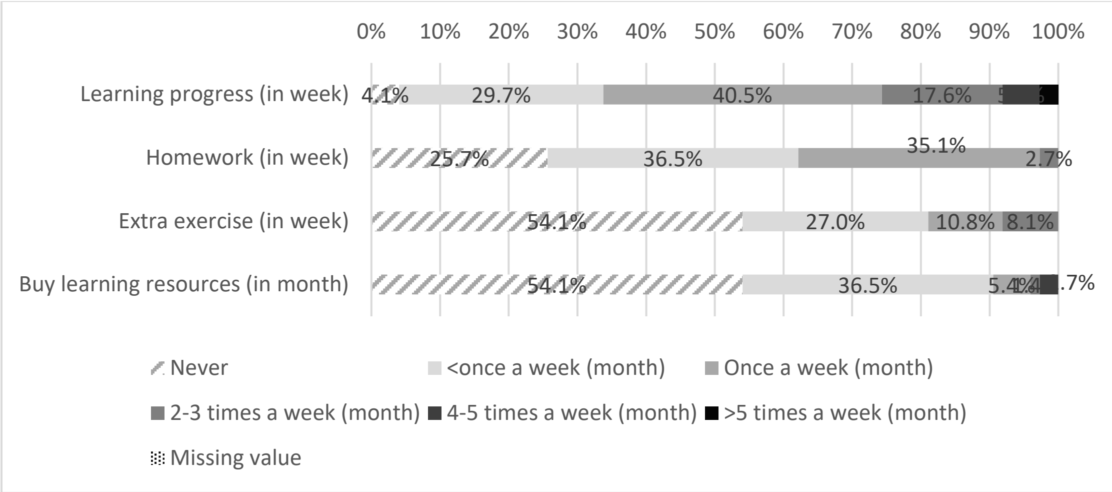


Figure 42 Percentage distribution of England's parents who got involved in their children's mathematics learning at different frequencies (parent survey)

Chi-square tests also verified that no significant differences were found between students' and parents' responses in terms of how often parents asked children to do extra exercises in mathematics and how often parents bought learning resources for their children. However, when it comes to parents' involvement in checking mathematics learning progress and assisting with homework, there were some different voices from students and their parents. More parents than students said that they discussed learning progress in mathematics, and most of the parents (40.5%) ticked the frequency of once a week, which was higher than the frequency chosen by the largest percentage (31.7%) of students (i.e. less than once a week). Moreover, 35.1% of the parents stated that they helped with children's mathematics homework once a week, while more students (18.7%) than parents (2.7%) chose the higher frequencies (i.e. 2 – 3 times a week).

Table 34. Results of Chi-square test of the difference between students' and parents' responses to parental involvement in mathematics learning (England)

	Learning progress	Homework	Extra exercise	Buy learning resources
χ^2	17.709	11.641	2.061	4.807
df	4[a]	3[b]	3[b]	3[c]
Sig.[1]	0.001	0.009	0.560	0.187
N[2]	210	212	212	212

1. Asymptotic significance (2-sided).
2. Number of students' and parents' responses excluding the missing values.
a. 5 standing for ">5 times a week (month)" was integrated to 4 to reduce the number of cells that have expected count less than 5. In this case, 1 cell (10%) has expected count less than 5. The minimum expected count is 4.58.
b. 5 standing for ">5 times a week (month)" and 4 for "4-5 times a week (month)" were integrated to value 3 to reduce the number of cells that have expected count less than 5. In this case, 0 cell has expected count less than 5.
c. 5 standing for ">5 times a week (month)" and 4 for "4-5 times a week (month)" were integrated to value 3 to reduce the number of cells that have expected count less than 5. In this case, 1 cell (12.5%) has expected count less than 5. The minimum expected count is 4.19.

Teacher mediation

The teacher questionnaire collected the data in regard to the frequency, timing, purpose, and access with which teacher instructions incorporated students' use of learning resources in mathematics. According to the responses from England, the main learning resources used by students under teacher instruction in mathematics were exercise books and worksheets.

Specifically, all the six teachers said that their students were required to use exercise books almost every school day of a week, three of them from school C indicated that exercise books were used by students both in and after class while the other three teachers only asked students to use exercise books in class. For worksheets, four of the teachers stated that they asked students to use them 2–3 days per week, while the other two instructed their students to use them at the frequency of 4–5 days every week, and all the teachers asked students to use worksheets both in and after class.

Also, the second commonly used resources were textbooks and e-learning systems. Two of the teachers from school C pointed out that their students were supposed to use textbooks at the frequency of 4–5 days per week in class, while the other two teachers from school C rarely (e.g. once a week) asked their students to use textbooks in class, and the teachers from schools A and B did not ask the students to use any textbook. Five of the teachers incorporated e-learning systems, such as MyMaths, in their instruction and asked their students to use them 2–3 times a week, except for one who required the students to use them once a week. The students from schools A and B were supposed to use e-learning systems both in and after class while the students from school C were guided to use them either in or after or both in and after class according to their teachers' instruction. Moreover, four of the teachers asked their students to use teaching videos once a week, while reference books and e-books were seldom used by the students based on their teachers' responses.

When it comes to the purpose for which teachers asked their students to use different resources in mathematics learning, the teacher from school A and one teacher from school C did not give any response. The other four teachers required their students to use exercise books and worksheets mainly for in-class learning and exercises, revision, and doing homework. Three of the teachers from C indicated that they asked students to use textbooks mainly for in-class learning and exercises, revision, and looking up definitions and examples. The teacher from school B and one of the teachers from school C asked the students to use e-learning systems for in-class learning and exercises, revision, and doing homework while another teacher from school C only asked the students to use them for homework. Also, teaching videos were mainly used by the students for revision according to teachers' responses, and reference books and e-books were mainly for revision and looking up definitions and examples.

When asked how their students usually gained access to the learning resources, all the teachers indicated that schools bought students exercise books, and they made worksheets for their students. The teachers incorporating textbooks and reference books in their instruction said that their students borrowed the books from classrooms and those who were involved e-learning systems pointed out that students usually gained access to the systems via the school website. For teaching videos and e-books, students went to the school website to use them or directly googled what they wanted on the internet.

For interviews and classroom observations, Table 35 summarizes the information of the participants so that the results can be presented according to the code of teachers.

Table 35. Information of England's teachers involving in classroom observations

Teacher[1]	School	Year[2]	Gender	Year of teaching	Topic of the observed lessons
T1	A	7-8	Female	1.5	Simplifying fractions/ Expanding single brackets/ Parallel line
T2	B	7-8	Male	7	Multiplication/ Standard form of numbers
T3	C	7	Male	24	Area and perimeter of rectangles
T4	C	7	Male	8	Conversion and unit
T5	C	8	Female	3	Substitution
T6	C	8	Female	10	Algebra brackets

1. Ti, i=1, 2 … 6, is the code of different teachers.
2. In general, England's teachers teach multiple year levels, the Year column only shows year levels of the observed classes.

Lessons and interview of T1

One of the year 7 lessons was the first lesson working on simplifying fractions and another was a review lesson for expanding single brackets, while the two year 8 lessons were on parallel lines. During the observations, exercise books and worksheets were the main resources used by students for in-class learning and exercises. T1's instruction clearly involved the use of those resources: "*book open, write down the date and content*", "*stick the sheets in your book*". It is worth mentioning that students did own their exercise books, which were provided by schools and usually stored in classrooms. Hence, teachers distributed exercise books to students when they came into the classroom and collected them back at the end of every lesson. T1 prepared worksheets for her students and cut the sheets to the right size so that they could stick the sheets in their exercise books, which saved time copying questions.

When asked about textbook use, T1 explained that they did not have textbooks, and their teaching and learning progress followed a "work scheme", which was dictated by the school and based on the national curriculum:

> *…Each year group is given a scheme to work with, to follow…the scheme work is dictated to us, so it says in one week, you need to do this, and within that week I choose how I do it…so you might see similarities and also differences (if you sit in different classrooms). One teacher might spend more time on one particular aspect, other teachers will try to do lots of aspects…*

In T1's class, homework is usually printed on worksheets and distributed to the students once a week:

…Students should have one piece of homework a week for maths, and they usually have two pieces of homework from every subject a night… This is the kind of homework (worksheet) my year 8 lower set will be given, very small, four questions. While my year 7 higher set, they will be given a longer piece of homework…

Also, T1 sometimes assigned homework from an e-learning program, which was bought by the school for students to use in mathematics learning, and expressed her concerns about the use of e-resources:

…The system they use, like MathsWatch, is a program that they can log in to, and they can watch videos, they can ask online questions…

I think the technology is quite good, but we don’t really have a lot of opportunities to use it, it is quite difficult… other teachers want to go in there as well, we only have three computer rooms for the whole school; most times, they’re taken up with ICT lessons, it is just very rare that we can use ICT lessons because we have to book it if we want to use it. It is very difficult to book it.

On average, students have ICT lessons for maths every two weeks, in which they will use the system and complete some tasks individually.

In short, exercise books and worksheets were the dominant learning resources in T1’s lessons, and e-learning systems and teaching videos were regularly incorporated in students’ learning as well. T1’s responses also showed that she was consciously trying to instruct students to use e-resources in mathematics learning.

Lessons and interview of T2

Two year 7 lessons were both new lessons introducing written methods of multiplication and multiplying two- by three-digit numbers including decimals respectively. Two of the year 8 lessons were the first lessons of the topic “standard form of numbers”, while the other two year 8 lessons were revision lessons without focusing on a particular topic.

During the observations, exercise books and worksheets were the main resources used by students for in-class learning and exercises. Particularly, students had two “exercise books” according to the constructs in this study: one was the class book used daily, like that used in T1’s class. The other ones, called “star books”, were used every two weeks to write down the summary after an assessment or some keynotes when doing revision, in which case T2 used a projector to show what he was writing on a piece of paper so that the students could write down the same notes in their star books by following their teacher. Also, T2 emphasized the format of the notes and asked students to copy exactly the same content of what he was writing. He explained the importance of exercise books, the role of worksheets, and the idea of using star books in the interview:

…I think the most important one would be the exercise books. If you define that as what they do in class every day, and also the reflection on what they've

done…

Interviewer: I saw that worksheets were not that common in classroom exercises. So worksheets are mostly used for homework?

T2: …I do use a lot of worksheets, but more at higher levels. Yeah, probably nine, ten, eleven. Um, and the reason for that normally is just to avoid them spending time copying out questions. So it's more prevalent in higher years.

Interviewer: In your lesson, you said that the star book is a second brain. So in your opinion, the star book is just like something that can give students opportunities to review everything they learned in your lesson. Does that happen only in your class or…?

T2: It's throughout the maths department and for years now. So we started probably three years ago to have this idea because what we saw was in their class books…very scrappy, rubbish work. So we thought…to have a "best book" we used to call it, and a lot of children like that idea... So it's keeping it all together, and then we were thinking what it is for and I think we've all come to the view now it's for revision. So you take what you've done from your class book and you summarize it in your star book and it can also be useful for review.

In the interview, T2 indicated his opinions about the strength and weakness of using textbooks. Compared to worksheets, textbooks seemed not to be the best resource for presenting examples and questions to students in class:

*You can give them the printout or the question straight away and they can read it and it stops wasting time. Some people will just copy out in order to avoid doing the work. That's the problem of textbooks I think, because if a textbook presents a question, do I say to students "I want you to copy questions from the textbook into your books and then write the answer" or do I just say to them "write down the answer" or do I say to them "**pre-see the question**", which is quite a high level thing for a lot of them to do and **they don't really understand**. Because the danger is having the working out and the question without the context. It will waste time. So I think sometimes they've even taken textbooks and they photocopy them and then they put them in a book to create a worksheet… I have been thinking that maybe they're writing the question down, does that help the learning process as much as doing it? I'm not sure.*

Then he thought that textbooks did benefit student's learning in terms of knowledge and concepts, but still expected some improvements in the textbooks:

*The textbooks in the top row, I did use them in previous years. They're quite well written, they **explain the concepts better**. I think that the textbooks we use for GCSE are good because they give you one page of explanation. But the explanation I think is **too brief** and you need a teacher to explain it. So what's the point? You know, it needs to be more uh, **richer**.*

T2 also provided an example of reference books, called "revision guides" and used in higher year levels:

…The closest thing I could think to a reference book is what we would call a revision guide, uh, which is just a kind of a cut-down version of the textbook… in year ten, we give them, um, we ask their parents to buy them revision guides.

I think though the revision guides are aimed at years ten and eleven, the GCSE issues, if there was a revision guide, which was more age-appropriate, I think that would be useful.

In brief, exercise books were the main resource used by students in T2's lessons while worksheets were taken as a complement to exercise books presenting questions. In addition to the exercise book used daily, there was another special book for students to summarize and reflect on the knowledge they learned under teacher instruction. Also, T2 realized the importance of textbooks but had difficulties incorporating them in students' learning at that stage.

<u>Lessons and interview of T3</u>

This was the only one English lesson observed in this study using textbooks, though the students did not participate in the questionnaire survey. It was the first lesson delivering how to calculate the area and perimeter of a rectangle. During the observation, the teacher firstly distributed exercise books as observed in other lessons, let students open their books and "*put the title and date in*" and then introduced three learning groups that were differentiated by learning mode (teacher-led learning/self-learning) and the difficulty of exercises posed in three types of textbooks, and labelled them with green, orange, and red tags from the basic level to the highest level. The students chose the group they wanted to join in and were given textbooks to work on. Most of them chose the green group and the teacher used the exercises in textbook A as examples to introduce the topic for them, while the other two groups were asked to do exercises in textbooks B and C respectively, on their own. Since the textbooks were borrowed from the classroom, students had to use exercise books to write down the answers to questions posed in textbooks. In the interview, T3 explained why there was a variety of textbooks in his classroom:

…So I look at lessons, other teachers taught that same topic, and then I decide how I want to deliver that. So I can use the worksheets that they might provide. But my lesson is a lot about… advanced differentiation. So it's about creating independent learners. So they need to have access to different resources so that every child is making progress. In order to do that, I need to have a wealth of resources in these textbooks. Once you understand them, they have a wealth of resources, but you need to know the books well.

When it came to the resources used for assigning homework, T3 mentioned worksheets and a web-based learning system:

I do two sides. Either I do worksheets or I use ***Diagnostic*** *questions, which is an interactive um website where students get instant feedback on how they've done. But also I can then see, that helps to avoid too much marking, what they did well., so it's efficient…*

T3 also expressed his worry about students' use of technology:

…I don't (use teaching videos)…I think as technology increases, I think the use of the internet is the best. But I don't know if you can get better control of that and understand it, and you got to make the students become more mature... So the approach to that would be, um, in my lessons, a combination of

> *worksheets and textbooks. And if you put videos up, it might be fine for two or three minutes and then they get disaffected afterwards…*

Therefore, in T3's class, textbooks, exercise books, and worksheets were used by students for in-class learning and exercises, while worksheets and sometimes e-learning systems were used for homework. T3 agreed that the use of technology positively influenced mathematics teaching and learning, but incorporated it conservatively in his class, especially in students' individual work.

Lessons of T4, T5, and T6

These three lessons were all review lessons covering the topics of conversion and units, substitution, and algebra brackets respectively. During the observations, students spent most of the time in the lessons working with dozens of questions in exercise books and worksheets. They were supposed to either write down the answers in exercise books when the teacher presented questions with slides, or work on some worded problems listed on a worksheet directly and glue it into an exercise book at the end of the lesson.

Interview of T6

Based on the observations, T6 did not use textbooks in her class though there were lots of different types of textbooks stored on shelves in the classroom. She thought that worksheets made students do their work in class and exercise books helped students review what they did in the classroom, which were the main advantages of using those resources instead of textbooks:

> *I don't use a textbook as often. I teach from the board and I tend to give them **worksheets** for most of the time because I find when they got a worksheet that has questions on it, they'll have it glued in their books. But if they have a textbook, they don't necessarily write the full question out from the textbook, and I think a lot of the… you can't use your **exercise book** to revise from if you can't remember what the question is. So that's just the way I teach.*

She also pointed out her dissatisfaction with textbooks:

> *…and I also find some of the textbooks or their content isn't good enough.*
>
> *Interviewer: The quality is poor?*
>
> *T6: Not say the quality. The textbooks are really good. Ok. But you know for a specific skill they need to actually have three or four of the same types of questions, not just one. So it's the quantity.*

And provided an example of teaching with online-videos:

> *…I don't use videos often, but this morning for my year 12 set, we actually went onto **YouTube video** on how to use… the new class with calculating when it comes to statistical functions. Because you can calculate um, to show children steps of what you press, calculating the variance in some deviation of frequency tables, and how to actually put it into the calculator.*

When it came to homework, T6 mentioned exercise books, worksheets, and a web-based e-learning system:

> *…Because if I set them homework, they would take them (exercise books) home….*
>
> *Interviewer: How do you assign homework to your students? Mainly from the uh, exercise book or you give them some online resources?*
>
> *T6: …Various things. So we use MyMaths. MyMaths is for…um… online resources and we can set them to work from that. We can give them a worksheet or we can give them a mini project…*

Therefore, in T6's lesson, worksheets were the dominant resource used by students for in-class learning and exercises, which were supposed to be attached to exercise books for reviewing purposes. She sometimes incorporated online-teaching videos in her teaching to show students specific steps of solving a problem. Exercise books, worksheets, and e-learning systems were used to assign homework, and students were allowed to take exercise books home for doing homework, which was not mentioned by other teachers.

Beliefs

For the authority of textbooks in mathematics education, Figure 43 depicts the results of whether English students agreed with the five statements (1.1–1.5). The responses from 139 students indicated that they held some critical views about the role of textbooks in mathematics learning. Specifically, a large percentage of the students agreed that textbooks closely followed the curriculum, hence they were the guideline for passing examinations (64%), and textbooks were trustworthy (58.3%) but nearly a half (49.6%) thought textbooks did not always present the "best way" to solve problems. For the other two statements that were supposed to reflect English views about textbooks, 41% of the students stated that "the teacher seems unreliable if she/he always follows the instructions posed in textbooks", which was slightly lower than the percentage of those who were on the opposite side. Moreover, only one-third of the students stood on the positive side when they described textbooks as "only a source of exercises", which was 25.7% lower than the percentage of those who disagreed with that.

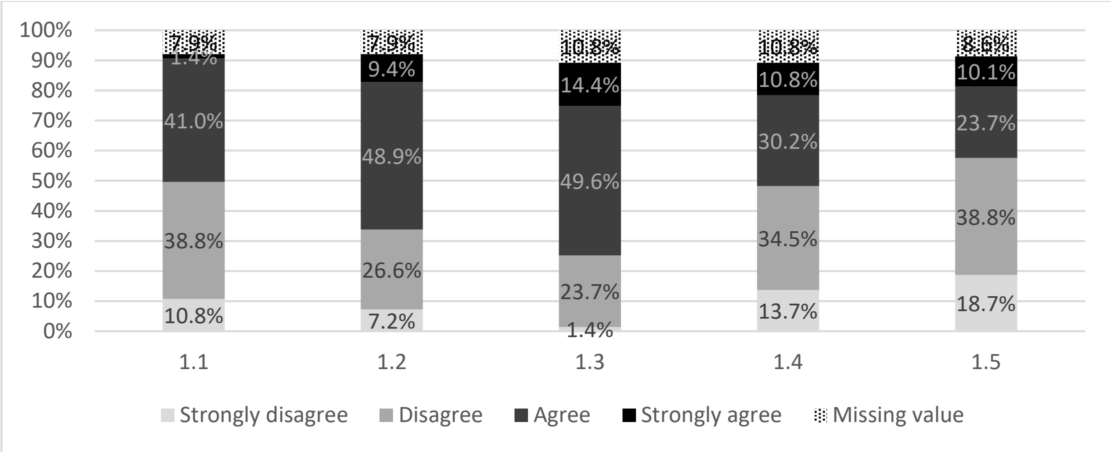


Figure 43 Percentage distribution of English students' beliefs about the authority of textbooks in mathematics learning

Figure 44 presents the result of what English students think about the five statements reflecting different views of doing mathematics exercises. Some differences were found between the statistics and what the relevant literature summarized about practice and doing exercises in mathematics. For the two statements in favour of Chinese views (2.3 and 2.4), over 80% of the students agreed that "doing exercises is an efficient way that helps me better understand mathematics knowledge" and "practice makes perfect" in their learning of mathematics; particularly, 42.4% of them strongly agreed with the latter, which might indicate that the emphasis on practice was also common in England. For the three statements in favour of English views (2.1, 2.2, and 2.5), 61.9% of the students approved when they described doing exercises as a repeat of fixed steps, 45.3% thought that doing exercises was boring, which was almost the same as the percentage of those who stood on the opposite side, and only 30.2% believed that doing exercises constrained the development of creativity, which did not show much support for what the literature said about drills and practice in mathematics from the western perspective.

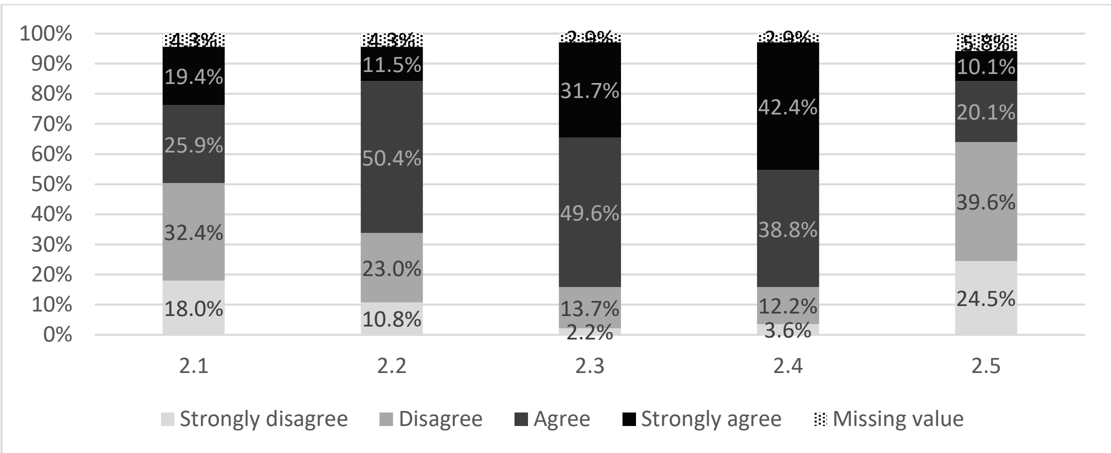


Figure 44 Percentage distribution of English students' beliefs about doing mathematics exercises

Figure 45 depicts the result of English students' responses to the five statements describing stressful situations related to examinations, which implies that they bear more pressure from the examination itself than the pressure extending from examination to some external issues, e.g. their futures and other people’s judgement. Specifically, 86.4% of the students agreed or strongly agreed that “I have to work hard because there are lots of examinations ahead of me”, approximately two-thirds (67.7%) of the students believed that “achieving good marks is the most important thing in learning mathematics at school”, and 64% of the students were in favour of the statement “it will upset me very much if I do not do well in mathematics examinations”. While 49.6% of the students deemed that “a good mark is the only way to a bright future”, which was almost the same as the proportion of those who disagreed with that, only 36.7% of them did think that other people such as their peers, teachers, and parents were likely to judge them by their performance in examinations.

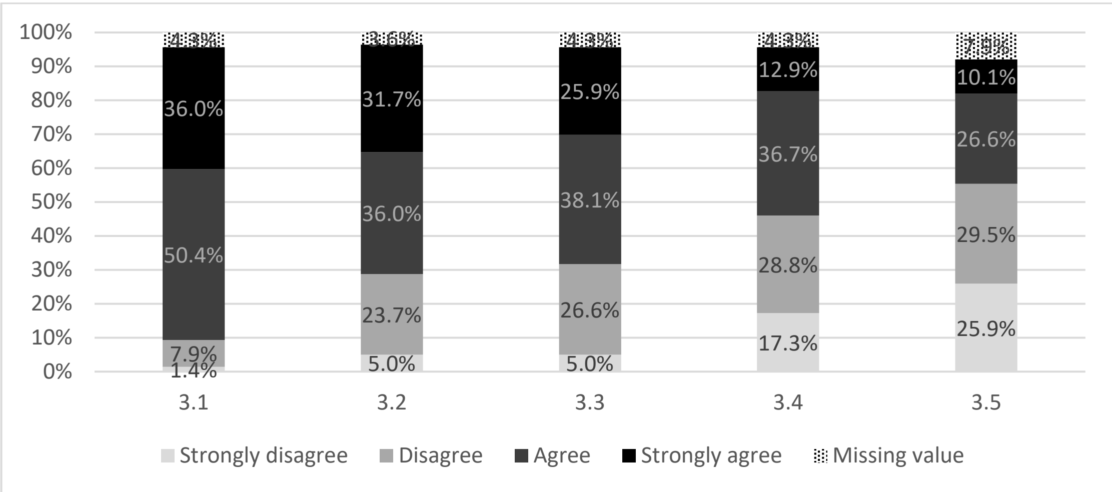


Figure 45 Percentage distribution of English students’ beliefs about the pressure of examinations

Finally, the result of English students’ beliefs about why they succeed or fail in the learning of mathematics is consistent with what the literature illustrated to some extent, while providing new voices as well. For the three statements in favour of western views (4.2, 4.4, and 4.5), most of the students (81.3%) supported that “everyone is born with different gift and talent, so it seems fine if mathematics is not one of the things that I am good at” and nearly half (47.5%) strongly agreed with that, 61.1% of them believed that aptitude mainly explained one’s success or failure in mathematics learning, and 51.1% agreed that the most important thing in schools is to develop one’s gift and talent rather than to make good the defects, which embodied the emphasis on individual ability in education to some extent. For the two statements in favour of Chinese views (4.1 and 4.3), 62.6% of the students agreed or strongly agreed that “hard work can make up the lack of natural ability in mathematics”, and 61.9% of them supported the view that “success or failure in the learning of mathematics mainly depends on how hard one works”, which was even slightly higher than the proportion of those who believed in aptitude; particularly, 24.5% strongly agreed with that, which was almost two times higher than the percentage of those who strongly supported the aptitude side.

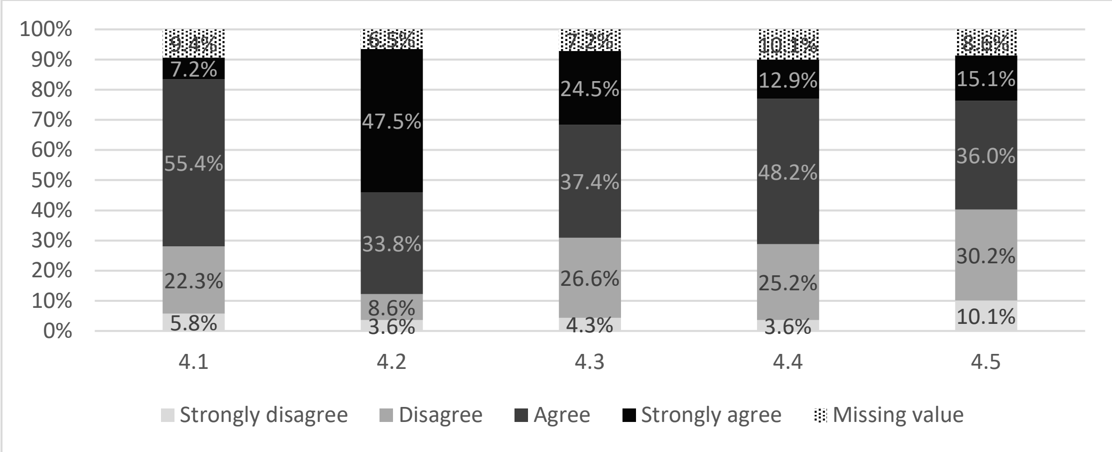


Figure 46 Percentage distribution of English students' beliefs about the attribution of success and failure in the learning of mathematics

Also, their parents' and four of the English teachers' views about the four beliefs involving 20 statements were also collected from questionnaires, which were consistent with students' responses to a great extent, though they expressed a more positive understanding of doing exercises, and parents additionally appeared to be less anxious about the future compared to their children.

7.3 Summary

This chapter reports the findings of how English students use learning resources in mathematics and the contextual factors that may influence their resource use. Generally speaking, paper-based and e-resources were both commonly incorporated in English students' mathematics learning; findings related to the factors confirmed some concerns of the social, didactical, and cultural contexts mentioned in the literature review, and revealed some facts that might bring unexpected images of the contexts.

1. The most-used resources were exercise books, worksheets, teaching videos, and e-learning systems in terms of frequency of use and duration.

2. Exercise books and teaching videos were supposed to be used only within the classroom in most cases, while worksheets were more likely to be used both in and after class.

3. All four frequently used resources were used for in-class learning and exercises, doing homework, and revision in most cases, except for teaching videos, which were not mentioned by many students in the activity of doing homework.

4. The most-cited motivation for using the four resources was teacher mediation, especially for the use of exercise books and worksheets, and self-regulation was the second-quoted motivation for the resource use.

5. Exercise books and worksheets were provided by schools and teachers, while teaching videos and e-learning systems could come from other websites in addition to access provided by schools and teachers.

6. In general, students explained that exercise books and worksheets positively influenced their learning of mathematics but held a critical view of the helpfulness of other resources in improving their mathematics learning.

7. Compared to the previous academic year, there were some changes in students’ resource use, especially for the use of textbooks, teaching videos, and e-learning systems. The changes mentioned indicated more increase than decrease in using frequency for all the resources except for textbooks, and the main reasons for the changes included different teachers’ instructions and students’ awareness of the difficulty of mathematics learning at a higher year level.

8. They hardly attended any out-of-school mathematics lessons.

9. A large percentage of parents took part in the children’s learning of mathematics. Asking about learning progress and assisting with homework were the main two types of parental involvement.

10. Teachers had great autonomy in how to deliver a lesson with different learning resources, but exercise books and worksheets were the basic and necessary resources in their usual practice.

11. Students seemed to have an ambiguous image of textbooks, since most of them agreed that textbooks were the guideline for passing examinations while half of them did not show much confidence in what textbooks said. They also held a complex view of doing exercises in mathematics: the majority believed that “doing exercises was an efficient way to learn mathematics better” and “doing exercises was just a repeat of practice with fixed steps” at the same time. Also, many of them did bear the stress of the examination itself, other than the issues related to their futures and others’ judgement. The majority believed that both effort and talent were important in mathematics learning. The parents’ and teachers’ responses were roughly consistent with students’ results in the beliefs about textbooks and attribution of success and failure in mathematics learning.

Chapter 8 Comparisons between Shanghai and England

8.1 Similarities and differences in resource use in mathematics between Shanghai and England

In the previous chapters, Shanghai and English students' use of the learning resources in mathematics and the contextual factors were presented. This chapter compares the resource use between the two places with Chi-square tests, and explores the explanations of the use and, possibly, the differences, by examining the associations between the defined factors and students' resource use.

As mentioned earlier, there were no "workbook" and "notebook" in English questionnaires since they were integrated and called an "exercise book" in the English version, while Chinese questionnaires still had them as they were different concepts in Chinese understanding. Thus, the differences between the use of workbooks and exercise books and the differences between the use of notebooks and exercise books were both tested in this section.

Frequency

Figure 47 shows a rough comparison of mean frequencies of using different resources between Shanghai and England. According to the results, Shanghai students used paper-based resources more frequently compared to English students, especially for textbooks and reference books, while the opposite only happened when it came to the use of e-resources except for e-books.

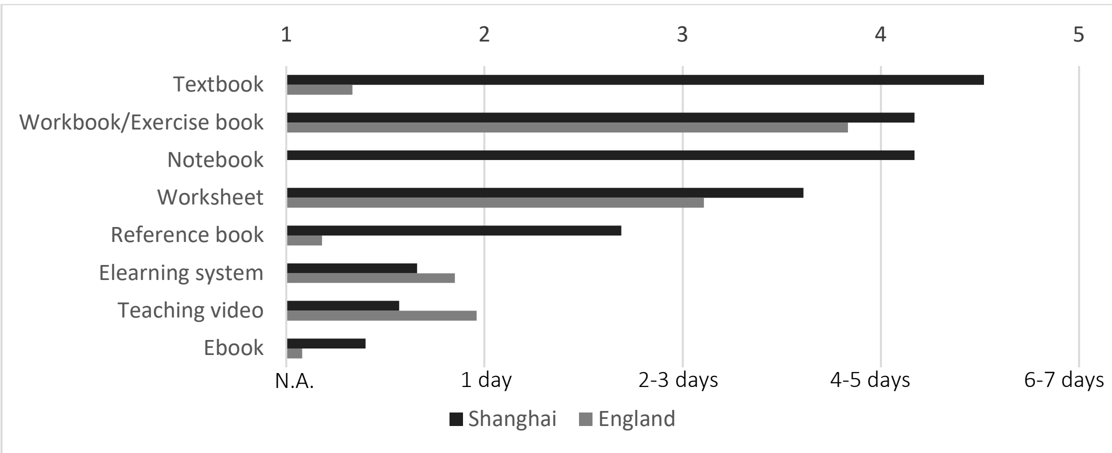


Figure 47 Mean frequencies of using learning resources in Shanghai and England

Chi-square tests indicate that the frequency of using the resources in the two places is significantly different at the 0.01 level.

Table 36. The differences in the frequencies of resource use between Shanghai and England

	Textbook	Workbook[2]	Notebook[3]	Worksheet	Reference book	Ebook	Teaching video	Elearning system
Shanghai	(N=143)	(N=143)	(N=143)	(N=142)	(N=143)	(N=143)	(N=143)	(N=143)
England	(N=150)	(N=150)	(N=150)	(N=150)	(N=150)	(N=150)	(N=150)	(N=150)
χ^2	253.888	50.446	137.489	78.035	96.398	23.067	68.225	37.135
df	4	2[a]	3[b]	3[b]	4	2[c]	3[d]	3[d]
Sig.[1]	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

1. Asymptotic significance (2-sided).
2. The comparison is between the use of workbooks in Shanghai and the use of exercise books in England.
3. The comparison is between the use of notebooks in Shanghai and the use of exercise books in England.
a. 1 standing for "N.A. (not applicable)" and 2 for "one day per week" was integrated to value 3 to reduce the number of cells that have expected count less than 5. In this case, 0 cell has expected count less than 5.
b. 1 standing for "N.A. (not applicable)" was integrated to value 2 to reduce the number of cells that have expected count less than 5. In this case, 0 cell has expected count less than 5.
c. 5 standing for "6-7 days per week" and 4 for "4-5 days per week" were integrated to value 3 to reduce the number of cells that have expected count less than 5. In this case, 0 cell has expected count less than 5.
d. 5 standing for "6-7 days per week" was integrated to value 4 to reduce the number of cells that have expected count less than 5. In this case, 0 cell has expected count less than 5.

More students from Shanghai than England incorporated the paper-based resources in their learning of mathematics and used them at a higher frequency. However, there is a different story when it comes to some e-resources. The majority of Shanghai students did not watch any teaching videos and use e-learning systems, while a large percentage of English students incorporated the two e-learning resources in their learning of mathematics.

Duration

The frequencies of using different resources provide a general view of which resources were usually used by students from Shanghai and England. Thus, in order to eliminate the effects of those who did not incorporate the defined resources in mathematics learning in the differences in resource use between the two places, the following tests exclude the "N.A." (not applicable) cases to present the result reflecting the "real differences" of resource use.

Figure 48 depicts the comparison of mean duration of using the resources between the two places. English students spent most of the time working with exercise books, compared to which, Shanghai students seemed to spend their time more evenly on different resources.

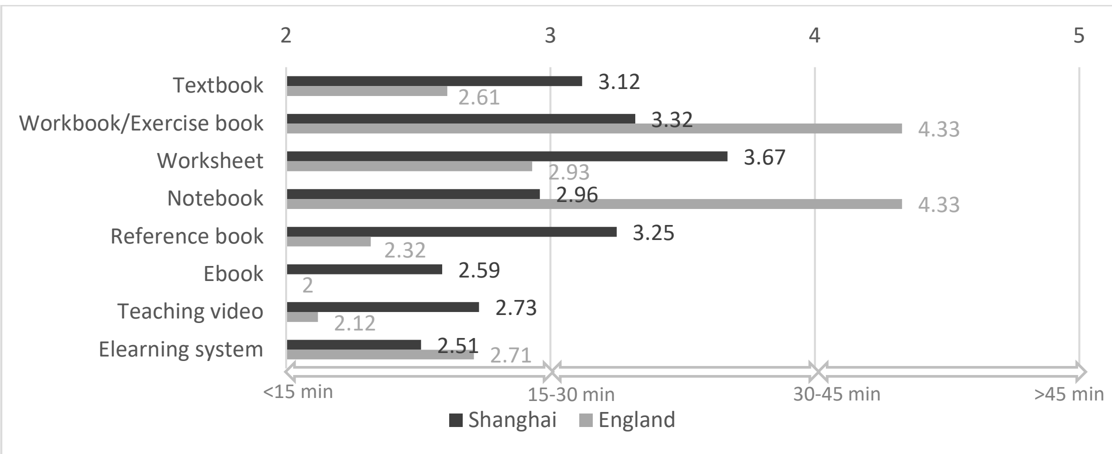


Figure 48 Mean duration of using learning resources in Shanghai and England

Chi-square tests imply that the duration of using those resources in the two places is significantly different at the 0.01 level except for e-learning systems.

Table 37. The differences in the duration of resource use between Shanghai and England

	Textbook	Workbook[2]	Notebook[3]	Worksheet	Reference book	Ebook	Teaching video	Elearning system
Shanghai	(N=142)	(N=140)	(N=134)	(N=137)	(N=88)	(N=27)	(N=44)	(N=51)
England	(N=44)	(N=150)	(N=150)	(N=150)	(N=19)	(N=12)	(N=109)	(N=93)
χ^2	10.428	83.221	106.034	59.805	17.536	--	27.746	4.354
df	3	3	3	3	2[a]	1[b]	2[c]	2[a]
Sig.[1]	0.015	0.000	0.000	0.000	0.000	--	0.000	0.113
F-F-H[4]	--	--	--	--	--	0.007	--	--

1. Asymptotic significance (2-sided).
2. The comparison is between the use of workbooks in Shanghai and the use of exercise books in England.
3. The comparison is between the use of notebooks in Shanghai and the use of exercise books in England.
4. Exact significance (2-sided) of Fisher–Freeman–Halton test.

a. 5 standing for “>45 minutes” was integrated to value 4 to reduce the number of cells that have expected count less than 5. In this case, 0 cell has expected count less than 5.

b. The observed count for 5 was 0 and 4 standing for “30-45 minutes” was integrated to value 3 to reduce the number of cells that have expected count less than 5. In this case, 1 cell (25%) has expected count less than 5. The minimum expected count is 3.69.

c. 5 standing for “>45 minutes” was integrated to value 4 to reduce the number of cells that have expected count less than 5. In this case, 1 cell (16.7%) has expected count less than 5. The minimum expected count is 2.59.

Timing

Table 38 presents Chi-square tests of the timing of using learning resources in Shanghai and England, which implies that the timings of using those resources in the two places are significantly different at the 0.01 level except for e-books. English students used those resources mostly in class while Shanghai students also used them after class in many cases.

Table 38. The differences in the timings of resource use between Shanghai and England

	Textbook	Workbook[2]	Notebook[3]	Worksheet	Reference book	Ebook	Teaching video	Elearning system
Shanghai	(N=142)	(N=139)	(N=133)	(N=136)	(N=91)	(N=27)	(N=44)	(N=50)
England	(N=44)	(N=150)	(N=150)	(N=150)	(N=19)	(N=12)	(N=109)	(N=94)
χ^2	38.079	110.713	21.754	26.127	30.513[a]	--	79.711[a]	44.929
df	2	2	2	2	2	1[b]	2	2
Sig.[1]	0.000	0.000	0.000	0.000	0.000	--	0.000	0.000
F-F-H[4]	--	--	--	--	--	0.023	--	--

1. Asymptotic significance (2-sided).
2. The comparison is between the use of workbooks in Shanghai and the use of exercise books in England.
3. The comparison is between the use of notebooks in Shanghai and the use of exercise books in England.
4. Exact significance (2-sided) of Fisher–Freeman–Halton test.

a. 1 cell (16.7%) has expected count less than 5.

b. The observed count for “both in and after class” was 0.

Purpose

Table 39 presents Chi-square tests of the purposes of the resource use in Shanghai and England, which implies that the purpose of using some resources in the two places is significantly different at the 0.01 level.

Table 39.[1] The differences in the purposes of resource use between Shanghai and England

	Textbook	Workbook[2]	Notebook[3]	Worksheet	Reference book	Ebook	Teaching video	Elearning system
Shanghai	(N=143)	(N=140)	(N=134)	(N=136)	(N=91)	(N=29)	(N=43)	(N=49)
England	(N=45)	(N=150)	(N=150)	(N=150)	(N=19)	(N=12)	(N=109)	(N=94)
Preview	0.000	0.546	0.481	0.645	0.569	0.024	0.000	0.000
In-class[4]	0.008	0.000	0.000	0.000	0.555[a]	0.202[a]	0.000	0.000
Revision	0.000	0.484	0.000	0.000	0.490	0.305[a]	0.337	0.562
DTF[5]	0.000	0.117	0.000	0.000	0.187	0.039[a]	0.266	0.000
EAR[6]	0.000	0.892	0.000	0.000	0.448	0.398[a]	0.210	0.000
Homework	0.000	0.000	0.001	0.194	1.000[a]	1.000[a]	0.470[a]	0.003
Extra[7]	0.577	0.034	0.003	0.006	0.006	1.000[a]	0.000[a]	0.010

1. The table only contains asymptotic significance (2-sided).
2. The comparison is between the use of workbooks in Shanghai and the use of exercise books in England.
3. The comparison is between the use of notebooks in Shanghai and the use of exercise books in England.
4. In-class learning and exercise.
5. Looking up definitions, theorems, and formulas.
6. Looking up examples, answers and references.
7. Doing extra exercises not assigned by teachers.
a. Exact significance (2-sided) of Fisher–Freeman–Halton test.

The purpose of using textbooks between the two places was significantly different at the 0.01 level except for doing extra exercises. According to Figure 49, textbooks were widely used by a large proportion of Shanghai students in the defined situations, especially for preview, in-class learning and exercises, and looking up information, while in England, students hardly used textbooks for those purposes except for in-class learning and exercises. The only similarity is that a few students used textbooks to do practice not assigned by their teachers in both Shanghai and England.

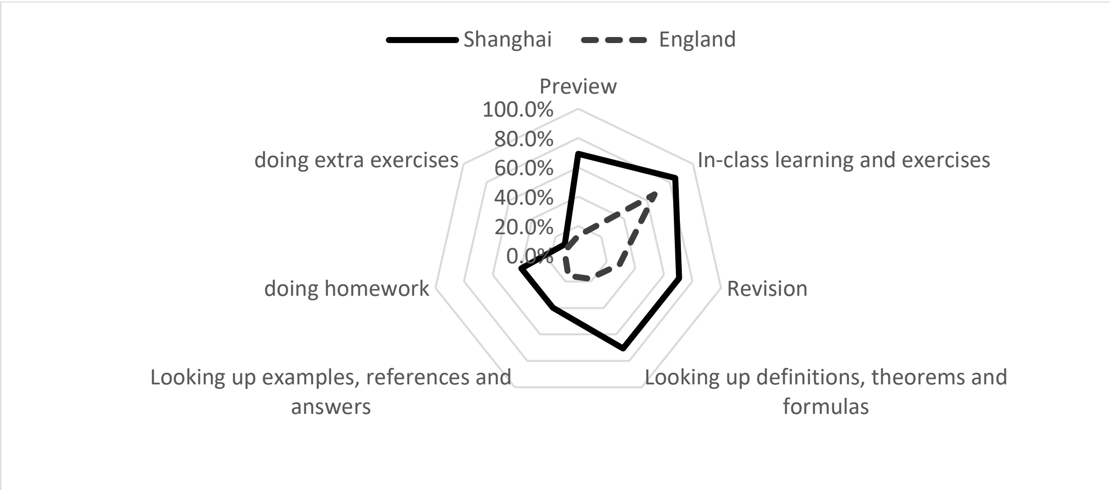
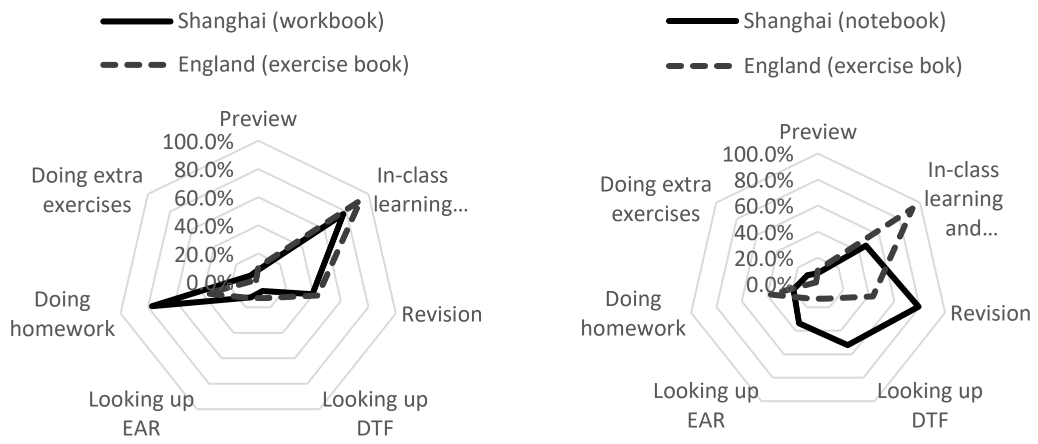


Figure 49 Distribution of Shanghai and English students who used textbooks for different purposes in mathematics

Next, the distribution of English students who used exercise books for different purposes has more similar features with the distribution of Shanghai's workbook use than the distribution regarding notebooks (see Figure 50). No significant difference in situations between the use of workbooks (Shanghai) and exercise books (England) was found, except that a larger percentage of English students used exercise books for in-class learning and exercises, while a smaller proportion of them used the books for doing homework compared to Shanghai's figures.



DTF: definitions, theorems, and formulas.
EAR: examples, answers, and references.

Figure 50 Distribution of Shanghai students who used workbooks and notebooks vs. English students who used exercise books for different purposes in mathematics

Moreover, students seldom used worksheets for preview before lessons while more than half of them did homework on worksheets, which were the situations found both in Shanghai and England. In fact, the significant differences in the purposes of using worksheets include the fact that a larger proportion of English students used worksheets for in-class learning and exercises, while smaller proportions of English students used worksheets for revision, looking up information, and doing extra exercises compared to Shanghai's figures. However, when it comes to reference books, no significant difference in purpose of use was found between Shanghai and England, except that a larger proportion of students from Shanghai than England used reference books for doing exercises not assigned by their teachers (p=0.006).

For e-learning resources, more similarities than differences in the purpose of using e-books and teaching videos was found between the two places, while it is not the case in the use of e-learning systems. Specifically, no significant difference for e-books in terms of purpose of use was found at the 0.01 level, though it might be due to the lack of responses to e-books. Meanwhile, some differences in using teaching videos were found in preview situations, in-class learning and exercises, and doing extra practice between England and Shanghai, and a larger proportion of English students watched videos for in-class learning and exercises, while smaller proportions of them used teaching videos for preview and doing extra practice compared to Shanghai's figures. Finally, despite about one-third of students using e-learning systems for revision, which was the case both in England and Shanghai, significant differences in using e-learning systems were found in all other situations: larger proportions of English students used e-learning systems for in-class learning and exercises and doing homework, while smaller proportions of English students incorporated the systems in preview, looking up information, and doing extra exercises compared to Shanghai's figures.

Motivation

Table 40 shows Chi-square tests of the motivation behind resource use in Shanghai and England, which implies that some non-activity-related reasons for the resource use in the two places were significantly different at the 0.01 level.

Table 40.[1] The differences in the motivations behind resource use between Shanghai and England

	Textbook	Workbook[2]	Notebook[3]	Worksheet	Reference book	Ebook	Teaching video	Elearning system
Shanghai	(N=143)	(N=140)	(N=134)	(N=137)	(N=92)	(N=28)	(N=44)	(N=50)
England	(N=45)	(N=150)	(N=150)	(N=150)	(N=19)	(N=13)	(N=109)	(N=94)
Enjoyment	0.004[a]	0.194	0.000	0.180	0.520[a]	0.280[a]	0.000	0.102
Challenge	0.008	0.002	0.637	0.000	0.149[a]	1.000[a]	0.028	0.046
Mark[4]	0.059	0.000	0.000	0.000	0.001	0.524	0.398	0.188
KSA[5]	0.000	0.000	0.000	0.000	0.012	0.164[a]	0.001	0.000
Teacher	0.356	0.889	0.000	0.511	0.760[a]	1.000[a]	0.000	0.000
Parent	0.016	0.183	0.100	0.001	1.000[a]	0.040[a]	0.006[a]	0.754
Other[6]	--	--	--	--	--	0.288[a]	0.690[a]	0.003[a]

1. The table only contains asymptotic significance (2-sided).
2. The comparison is between the use of workbooks in Shanghai and the use of exercise books in England.
3. The comparison is between the use of notebooks in Shanghai and the use of exercise books in England.
4. Self-regulation: "I keenly know that it can improve my mathematics Mark".
5. Self-regulation: "I think it can help me better understand mathematics Knowledge and Skills, and enhance mathematical Abilities".
6. "It is the fastest way to get the information I need", which was only applied to e-learning resources.
a. Exact significance (2-sided) of Fisher–Freeman–Halton test.

According to Figure 51, teacher mediation was an important reason for students using textbooks in their mathematics learning, which was the case in both England and Shanghai. However, the proportion of Shanghai students who chose the other aspects as reasons for textbook use were significantly higher than England's; especially the proportion of Shanghai students who identified the relation between textbook use and their improvement of mathematics knowledge, skills, and abilities (KSA), and those who deemed that it could benefit their mathematics marks, was about twice as high as England's.

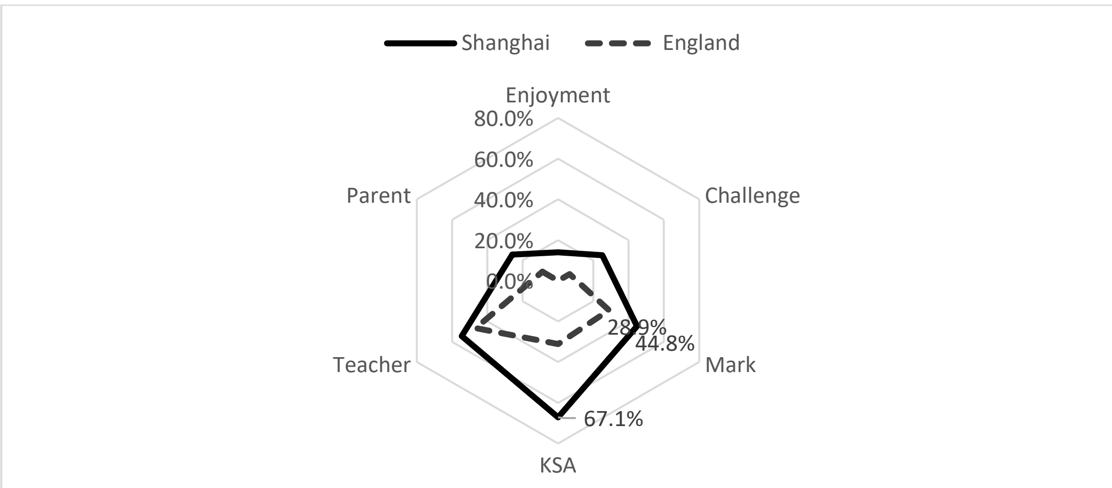


Figure 51 Distribution of Shanghai's and English students who used textbooks with different motivations

The distribution of motivations for using exercise books in England and workbooks in Shanghai has a more similar shape, compared to the distribution regarding notebooks (see Figure 52). Most of the English students used exercise books in their learning of mathematics simply because their teachers asked them to do so, and a few of them used the books because they found them interesting or followed what their parents said, which was the same case for workbooks in Shanghai. However, significant differences were found in other aspects between the use of exercise books and workbooks; for instance, larger proportions of Shanghai students identified the relationship between workbook use and the improvement of marks and KSA compared to England's. It is worth mentioning that the same awareness of connections between resource use and the improvement of mathematics marks and KSA was also found in the use of notebooks in Shanghai, and nearly a half of Shanghai students thought that taking notes was enjoyable.

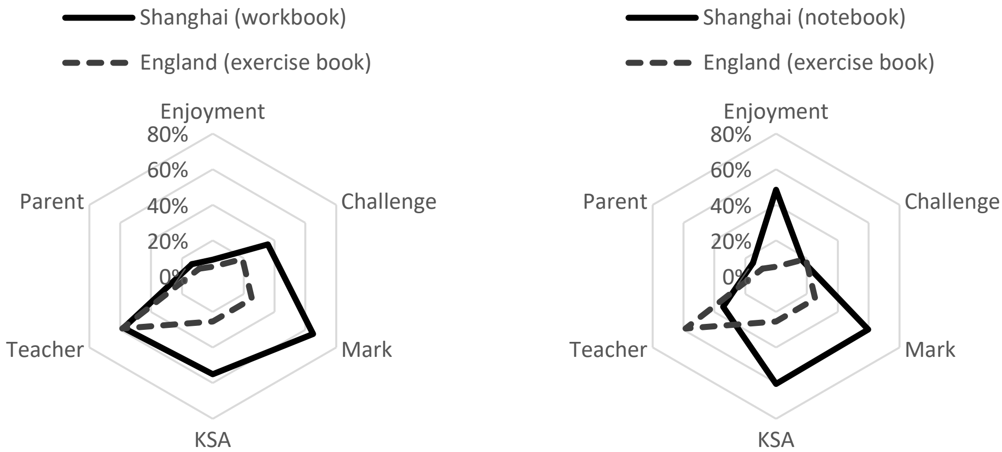


Figure 52 Distribution of Shanghai students who used workbooks and notebooks vs. English students who used exercise books with different motivations in mathematics

The main difference in motivation for using worksheets and reference books between the two places still focuses on students who used those resources for self-regulation (aiming to improve their marks and KSA), which accounted for more than a half of the students in Shanghai while no more than one-fourth in England. Moreover, Shanghai had significantly larger proportions of students who felt fulfilled when solving difficult problems on worksheets and who used worksheets when studying with their parents.

For e-learning resources, no significant difference of motivation was found in the use of e-books between the two places, possibly due to the lack of responses to e-books. Then, a larger proportion of Shanghai students watched teaching videos since the videos seemed interesting, could help with learning mathematics knowledge and skills and the improvement of abilities, and were recommended by their parents, while a smaller proportion of Shanghai students used teaching videos under teacher instruction compared to England's. Finally, a larger proportion of Shanghai students used e-learning systems for self-regulation and getting instant information, while a much smaller proportion of them indicated that the use of e-learning systems was teacher-led compared to England's distribution.

Access

Table 41 presents Chi-square tests of access to the learning resources in Shanghai and England, which implies that the ways that students gained access to those resources are significantly different at the 0.01 level except for workbooks, i.e. exercise books in English.

To obtain a robust test, the item was omitted when less than 10% of students chose it. In other words, the comparison only presented the differences between 2 to 4 main ways of how students gained access to the learning resources. Specifically, almost all students from the two places said that the schools bought them workbooks and exercise books, which was the only similarity according to the test. In fact, it was not a surprise that a significant difference existed in terms of how students got their textbooks between Shanghai and England: all Shanghai students owned free textbooks while the majority of English students borrowed textbooks from the classroom. Next, larger proportions of English students said that their worksheets were bought by schools and made by teachers compared to Shanghai's figures, while England's students hardly obtained worksheets from parents, which was not the case in Shanghai. Moreover, almost all of Shanghai students pointed out that their parents bought them reference books and the remaining ones said that schools and sponsors did it, while there were fewer English students who used parent-paid reference books and more got the books from schools.

For e-learning resources, no robust result was obtained for e-books since only a few students who participated in the survey used e-books. The main ways to obtain teaching videos were searching them on Google or the publisher's website and buying the access by parents in Shanghai, while English students had other choices: apart from Google or the publisher's website, a large percentage of them also used teacher-made videos and gained access through the school website. Similarly, when it comes to e-learning systems, search engines and parents provided the access for most of Shanghai students to use the systems, while half of English students gained access through the school website in addition to those who used search engines to find them.

Table 41. The differences in the accesses to learning resources between Shanghai and England

	Textbook	Workbook[2]	Worksheet	Reference book	Ebook	Teaching video	Elearning system
Shanghai England	(N=139) (N=43)	(N=140) (N=146)	(N=135) (N=134)	(N=91) (N=14)	(N=27) (N=13)	(N=42) (N=93)	(N=45) (N=76)
χ^2	145.067	--	16.249	--	--	24.818	30.545
df	1	--	2	--	--	3	2
Sig.[1]	0.000	--	0.000	--	--	0.000	0.000
F-F-H[3]	--	0.114	--	0.009	--	--	--

1. Asymptotic significance (2-sided).

2. The comparison is between the use of workbooks in Shanghai and the use of exercise books in England.

3. Exact significance (2-sided) of Fisher–Freeman–Halton test.

Influence

Table 42–44 present Chi-square tests of the influence of using different resources on mathematics learning in Shanghai and England, which suggests that the helpfulness of most resources to students from the two places are significantly different at the 0.01 level. In order to obtain a robust result, some counts of "not helpful" were integrated to "slightly helpful" to reduce the number of cells with an expected count less than 5 in Chi-square test.

Based on the mean scores of helpfulness ratings for those resources, more Shanghai students than England's thought that the use of resources positively influenced their learning of mathematics knowledge and skills (see Table 42), especially paper-based resources, as the ratings for textbooks, worksheets, and reference books from Shanghai were nearly 1 point above the ratings from England. Though there was not a robust result of Chi-square test for e-books, the ratings for teaching videos and e-learning systems from Shanghai students were also higher than those from England's. No significant differences at the 0.01 level were found in terms of the helpfulness of workbooks and notebooks, or "exercise books" in English, between the two places, which were deemed to play a positive role in students' learning of mathematics knowledge and skills in both England and Shanghai.

Table 42. Comparison of the influence of resource use on mathematics knowledge and skills between England and Shanghai

Mean	Textbook	Workbook[2]	Notebook[3]	Worksheet	Reference book	Ebook	Teaching video	Elearning system
Shanghai	3.98 (n=143)	4.09 (n=140)	4.14 (n=134)	4.34 (n=137)	4.26 (n=92)	3.35 (n=23)	3.73 (n=41)	3.49 (n=47)
England	2.94 (n=47)	4.15 (n=139)	4.15 (n=139)	3.40 (n=139)	3.14 (n=14)	2.69 (n=13)	3.12 (n=108)	2.85 (n=95)
χ^2	47.070	8.667	4.189	64.131	15.788	--	15.461	19.645
df	3[a]	3[a]	3[a]	3[a]	2[b]	--	3[a]	3[a]
Sig.[1]	0.000	0.034	0.242	0.000	0.000	--	0.001	0.000

1. Asymptotic significance (2-sided).
2. The comparison is between the use of workbooks in Shanghai and the use of exercise books in England.
3. The comparison is between the use of notebooks in Shanghai and the use of exercise books in England.
a. 1 standing for "Not helpful" was integrated to value 2 to reduce the number of cells that have expected count less than 5. In this case, no more than 1 cell (12.5%) has expected count less than 5.
b. 1 standing for "Not helpful" and 2 standing for "little help" were integrated to value 3 to reduce the number of cells that have expected count less than 5. In this case, 1 cell (16.7%) has expected count less than 5, the minimum expected count is 2.64.

Similarly, significantly more Shanghai students than England's thought that the use of those resources positively influenced their ability in mathematical reasoning except for workbooks and notebooks, or "exercise books" in English (see Table 43), especially for textbooks, worksheets, and e-learning systems, the ratings of which from Shanghai students were about 0.9 points higher than those from England.

Table 43. Comparison of the influence of resource use on the ability in mathematical reasoning between England and Shanghai

Mean	Textbook	Workbook[2]	Notebook[3]	Worksheet	Reference book	Ebook	Teaching video	Elearning system
Shanghai	3.69 (n=143)	3.96 (n=140)	3.97 (n=134)	4.11 (n=137)	4.09 (n=92)	3.42 (n=24)	3.63 (n=43)	3.42 (n=48)
England	2.76 (n=46)	3.78 (n=139)	3.78 (n=139)	3.22 (n=139)	3.14 (n=14)	2.75 (n=12)	2.91 (n=106)	2.57 (n=94)
χ^2	25.222	2.844	2.239	49.103	--	--	17.602	18.613
df	4	3[a]	3[a]	4	--	--	4	4
Sig.[1]	0.000	0.416	0.524	0.000	--	--	0.001	0.001

1. Asymptotic significance (2-sided).
2. The comparison is between the use of workbooks in Shanghai and the use of exercise books in England.
3. The comparison is between the use of notebooks in Shanghai and the use of exercise books in England.
a. 1 standing for "Not helpful" was integrated to value 2 to reduce the number of cells that have expected count less than 5. In this case, no more than 1 cell (12.5%) has expected count less than 5.

When it comes to ability in problem-solving, more differences in the helpfulness of using the resources were found between the two places as Shanghai students seemed to remain optimistic about the role of those resources, while English students further lowered the ratings, especially for exercise books, which resulted in a significant difference that was not obtained in the two tests above.

Table 44. Comparison of the influence of resource use on ability in problem-solving between England and Shanghai

Mean	Textbook	Workbook[2]	Notebook[3]	Worksheet	Reference book	Ebook	Teaching video	Elearning system
Shanghai	3.87 (n=139)	3.94 (n=136)	3.97 (n=131)	4.20 (n=133)	4.11 (n=90)	3.14 (n=22)	3.43 (n=40)	3.48 (n=46)
England	2.93 (n=46)	3.39 (n=138)	3.39 (n=138)	2.85 (n=137)	2.79 (n=14)	2.54 (n=13)	2.65 (n=106)	2.66 (n=94)
χ^2	26.115	19.097	18.795	88.270	--	--	19.462	20.403
df	4	4	4	4	--	--	4	4
Sig.[1]	0.000	0.001	0.001	0.000	--	--	0.001	0.000

1. Asymptotic significance (2-sided).
2. The comparison is between the use of workbooks in Shanghai and the use of exercise books in England.
3. The comparison is between the use of notebooks in Shanghai and the use of exercise books in England.

Change

In the questionnaire, students were supposed to recall whether there existed any change in resource use compared to their previous academic year. Table 45 implies that whether students changed the way of using textbooks, worksheets, e-books, and teaching videos was significantly different at the 0.01 between England and Shanghai. Combined with Figure 53, more of England's than Shanghai students had changes in the use of those resources in mathematics.

Table 45. The differences in the changes in resource use between Shanghai and England

	Textbook	Workbook[2]	Notebook[3]	Worksheet	Reference book	Ebook	Teaching video	Elearning system
Shanghai	(N=143)	(N=140)	(N=134)	(N=137)	(N=95)	(N=28)	(N=45)	(N=50)
England	(N=56)	(N=139)	(N=139)	(N=139)	(N=18)	(N=14)	(N=107)	(N=87)
χ^2	29.580	2.216	0.208	9.435	1.963	8.351	11.252	3.238
df	1	1	1	1	1	1	1	1
Sig.[1]	0.000	0.137	0.648	0.002	0.161	0.004	0.001	0.072

1. Asymptotic significance (2-sided).
2. The comparison is between the use of workbooks in Shanghai and the use of exercise books in England.
3. The comparison is between the use of notebooks in Shanghai and the use of exercise books in England.

Specifically, more than half of English students changed the way of using mathematics textbooks, while the proportion of which in Shanghai was just 18.2%. Another significant difference for paper-based resources was found in the use of worksheets as nearly one-third of English students made some changes related to worksheets, which was twice as high as the proportion of Shanghai students. Moreover, most of the students from the two places did not find any change in the use of workbooks, notebooks, or “exercise books” in English, and reference books.

For e-learning resources, though significant differences were found in the use of e-books and teaching videos as much larger proportions of English students than Shanghai students indicated the changes in using the two resources, the result for e-books should not be overgeneralized as the number of responses to e-books was just 14. Also, most of the students from both England and Shanghai used e-learning systems the same as they did the previous academic year.

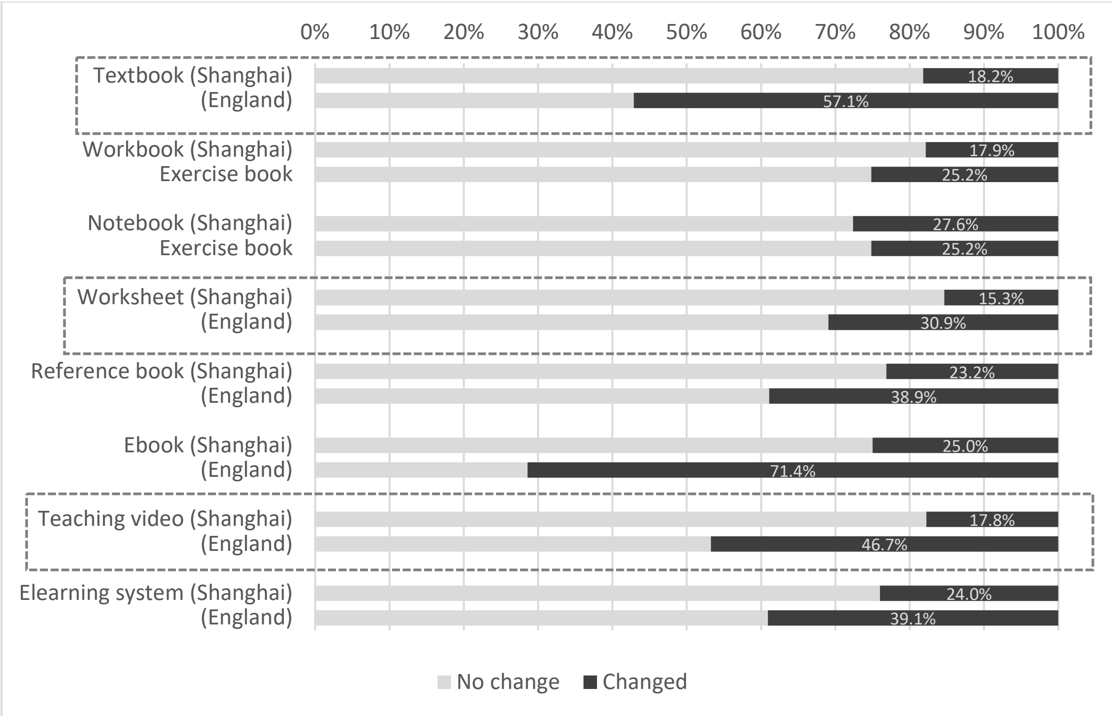


Figure 53 Comparison of whether students change the way of using learning resources between England and Shanghai

8.2 The factors that may influence students’ use of learning resources in mathematics

It is natural to ask "why?” about the results after a comparison. To give evidence-based thinking about the reasons, this study involves some contextual factors that could possibly influence students’ use of learning resources in mathematics, which could to some extent also be seen as explanations of the differences between Shanghai and England. In this section, the differences in the defined factors between Shanghai and England are examined in the first section, and clues about associations between those factors and resource use are explored and tested in the second section.

Out-of-school lessons

As elaborated in previous two chapters, more Shanghai than English students attended out-of-school lessons in mathematics. The differences in the prevalence of the two types of lessons are both significant at the 0.01 level (χ^2=107.439, *df*=5, *p*=0.000 for lessons organized by commercial companies, and χ^2=30.293, *df*=2[9], *p*=0.000 for lessons with a private tutor).

The first clue is the association between attending out-of-school lessons and Shanghai students' resource use for doing exercises not assigned by their teachers. As mentioned in Chapter 6, 35.4% of Shanghai students said that they used reference books to do extra exercises, which accounted for the largest proportion among all the purposes that reference books were used for and all the resources used for that purpose.

Based on the results of Chi-square tests, it seems no matter whether Shanghai students studied with tutors and how they used reference books, while it is more likely to bring about some differences in using reference books by attending out-of-school mathematics lessons organized by commercial companies (cram school); 42.6% of Shanghai students who attended out-of-school lessons used reference books for doing extra exercises, which was significantly larger than the proportion (22.9%) of those who used the books for the same purpose without having the lessons (χ^2=5.323, *df*=1, *p*=0.021).

The second clue is the association between attending out-of-school lessons and the use of worksheets in Shanghai, which was pointed out by students in interviews:

> *Researcher: "What resources do you use in out-of-school lessons?"*
> *Student1: "The institution provides us handouts."*
> *Student2: "The teacher always distributes worksheets to us."*
> *Student3: "Worksheets."*

Therefore, the association was proved depending on whether Shanghai students attended out-of-school lessons and how they used worksheets. It seems to be no matter whether Shanghai students studied with tutors and how they used worksheets, attending after-school mathematics lessons organized by commercial companies (cram school) did have some association with their use of worksheets; 18.2% of Shanghai students who attended after-school lessons received

[9] Six categories were integrated to three: "N.A.", "less than 1.5 hours" and "more than 1.5 hours", to reduce the number of cells with expected count less than 5 in Chi-square test.

worksheets from their parents, which was significantly larger than the proportion (4.4%) of those who did not have the lessons while receiving parent-paid worksheets (χ^2=4.802, *df*=1, *p*=0.028).

Parental involvement

Generally speaking, Shanghai parents were involved in students' mathematics learning more frequently compared to English parents (see Figure 54). According to students' responses, the differences in parental involvement in students' mathematics learning between Shanghai and England were tested to be significant at the 0.01 level, in terms of the frequency with which parents checked or discussed their children's learning progress (χ^2=67.144, *df*=5, *p*-value=0.000), assisted their children's mathematics homework (χ^2=37.287, *df*=5, *p*-value=0.000), assigned extra exercises (χ^2=67.410, *df*=5, *p*-value=0.000), and bought their children learning resources to learn mathematics (χ^2=37.313, *df*=4[10], *p*-value=0.000).

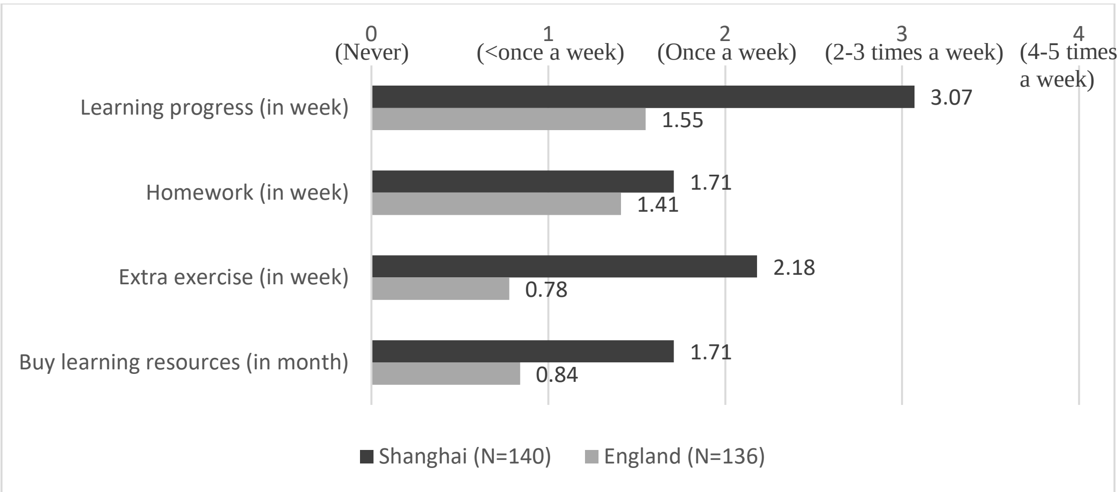


Figure 54 Comparison of mean scores of parental involvement in students' mathematics learning between Shanghai and England

As shown in Figure 55, more Shanghai than English parents were involved in children's learning of mathematics at higher frequencies.

[10] ">5 times a month" was integrated into "4-5 times a month" to reduce the number of cells that have expected count less than 5. In this case, 0 cell has expected count less than 5.

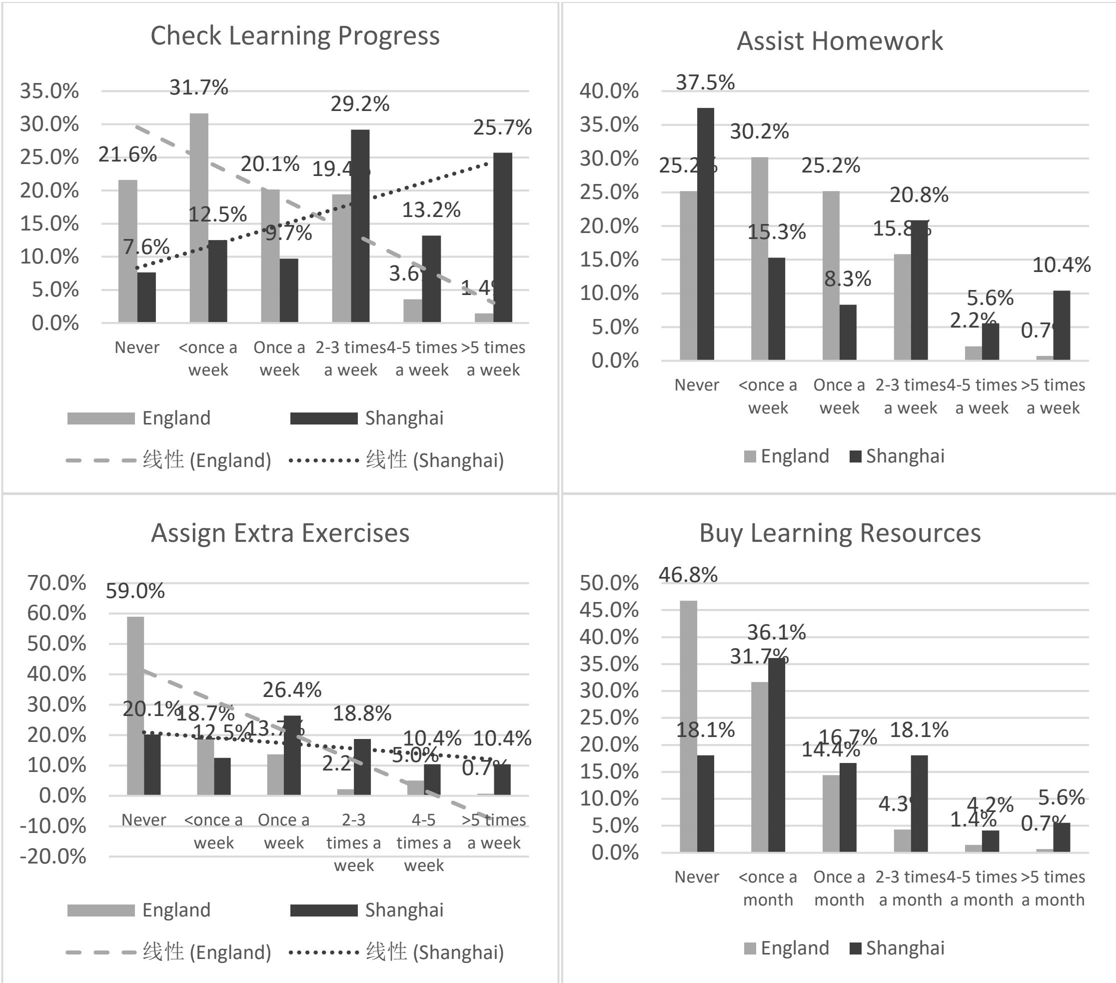


Figure 55 Comparison of percentages of parental involvement in students' mathematics learning between England and Shanghai

In Shanghai, the first clue is the association between parental involvement by checking learning progress and students' textbook use, as 25.7% of them pointed out that parent-supervision was one of the motivations for using textbooks, which accounted for the largest proportion of all the resources used with that motivation. Hence, the association was proved between the frequency with which Shanghai parents checked children's learning progress in mathematics and how the students used textbooks.

In order to improve the accuracy of the test while keeping the results meaningful, the categories of the frequency with which parents were involved in students' mathematics learning were integrated from six into three: "Never" and "<once a week (month)" were integrated as "Rarely", "Once a week (month)" and "2–3 times a week (month)" were integrated as "Sometimes", and "4–5 times a week (month)" and ">5 times a week (month)" were integrated as "Frequently".

According to the results of Chi-square tests, it matters that how often Shanghai parents checked their children's learning progress and how the students used mathematics textbooks in terms of duration and the influence of textbook use on the improvement of their ability in problem-solving, which was significant at the 0.05 and 0.01 levels respectively. The students whose parents rarely or frequently checked their learning progress were more likely to use mathematics textbooks for more than 30 minutes in a school day (44.8% for "rarely" and 39.3% for "frequently") compared to those whose parents sometimes did it (20.4%) (χ^2=15.961, *df*=6, *p*=0.014). However, a larger proportion (88.9%) of students whose parents sometimes checked their learning progress rated the helpfulness of mathematics textbooks in improving their problem-solving ability with "helpful" and "very helpful", compared to those whose parents rarely (62.1%) or frequently (63.6%) did it, and these differences were further tested to be both significant at the 0.01 level ("rarely" vs. "sometimes": χ^2=11.201, *df*=2, *p*=0.004, "frequently" vs. "sometimes": χ^2=9.649, *df*=2, *p*=0.008).

The second clue is the association between parental involvement by assisting with homework and Shanghai students' use of workbooks, worksheets, and textbooks, as large proportions of Shanghai students claimed that they used them for doing homework in mathematics (75.0% for workbooks, 56.9% for worksheets, and 39.6% for textbooks). However, no significant association between the frequencies with which Shanghai parents assisted with homework and students' use of textbooks, workbooks, and worksheets were found by Chi-square tests.

The third clue is the association between parental involvement by assigning extra exercises and Shanghai students' use of worksheets and reference books, since 35.4% and 13.2% of the students said that they used the two resources to do extra exercises in mathematics, which accounted for the two largest proportions among all the resources used in that situation.

According to the results of Chi-square tests, how often Shanghai parents asked their children to do extra exercises and how the students used worksheets in mathematics in terms of frequency and the influence of using worksheets on the improvement of their mathematics learning. Specifically, a larger proportion (75.9%) of Shanghai students whose parents frequently assigned extra exercises to them used worksheets at least 4–5 days per week compared to students whose parents rarely (44.2%) or sometimes (55.7%) did it (χ^2=7.086, *df*=2[11], *p*=0.029). Moreover, larger proportions of Shanghai students whose parents frequently asked them to do extra exercises rated highly ("very helpful") the helpfulness of worksheets in improving mathematics knowledge and skills (65.5%), their ability in reasoning (65.5%), and their ability in problem-solving (67.9%) compared to those whose parents sometimes or rarely did so (44.3% and 33.3% for mathematics knowledge and skills, *p*=0.043[12]; 34.4% and 26.7% for ability in reasoning, χ^2=12.213, *df*=4[13], *p*=0.016; and 40.0% and 28.9% for their ability in problem-solving, χ^2=11.022, *df*=4[13], *p*=0.026).

[11] "1 day per week" was integrated to "2-3 days per week" and "6-7 days per week" was integrated to "4-5 days per week" so that there were only two categories in terms of frequencies in addition to "N.A." in the test.

[12] Exact significance (2-sided) of Fisher's exact test.

[13] "not helpful" and "slightly helpful" were integrated to "somewhat helpful" to reduce the number of cells that have expected count less than 5. In this case, no more than 1 cell (11.1%) has expected count less than 5.

The tests also suggest that significant associations existed between how often Shanghai parents assigned extra exercises and how the students used reference books, in terms of whether they used the books in mathematics, whether they incorporated the books in doing extra exercises, and whether the use of the books positively influenced their mathematics learning. Specifically, a larger proportion of Shanghai students whose parents frequently asked them to do extra exercises after school incorporated reference books in mathematics learning (80%) and used them for doing extra exercises (76%), compared to those whose parents just sometimes (69.2% and 50.0%) or rarely (45.7% and 45.5%) gave them exercises in addition to the school's assignment, which were significant at the 0.01 level (χ^2=10.802, *df*=2, *p*=0.005) and marginally at the 0.05 level (χ^2=5.695, *df*=2, *p*=0.058) respectively. Also, similar to the result relating to worksheets mentioned above, larger proportions of Shanghai students whose parents frequently asked them to do extra exercises rated highly ("very helpful") the helpfulness of reference books in improving mathematics knowledge and skills (62.5%), their ability in reasoning (66.7%), and their ability in problem-solving (60.9%); this is compared to those whose parents sometimes or rarely did so (43.5% and 22.7% for mathematics knowledge and skills, 30.4% and 27.3% for ability in reasoning, and 26.7% and 31.8% for their ability in problem-solving), the first of which was significant at the 0.01 level (*p*=0.004[12]) and the latter two of which were significant at the 0.05 level (χ^2=11.010, *df*=4[13], *p*=0.026 and *p*=0.028[12]).

Finally, it was pointed out by Shanghai students in focus-group interviews that reference books and worksheets were the resources that their parents usually bought them for mathematics learning, which was also statistically verified as shown in Figure 20 (58.3% and 12.5% of Shanghai students received reference books and worksheets from their parents respectively, which accounted for the largest two proportions of all the resources bought by parents).

Thus, the association between parental involvement by buying learning resources and Shanghai students' use of reference books and worksheets was tested. The results indicated that the association between how often parents bought their children resources for mathematics learning and how Shanghai students used reference books was not significant, except for the timing of use: a larger proportion (80.6%) of the students whose parents sometimes bought them learning resources used reference books only after class compared to those whose parents frequently (41.7%) or rarely (69.8%) did that (χ^2=6.535, *df*=2, *p*=0.038). Moreover, larger proportions of the students whose parents sometimes bought them learning resources used worksheets received from their parents (26.7%) and for doing extra exercises (29.8%), compared to those whose parents frequently (7.7% used worksheets bought by parents and 7.7% used worksheets for doing extra exercises) or rarely (6.7% used worksheets bought by parents and 5.4% used worksheets for doing extra exercises) did so, which were statistically significant at the 0.01 level (χ^2=10.034, *df*=2, *p*=0.007; χ^2=14.540, *df*=2, *p*=0.001).

In England, according to students' responses in questionnaires and interviews, the only clue was the association between parental involvement by assisting with homework and students' use of worksheets, exercise books, and e-learning systems, which were the main resources used for doing homework. Since the number of English parents who frequently got involved in children's mathematics learning was small, the categories of the frequency were further integrated into two of them, "Rarely" referring to "Never" and "<once a week (month)", and "Sometimes" for all the higher frequencies. The results of Chi-square tests showed that larger proportions of English students with parents who sometimes assisted with children's homework used worksheets for revision and were happy to solve difficult problems on worksheets (i.e. used worksheets with the motive of *challenge*) compared to those whose parents rarely helped them do homework (χ^2=5.350, *df*=1, *p*=0.021 for revision, and χ^2=5.293, *df*=1, *p*=0.021 for the motivation of *challenge*). Larger proportions of English students whose parents sometimes got involved in children's homework rated the helpfulness of using worksheets in improving their reasoning and problem-solving abilities, with higher scores compared to those whose parents rarely assisted with children's homework (χ^2=8.662, *df*=2, *p*=0.013 for reasoning ability, χ^2=8.035, *df*=2, *p*=0.018 for problem-solving ability).

Moreover, students with parents who sometimes assisted with their homework spent less time on exercise books compared to those whose parents rarely gave them help (χ^2=5.664, *df*=1, *p*=0.017), and though it marginally missed the significant level at 0.05, a larger proportion of students whose parents sometimes assisted with their homework positively rated the helpfulness of using e-learning systems in improving their mathematics knowledge and skills, compared to those whose parents rarely got involved in children's homework (χ^2=5.437, *df*=2, *p*=0.066).

Teacher mediation

According to the data collected from teachers' questionnaires, the three most frequently used resources in Shanghai were workbooks, textbooks, and notebooks, while in England, they were exercise books, worksheets, and e-learning systems, which were considerably consistent with their students' responses.

Combined with classroom observations and teachers' interviews in Shanghai, the most-used resources by students within a lesson were notebooks and worksheets while other paper-based resources, such as textbooks and workbooks, were mainly used beyond class for preview, revision, and completing homework, which was slightly different from students' self-report that textbooks and workbooks were the two resources incorporated by most of them in in-class learning and exercises. Also, it was reflected on the students' side that the teachers hardly mentioned e-resource use, since only a few Shanghai students used them.

In England, exercise books and worksheets were the two most-used materials within the classroom, and the teachers also used worksheets and sometimes e-learning systems to assign homework, while reference books and e-books were rarely referred to by the teachers, which thoroughly corresponded to the students' responses as shown in the previous chapter.

Moreover, in Shanghai, teachers from the same school instructed students to use the resources in a similar way, and teachers from different schools were more likely to incorporate different resources in students' mathematics learning: all of the teachers from schools A and B said that they asked students to use notebooks almost every day even including weekends, while the teachers from school C said that they did not require students take notes in their lessons. Chi-square tests showed that the differences in students' use of notebooks between school C and schools A and B are significant both at the 0.01 level (p^{14}=0.000, while school A vs. school B: χ^2=4.141, *df=2*, *p*=0.126), and students from school C used notebooks much less frequently than the other two schools. Instead, school C's teachers said that they made worksheets for students to work with within the classroom, which was also tested to be significantly different from the use of worksheets in the other schools (p^{18}=0.000 for both, while school A vs. school B: p^{18}=0.768), and students from school C used worksheets at a higher frequency compared to the other schools.

Similarly, in England, teachers from different schools also had different considerations of resource use in mathematics teaching and learning: teachers from schools A and B indicated that they, their colleagues, and their students did not use any textbooks in mathematics, while teachers from school C said that they did sometimes ask students to use textbooks but rarely incorporated teaching videos in their lessons. Chi-square tests showed that the differences in students' use of the two resources between school C and schools A and B are significant at the 0.01 level (see the table below); a larger proportion of students from school C incorporated textbooks while a smaller proportion of them used teaching videos in mathematics learning compared to the other two schools.

Table 46. Chi-square tests of the differences in English students' use of textbooks and teaching videos between school C and schools A and B

School	Textbook			Teaching video		
	χ^2	*df*	p^1	χ^2	*df*	p^1
C vs. A	23.493	1	0.000	16.5301	1	0.000
C vs. B	18.480	1	0.000	21.709	1	0.000
A vs. B	4.059	1	0.044	0.434	1	0.510

1. Asymptotic significance (2-sided).

Also, the teacher from school A, who emphasized her desire of integrating technology into her lessons, particularly preferred web-based learning systems. In fact, her students were more likely to use e-learning systems compared to the other two schools and the differences were tested

[14] Exact significance (2-sided) of Fisher's exact test.

to be significant at the 0.01 level (school A vs. school C: χ^2=6.783, *df=1*, *p*=0.009, school A vs. school B: χ^2=9.833, *df=1*, *p*=0.002, school B vs. school C: χ^2=0.087, *df=1*, *p*=0.769).

Beliefs

To make a comparison between Shanghai and England, the response items from "strongly disagree" to "strongly agree" were valued from 1 to 4 and the scoring was converted to support the Chinese side, which means that the higher the score, the more likely it was that the students agreed with the statements supporting Chinese views. By adding up scores on the five statements, it became a scale variable with the maximum of 20. Table 47 presents the scores of each belief for Shanghai and English students.

Table 47. Students' scores on the beliefs

Beliefs	Shanghai (N=140)			England (N=112)		
	Min/Max	Mean	S.D.[1]	Min/Max	Mean	S.D.[1]
Authority of textbook	6/20	14.85	2.609	8/19	13.52	2.475
Doing exercises	8/20	15.76	2.387	7/20	14.04	2.724
Pressure of examination	7/20	13.74	2.863	6/20	13.82	2.892
Attribution of success and failure	7/18	13.04	2.017	7/20	12.16	2.163

1. Standard deviation.

T-tests indicated that the differences in beliefs about the authority of textbooks, doing exercises, and attribution of success and failure in mathematics are significant at the 0.01 level, whereas their perceptions of the pressure of examinations were statistically the same (see Table 48).

Table 48. Independent samples test of the differences in beliefs between Shanghai and England

Beliefs	Levene's Test for Equality of Variance		T-test for Equality of Means		
	F	Sig.	T	*df*	Sig. (2-tailed)
Authority of textbooks	0.067	0.795	4.121	250	0.000
Doing exercises	1.649	0.200	5.342	250	0.000
Pressure of examination	0.072	0.789	-0.235	250	0.814
Attribution of success and failure	0.168	0.682	3.340	250	0.001

To be more specific, the significant differences in the authority of textbooks for years 7 and 8 focused on whether textbooks always presented the best way to solve problems[15] (χ^2=48.242, *df*=3, *p*=0.000), whether textbooks were their guideline for passing examinations[16] (χ^2=13.587,

[15] Statement 1.1: Textbooks always present the most elegant and simplest, namely, the best way to solve problems.
[16] Statement 1.3: Textbooks always follow essentially the curriculum, which is a guideline for passing examinations.

df=2, *p*=0.001), and whether textbooks were just a resource of exercises[17] (χ^2=36.298, *df*=3, *p*=0.000). Compared to England's responses, Shanghai students showed greater trust in textbooks and did not regard textbooks only as a source of exercises, which was consistent with how they answered in questionnaires, that they used textbooks widely in different situations.

Moreover, in the interviews, Shanghai students did express stronger belief in mathematics textbooks compared to English students:

> *"The knowledge presented in the textbook will 100% appear in the examination."*
>
> *"The textbook shows me the steps for solving a problem."*
>
> *"The textbook is my pathfinder."*

Their teachers also emphasized the importance of textbooks in mathematics learning:

> *"Textbooks play the role of a judge. The examples in textbooks are the standard for students to do maths."*
>
> *"Textbooks are the teacher at home."*

T-tests were employed to explore the association between the beliefs and textbook use, and the results show that:

1. Students who used textbooks both *in and after class* scored significantly higher than those who used textbooks only in class (*t*=-2.372, *df*=134, *p*=0.019).
2. Students who used textbooks for the purposes of preview, revision, and looking up examples, references, and answers scored significantly higher compared to those who did not incorporated textbooks in these situations (t=-2.218, df=140, p=0.028; t=-2.260, df=140, p=0.025; and t=-2.772, df=140, p=0.006).
3. Students who used textbooks with the motivations of enjoyment and self-regulation scored significantly higher than those who did not have these motivations when using textbooks (*t*=-2.101, *df*=140, *p*=0.037; *t*=-2.762, *df*=140, *p*=0.007 (Mark); and *t*=-3.337, *df*=140, *p*=0.001 (KSA)).

Also, there existed a significantly positive correlation between students' views about the authority of textbooks and the helpfulness rating[18] of textbooks in improving their mathematics learning (r=0.564, p=0.000).

However, similar descriptions can hardly be found on England's side, since not many of the students used textbooks in mathematics learning. Some students pointed out that it seemed to be the case only in mathematics:

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[17] Statement 1.5: Textbooks are just a source of exercises, I do not care about what textbooks say about mathematics in other parts.

[18] Helpfulness rating: by adding up the three helpfulness ratings of each resource, eight scale variables with the maximum of 15 measuring the influences of the learning resources on the improvement of students' mathematics learning (including the aspects of knowledge and skills, reasoning ability, and problem-solving ability) were created, which made it possible to examine the associations between the beliefs and how students thought about the influences of each resource on their mathematics learning.

Interviewer: I noticed that you don't use textbooks very often?

Student: No…Not in mathematics. If we have like a teacher that's not actually a maths teacher then we usually use the textbooks.

They also specified that they did not "really" use textbooks as they did not own the books, in which case they could not make any notes in them and take them home:

"Like those questions inside the textbooks, you write them in exercise books."

"Usually you do like a photocopied sheet from the textbook…and complete the blanks on the sheet."

Therefore, it seems that English students were not familiar with what the textbook was really about and did not have a whole picture of the textbook, since they either did not use them or used the book in sections. Hence, it was hard for some of them to give attitudes towards the authority of textbooks, thus they just left it blank in their questionnaires. Also, no significant association was found between the belief about textbooks and their textbook use.

The essential differences regarding doing exercises in mathematics were instantiated in whether doing exercises was boring[19] (χ^2=29.238, *df*=3, *p*=0.000), whether doing exercises was just a repeat of work[20] (χ^2=22.826, *df*=3, *p*=0.000), and whether doing exercises could help with better understanding knowledge[21] (χ^2=12.144, *df*=2, *p*=0.002). Compared to England's responses, a larger proportion of Shanghai students deemed that doing exercises was not a dull and robotic process, and positively influenced their mathematics learning.

In interviews, Shanghai students indicated that workbooks, worksheets, and reference books were the three main resources for doing exercises in mathematics, and they further explained why they thought doing exercises was necessary for mathematics learning:

"I think practice is necessary for mathematics learning because you won't know how to solve problems if you only learn from teachers' explanations, which are just about concepts."

"I think the more exercises the better (the marks)…"

"I can tell the trap of a question after doing enough exercises."

T-tests showed that there existed some significant associations between the belief about doing exercises and Shanghai students' resource use:

1. Students who used workbooks with the motivations of *challenge* and *self-regulation* scored higher than those who used workbooks without these motivations (*t*=-2.611, *df*=137, *p*=0.010; *t*=-3.049, *df*=137, *p*=0.003 (Mark); and *t*=-3.276, *df*=137, *p*=0.001 (KSA)).

[19] Statement 2.1: Doing maths exercises is boring.
[20] Statement 2.2: Doing exercises is just a repeat of practice with fixed steps.
[21] Statement 2.3: Doing exercises is an efficient way to help me better understand mathematics knowledge.

2. Students who used worksheets at a *higher frequency* scored significantly higher compared to those who used worksheets at a lower frequency (*t*=-3.580, *df*=132, *p*=0.000), while students who used worksheets for longer periods of time scored lower than those who used worksheets for a *shorter time* in a school day (*t*=2.674, *df*=134, *p*=0.008).
3. Students who used worksheets for *in-class learning and exercises* scored significantly higher than those who did not use worksheets in that situation (*t*=-2.226, *df*=134, *p*=0.028).
4. Students who used worksheets with the motivations of *enjoyment*, *challenge*, and *self-regulation (Mark)* scored higher compared to those who used worksheets without those motives (*t*=-2.260, *df*=134, *p*=0.025; *t*=-3.145, *df*=134, *p*=0.002; *t*=-2.630, *df*=134, *p*=0.010).
5. Students who used reference books with the motivations of *enjoyment*, *challenge*, and *self-regulation (Mark)* scored higher than those who did not have these motives to use reference books (*t*=-2.180, *df*=89, *p*=0.032; *t*=-2.037, *df*=88, *p*=0.045; *t*=-2.454, *df*=89, *p*=0.016).

Also, significant correlations existed between students' views about doing exercises and the helpfulness ratings of worksheets (r=0.356, *p*=0.000) and reference books (r=0.378, *p*=0.000) in improving their mathematics learning.

In England, the resources most mentioned for doing exercises in student interviews were exercise books and worksheets, and they stated the importance of doing exercises while expressing different feelings about it:

> *Interviewer: …and what do you think about doing exercises in mathematics? Do you think it is necessary?*
>
> *Student: Yeah.*
>
> *Interviewer: Do you think it is boring?*
>
> *Student 1: Sometimes… It depends on the teacher, like the teacher makes it exciting or…*
>
> *Student 2: Honestly just copying questions and trying to answer (seems boring)… And you're working and you can also have your friend is the best part...*

T-tests only detected that students who changed their ways of using exercise books scored higher on the belief about doing exercises, compared to those who did not have any *change in* exercise book use (*t*=-2.176, *df*[22]=63.477, *p*=0.033), and students who used worksheets with the motivation of *challenge* scored significantly higher than those who did not have that motive to use worksheets (*t*=-2.703, *df*=103, *p*=0.008). Moreover, there existed a significant correlation

[22] Equal variances not assumed.

between students' views about doing exercises and the helpfulness ratings of exercise books (r=0.264, p=0.008) and worksheets (r=0.258, p=0.010) in improving their mathematics learning.

As illustrated earlier, there was no significant difference of scores in the belief about the pressure of examinations between Shanghai and England. Correspondently, similar descriptions were collected in Shanghai and English student interviews: some students did worry about examinations while some thought it was fine for them. Also, Shanghai students pointed out that the main resources for preparing examinations were notebooks, worksheets, and textbooks. In England, they were worksheets, exercise books, and e-learning systems, which were consistent with what students cited for revision in questionnaires.

T-tests showed that there existed some significant associations between the belief about the pressure of examinations and Shanghai students' resource use:

1. Students who used notebooks *both in and after class* scored higher than those who only used notebooks within class (t=-2.110, df=117, p=0.037).
2. Students who used notebooks for *doing extra exercises* scored higher compared to those who did use notebooks in that situation (t=-2.778, df=130, p=0.006).
3. Students who use worksheets for the *longest time* (> 45 minutes) scored higher than those who used worksheets for a shorter time in a school day with mathematics lessons (t=-2.089, df=131, p=0.039).

The only significant association between the belief and English students' resource use was that students who used worksheets with the motivation of *self-regulation (Mark)* scored higher compared to those who did not have that motive to use worksheets (t=-2.150, df=104, p=0.034).

Finally, the significant differences regarding the attribution of success and failure in mathematics learning were embodied in whether hard work could make up for the lack of natural ability[23] (χ^2=37.720, df=3, p=0.000), whether success or failure in mathematics learning mainly depended on effort[24] (χ^2=10.568, df=1, p=0.001), and whether it was more important to develop one's strength rather than to make up for weakness[25] in school (χ^2=16.453, df=3, p=0.001). Compared to English responses, larger proportions of Shanghai students believed that *hard work* was the key to be successful in mathematics learning at their stage and could be a remedy for natural deficiency in mathematics, which was supposed to be the most important thing about schooling.

Based on interviews, Shanghai and English students had a similar view on what made them successful in mathematics learning: though some of them deemed that personal ability and talent

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[23] Hard work can make up the lack of natural ability in mathematics.

[24] A success or failure in the learning of mathematics mainly depends on how hard one works.

[25] The most important thing in schools is to develop one's gift and talent rather than to focus on the things that I am not good at.

accounted for a large part, more of them attributed the success to effort and hard work. However, when it came to what kind of effort and work they were going to do to improve their learning in mathematics, they provided different voices. Shanghai students thought that it was important to do more exercises and revision, while English students stated that it would be better if they listened carefully in lessons.

T-tests showed that there existed some significant association between Shanghai students' attribution of success and failure and their use of workbooks, worksheets, and reference books:

1. Students who used workbooks with the motivations of *challenge* and *self-regulation (knowledge, skills and abilities)* scored higher than those who used workbooks without these motives (t=-2.556, *df*=135, *p*=0.012; t=-2.504, *df*=135, *p*=0.013).
2. Students who used worksheets 4–5 days a week scored highest compared to those who used sheets at a lower frequency (t=-2.661, *df*=81, *p*=0.009), and those who used them almost every day including weekends (t=2.461, *df*=72, *p*=0.016).
3. Students who changed their way of using worksheets compared to the previous academic year scored higher than those who stayed the same (t=-2.106, *df*=132, *p*=0.037).
4. Students who used worksheets with the motivations of *challenge* and *self-regulation (mark)* scored higher than those who used worksheets without these motives (t=-2.041, *df*=132, *p*=0.043; t=-2.771, *df*=132, *p*=0.006).
5. Students who used reference books for over 30 minutes in a day with mathematics lessons scored higher than those who used the books for a shorter time (t=-2.102, *df*=85, *p*=0.038).
6. Students who changed their way of using reference books compared to the previous academic year scored higher than those who remained the same (t=-2.268, *df*=92, *p*=0.026).

Also, a significant correlation existed between students' attribution of success and failure and their helpfulness ratings of workbooks (r=0.309, *p*=0.000), worksheet (r=0.260, *p*=0.003), and reference books (r=0.346, *p*=0.001) in improving their mathematics learning.

In England, the statistically significant associations between the belief and students' resource use include the fact that students who changed their ways of using worksheets compared to the previous academic year scored higher than those who remained the same (t=-2.144 *df*=91, *p*=0.035), and students who used teaching videos with the motivation of *teacher mediation* scored lower than those who did not have that motive when watched videos (t=2.522, *df*=78, *p*=0.014).

8.3 Summary

This chapter presents the comparison of students' resource use in mathematics and the associations between the contextual factors and students' resource use in Shanghai and England.

Generally speaking, many significant differences existed between the two places as to which resources were mostly used and how the resources were incorporated in students' mathematics learning. The findings relating to the factors confirmed some concerns of the social, didactical, and cultural differences mentioned in the literature review and indicated some connections between the factors and students' resource use in mathematics.

1. Shanghai students depended on various paper-based resources in their mathematics learning and paid much less attention to e-resources, while English students used both paper-based and e-resources, and particularly, exercise books were the dominant resources in terms of the duration of using in a school day with mathematics lessons.

2. Most Shanghai students often used learning resources both in and after class while English students were more likely to use them only within the classroom.

3. To English students, in-class learning and exercises, doing homework, and revision were the three main situations in which they incorporated learning resources, while many Shanghai students used the resources also in other learning activities, such as preview, looking up information, and doing exercises not assigned by their teachers.

4. Compared to English students, Shanghai students expressed a stronger sense of self-regulation as it was the most cited motivation for their use of learning resources in mathematics, though teacher mediation was still one of the main reasons for resource use in both Shanghai and England.

5. Most English students only used school- and teacher-provided resources; particularly, some students who did incorporate textbooks in their learning of mathematics could only use them within the classroom, because the school textbooks were only available for them to borrow rather than to possess. However, many Shanghai students also used resources bought by their parents, including worksheets, reference books, and some e-resources, and they possessed all the resources provided by schools and governments.

6. Shanghai students thought that all the resources positively influenced their learning of mathematics while English students doubted the helpfulness of using the resources except for exercise books and worksheets. Also, students' ratings of the influence of each resource on their mathematics knowledge and skills, reasoning ability, and problem-solving ability were significantly consistent with each other in both Shanghai and England.

7. Compared to Shanghai students, English students had more changes in terms of how they used textbooks, worksheets, and teaching videos in mathematics at a higher year level.

8. Many Shanghai students attended out-of-school lessons, which was not the case in England, and it had some association with whether they used reference books for doing extra exercises and whether they used worksheets bought by their parents.

9. Compared to English parents, parents from Shanghai were more likely to assign extra exercises and buy learning resources for their children in mathematics and checked children's learning progress more frequently. However, a larger proportion of English parents helped their children with homework, though the majority did it less than once a week and many Shanghai parents assisted with children's homework several times a week. Moreover, in Shanghai, parental involvement in all four ways except for assisting with homework influenced to some extent how students used the relevant resources, while in England, the only association between parental involvement and students' resource use was found in the form of assisting with homework.

10. In both Shanghai and England, students' resource use depended to a certain extent on teachers' instructions. Teachers from the same school were more likely to instruct students to use learning resources in a similar way, while teachers from different schools had different ideas of which resources should be incorporated and how they should be used by students in mathematics, which accordingly resulted in significant differences in students' resource use between different schools.

11. Students' beliefs about the authority of textbook, doing exercises, and attribution of success and failure in mathematics were significantly different. Compared to English students, Shanghai students showed more trustfulness of and familiarity with textbooks, took doing exercises more positively, and were more likely to attribute the success of learning mathematics to hard work, while no statistical difference in the belief about the pressure of examinations was found between Shanghai and England from the students' perspective. Also, compared to England's results, more significant associations existed between Shanghai students' resource use and their scores on the beliefs.

Table 49 summarizes the details of the differences in resource use in mathematics between Shanghai and England, which are significant at the 0.01 level (the results of e-books were omitted since the number of responses was less than 30, which might not have the same representation as others.).

Table 49. Differences in resource use in mathematics learning between Shanghai and England

Textbooks	**Shanghai (n=144)**			**England (n=150)**		
Frequency (in a week)	<2-3 days	4-5 days	>5 days	<2-3 days	4-5 days	>5 days
	11.1%	19.4%	68.8%	100% [a]	0%	0%
Timing	In class	After class	Both	In class	After class	Both
	47.2%	3.5%	47.9%	29.3%	0%	0%
Duration (in a day)	"15-30 minutes"			"<15 minutes"		
Access	"School or sponsors buy for me" (96.5%)			"Borrow from classroom" (24.0%)		
Purpose	"Preview" (68.8%) "In-class learning and exercise" (84.6%) "Revision" (70.1%) "Looking up DTF" (70.1%) "Looking up ERA" (39.6%) "Doing homework" (39.6%)			"Preview" (13.3%) [b] "In-class learning and exercise" (66.7%)[b] "Revision" (28.9%) [b] "Looking up DTF" (17.8%) [b] "Looking up ERA" (15.6%) [b] "Doing homework" (8.9%)[b]		
Motivation	Challenge (25.0%) Enjoyment (13.9%) Self-regulation (KSA: 66.7%)			Challenge (6.7%) [b] Enjoyment (0%) [b] Self-regulation (KSA: 31.1%) [b]		
Influence	KS: 3.98, MR: 3.69, PS: 3.87, (n=143)			KS: 2.94, MR: 2.76, PS: 2.93, (n=44)		
Change	No change: 81.8%, Changed: 18.2%			No change: 42.9%[c], Changed: 57.1%[c]		
Workbook[1]	**Shanghai (n=144)**			**England (n=150)**		
Frequency (in a week)	<2-3 days	4-5 days	>5 days	<2-3 days	4-5 days	>5 days
	16.0%	41.7%	41.7%	22.7%	70.7%	6.7%
Timing	In class	After class	Both	In class	After class	Both
	17.4%	22.9%	56.3%	78.0%	0.7%	21.3%
Duration (in a day)	"15-30 minutes"			"30-45 minutes"		
Purpose	"In-class learning and exercises" (75.0%) "Doing homework" (75.0%)			"In-class learning and exercises" (92.7%) "Doing homework" (37.3%)		
Motivation	Challenge (34.7%) Self-regulation (63.2% & 53.5%)			Challenge (19.3%) Self-regulation (25.3% & 25.3%)		
Influence	PS: 3.94, (n=136)			PS: 3.39, (n=138)		
Notebook[2]	**Shanghai (n=144)**			**England (n=150)**		
Frequency (in a week)	<2-3 days	4-5 days	>5 days	<2-3 days	4-5 days	>5 days
	25.7%	13.2%	60.4%	22.7%	70.7%	6.7%
Timing	In class	After class	Both	In class	After class	Both
	50.7%	8.3%	33.3%	78.0%	0.7%	21.3%
Duration (in a day)	"15-30 minutes"			"30-45 minutes"		
Purpose	"In-class learning and exercise" (43.8%) "Revision" (73.6%) "Looking up DTF" (48.6%) "Looking up EAR" (31.3%) "Doing homework" (18.1%) "Doing extra exercises" (13.2%)			"In-class learning and exercise" (92.7%) "Revision" (43.3%) "Looking up DTF" (12.7%) "Looking up EAR" (12.7%) "Doing homework" (37.3%) "Doing extra exercises" (2.0%)		
Motivation	Enjoyment (45.1%) Self-regulation (55.6% & 56.3%) Teacher (31.9%)			Enjoyment (5.3%) Self-regulation (25.3% & 25.3%) Teacher (58.7%)		
Influence	PS: 3.97, (n=131)			PS: 3.39, (n=138)		

Worksheet	**Shanghai (n=144)**				**England (n=150)**			
Frequency (in a week)	1 day	2-3 days	4-5 days	>5 days	1 day	2-3 days	4-5 days	>5 days
	18.8%	21.5%	18.8%	34.7%	12.0%	70.7%	12.0%	5.3%
Timing	In class	After class	Both		In class	After class	Both	
	21.5%	22.9%	50.0%		46%	6.7%	47.3%	
Duration (in a day)	"30-45 minutes"				"15-30 minutes"			
Access	"Parents buy for me" (12.5%)				"Parents buy for me" (0.7%)			
Purpose	"In-class learning and exercises" (58.3%) "Revision" (43.4%) "Looking up DTF" (11.2%) "Looking up ERA" (11.8%) "Doing extra exercises" (13.2%)				"In-class learning and exercises" (82.7%) "Revision" (24.0%) "Looking up DTF" (0%) "Looking up ERA" (0.7%) "Doing extra exercises" (4.7%)			
Motivation	Challenge (36.1%) Self-regulation (61.8% & 54.2%) Parent (18.1%)				Challenge (16.0%) Self-regulation (22.7% & 20.0%) Parent (6.0%)			
Influence	KS: 4.34, MR: 4.11, PS: 4.20, (n=137)				KS: 3.40, MR: 3.22, PS: 2.85, (n=139)			
Change	No change: 84.7%, Changed: 15.3%				No change: 69.1%, Changed: 30.9%			

Reference book	**Shanghai (n=144)**			**England (n=150)**		
Frequency	62.9% (non-"N.A.")			12.7% (non-"N.A.")		
Timing	In class	After class	Both	In class	After class	Both
	1.4%	44.4%	17.4%	5.3%	4.7%	2.7%
Duration (in a day)	"15-30 minutes"			"<15 minutes"		
Access	"Parents buy for me" (58.3%)			"Parents buy for me" (6.0%)		
Purpose	"Doing extra exercises" (35.4%)			"Doing extra exercises" (2.7%)		
Motivation	Self-regulation (43.1% & 41.0%)			Self-regulation (3.3% & 4.0%)		
Influence	KS: 4.26, MR: 4.09, PS: 4.11, (n=92)			KS: 3.14, MR: 3.14, PS: 2.79, (n=14)		

Teaching video	**Shanghai (n=143)**			**England (n=150)**		
Frequency (in a week)	N.A.	1 day	> 1 day	N.A.	1 day	> 1 day
	68.8%	12.5%	18.1%	27.3%	50.7%	22.0%
Timing	In class	After class	Both	In class	After class	Both
	6.9%	22.9%	0.7%	62.7%	4.0%	6.0%
Duration (in a day)	"15-30 minutes"			"<15 minutes"		
Access	"Parents buy for me" (7.6%) "Google or publisher's website" (14.6%) "Teacher makes for me" (3.5%)			"Parents buy for me" (1.3%) "Google or publisher's website" (26.7%) "Teacher makes for me" (25.3%)		
Purpose	"Preview" (55.8%)[d] "In-class learning and exercise" (20.9%)[d] "Doing extra exercises" (25.6%)[d]			"Preview" (22.9%)[e] "In-class learning and exercise" (70.6%)[e] "Doing extra exercises" (3.7%)[e]		
Motivation	Enjoyment (47.7%)[d] Self-regulation (KSA: 56.8%)[d] Teacher (6.8%)[d] Parent (15.9%)[d]			Enjoyment (19.3%)[e] Self-regulation (KSA: 27.5%)[e] Teacher (36.7%)[e] Parent (2.8%)[e]		
Influence	KS: 3.73, MR: 3.63, PS: 3.43, (n=41)			KS: 3.12, MR: 2.91, PS: 2.65, (n=106)		

Elearning system	**Shanghai (n=143)**			**England (n=150)**		
Frequency (in a week)	N.A.	1 day	> 1 day	N.A.	1 day	> 1 day
	64.6%	13.2%	21.5%	37.3%	45.3%	17.3%

Timing	In class	After class	Both	In class	After class	Both
	4.2%	29.9%	0.7%	30.0%	17.3%	15.3%
Access	"Parents buy for me" (7.6%) "School website" (2.1%)			"Parents buy for me" (1.3%) "School website" (25.3%)		
Purpose	"Preview" (38.8%)[f] "In-class learning and exercise" (8.2%)[f] "Looking up DTF" (38.8%)[f] "Looking up ERA" (38.8%)[f] "Doing homework" (10.2%)[f]			"Preview" (11.7%)[g] "In-class learning and exercise" (59.6%)[g] "Looking up DTF" (3.2%)[g] "Looking up ERA" (6.4%)[g] "Doing homework" (33.0%)[g]		
Motivation	Self-regulation (KSA: 60.0%)[f] Teacher (4.0%)[f]			Self-regulation (KSA: 18.1%)[g] Teacher (33.0%)[g]		
Influence	KS: 3.49, MR: 3.42, PS: 3.48, (n=47)			KS: 2.85, MR: 2.57, PS: 2.66, (n=94)		

1. The comparison is between the use of workbooks in Shanghai and the use of exercise books in England.
2. The comparison is between the use of notebooks in Shanghai and the use of exercise books in England.
a. 106 of English students (70.7%) ticked "N.A.", which implies that they did not use textbooks in mathematics.
b. The percentage is calculated excluding the number of students who ticked "N.A." for textbooks, i.e. n=44.
c. n=56 (there were some students used to use textbooks in their previous academic year but no longer used them by then.)
d. The percentage is calculated excluding the number of students who ticked "N.A." for teaching videos, i.e. n=43.
e. The percentage is calculated with the real number of students who ticked "N.A." for teaching videos, i.e. n=109.
f. The percentage is calculated with the real number of students who ticked "N.A." for e-learning systems, i.e. n=49.
g. The percentage is calculated with the real number of students who ticked "N.A." for e-learning systems, i.e. n=94.
DTF: definitions, theorems, and formulas, ERA: examples, references, and answers.
KSA: "I think it helps me to better understand mathematics Knowledge and Skills and enhance my mathematical Abilities".
KS: mathematics Knowledge and Skills, MR: ability in mathematical Reasoning, PS: ability in problem-Solving.

Chapter 9 Discussion

This chapter responds to the research questions set out in Chapter 1 along with some explanations and relevant issues based on the experience of fieldwork and the process of completing the whole study, and links the results to the research area of mathematics education.

9.1 How do secondary school students in Shanghai and England use learning resources in their learning of mathematics?

Shanghai

The results reveal that Shanghai students rely heavily on paper-based resources, especially on textbooks, workbooks, worksheets, and notebooks. It seems not surprising that textbooks play a dominant role in mathematics learning since some researchers have come to this conclusion (Lianghuo Fan, Chen, et al., 2004; Y. Li, Zhang, & Ma, 2009), and in fact, the use of textbooks is mandated by the central government. It is still impressive when textbook use was compared to students' use of other paper-based resources. Firstly, textbooks were used the most frequently by students in mathematics learning; particularly, the majority used textbooks almost every day including weekends. Then, textbooks were the most widely used resource, which were incorporated by a large percentage of students in various learning activities, including preview, in-class learning, revision, and looking up information. Also, most students clearly knew that textbooks could help with improving mathematics knowledge, skills, and abilities, which was the most cited motivation for their use of textbooks. There is no doubt that textbooks play an indispensable role to Shanghai students in their learning of mathematics.

However, it is not true that Shanghai students adhere to their textbooks all the time during a lesson. Actually, according to classroom observations, not many of them opened and read their textbooks, as most of them just listened to the teacher and took some notes or worked on sheets when the teacher asked them to do so. As students and their teachers said in interviews, textbooks were more likely to be used by students as a dictionary for knowing concepts, a template for solving questions, and guidance for preparing for examinations, other than a source for doing exercises, which corresponded to the highest frequency, multi-purposes, and mainly for self-regulation, but with shorter duration and lower helpfulness ratings in improving mathematical skills and abilities in terms of using textbooks, compared to the use of other paper-based resources.

Look through the figures in section 6.1, it can be found that students' use of notebooks has a rough analogy to their textbook use based on the using frequency, timing, duration, and some reasons for the use. For example, textbooks and notebooks were used by the majority almost every day including weekends, but usually for a short time each day. Notebooks were also used for many purposes by a large percentage of students, and revision can be highlighted as the most-mentioned purpose of using notebooks. In interviews, some students did take notebooks as a parallel resource to textbooks:

> *Interviewer: Which resource is the most important one in your learning of mathematics?*
>
> *Students 1: The textbook is the most important one, the second is the notebook and the resources for doing exercises should be in third place… the notebook is a supplement to the textbook…*
>
> *Student 2: I think the notebook is more important, because I take down examples and simplify concepts in the notebook, which looks better than the textbook…*

It seems that some students made themselves a "personalized textbook", which though it was called a "notebook" it played perhaps the same role as textbooks in some cases. Many studies have shown the evidence that students could benefit from taking notes (Fisher & Harris, 1973; Kiewra, 1983, 1987), which is a complex activity demanding more effort than just reading texts (Piolat, Olive, & Kellogg, 2005). Accordingly, it is worth mentioning that nearly half of the students thought that it was enjoyable to take notes in mathematics learning, though self-regulation still was the most cited motivation for notebook use, which suggests that for some students, "to learn better" was not always the first reason for taking notes, and they might also enjoy the achievement in personalizing a book for themselves.

Workbooks and worksheets are another pair of analogues in terms of the timing, duration, purposes, and motivations for using the two resources. A large percentage of students used workbooks and worksheets both in class for learning and exercises and after class for doing homework. The average time of using workbooks and worksheets ranked first and second place respectively, and both over 30 minutes in a school day with mathematics lessons. The main motivations behind the use of the two resources were self-regulation and teacher mediation. Hence, there is no doubt that workbooks and worksheets were the main sources of exercises in students' mathematics learning.

According to students' responses and teachers' interviews, workbooks could be provided by three administration levels, including the Shanghai government, the district-level government, and schools. Therefore, their students normally have at least two workbooks supported by Shanghai and district-level governments. Some schools also organize teachers to create workbooks for their own students to use, in which case the students would have three workbooks in mathematics. The difficulty of questions in those books increases as the sponsors' administration level goes down, since the Shanghai government book is supposed to lay the benchmark of basic literacy for all students, the district's book is designed based on local performance, and schools' books usually represent their expectations of their own students.

However, worksheets could be provided by schools, teachers and, sometimes, parents. Schools usually distributed worksheets to students for intensive exercises and regular mock tests before examinations, and as homework for holidays. Teachers made worksheets for their students to use in lessons. Some parents bought their children worksheets for doing additional exercises.

It seems that, for Shanghai students, the sources of mathematics exercises came from different panels including governments at different administration levels, schools, teachers, and parents (parents bought resources published by commercial companies). It is undeniable that, in many cases, students' use of those exercises was dependent on their teacher's instructions. For instance, according to teachers' interviews, the district's workbook was used the most for assigning homework and the Shanghai government's workbook was usually used in schools for completing some quick and simple questions. It is not to say that the more exercises and practice, the better students can learn mathematics, but rich, reliable, and selective sources of exercises may help both students and teachers to carry out effective practice in mathematics learning (S. Li, 1999).

Reference books play a very unique role in Shanghai students' mathematics learning since the distribution of students' use of the books did not appear in any similar patterns with other resources. It seems that students have their own understanding of how to incorporate reference books in their learning. For example, some students used reference books 2–3 days a week while some used them almost every day including weekends, and the majority used them for 15–30 minutes a day, while many students used the resource less than 15 minutes a day. It might because that they were the only non-unified paper-based resource provided mainly by parents, and the market sales included various types of reference books supporting different students with different learning needs in mathematics; for instance, some aim to help students sort out the concepts and formulas, while others are designed with plenty of exercises under particular topics. Hence, it is not a surprise that reference books were incorporated in many learning activities, mainly including revision, doing extra exercises, and preview, and were usually used by students with the motive of self-regulation. Finally, although reference books were not used as commonly as other paper-based resources, they did help students greatly in improving their mathematics learning according to the ratings.

E-resources receive much less attention compared to paper-based resources in Shanghai. A few students used them occasionally after school for a short amount of time mainly with the purpose of preview, revision, and looking up information. Those students needed to build up for themselves an e-learning environment, since the e-resources mainly came from their parents or found by themselves, which echoed the fact that self-regulation was the most cited motivation for the use of e-resources, and implied that schools might not provide students many opportunities to be exposed to an e-learning environment in mathematics.

England

The results disclose that exercise books play a considerably dominant role in English students' learning of mathematics. Most students used exercise books almost every school day for at least 30 minutes under teachers' instruction. Despite the majority using them for in-class learning and exercises, a large percentage of the students also used exercise books for revision and doing homework. Also, according to students' responses, exercise books were the most helpful resource and changed the least in terms of how they were incorporated in their learning of mathematics among all the resources compared to the previous academic year, and it was further confirmed in interviews that exercise books were regarded as the most important resource in mathematics learning. Hence, it can be concluded that exercise books are the resource containing essential content that English students are supposed to learn and use routinely in mathematics.

Worksheets seem to be used as a supplement to practice in exercise books both in and after class, since the using frequency and duration of the former were just next to the latter, and the reasons for using worksheets were almost the same as exercise books, though worksheets were more likely to be used for doing homework rather than revision. It is worth mentioning that students seldom brought exercise books home, and their teachers always collected exercise books at the end of lessons and stored them in classrooms; instead, worksheets were used for doing exercises at home and pasted into exercise books when students brought them back to class. Moreover, worksheets were rated as the second most helpful resource in improving their knowledge, skills, and reasoning ability in mathematics, and also mainly stayed the same as how they were used in the previous academic year. Therefore, it suggests that worksheets perform similarly to exercise books in students' mathematics learning.

Teaching videos and e-learning systems are another pair of "parallel" resources in terms of how they were incorporated into students' learning of mathematics. The majority used them at the frequency of 1 day per week in class and spent less than 15 minutes on teaching videos and no more than 30 minutes on e-learning systems. Both of them were mainly used for in-class learning and exercises and revision, while e-learning systems were additionally employed by some students for doing homework. Teacher mediation and self-regulation were the two primary motivations for their use of the two resources; however, it seems that not many students were aware of their helpfulness in improving their learning of mathematics except for the influence of using teaching videos on mathematics knowledge and skills. Also, though a large percentage of students indicated that they usually used the e-resources through Google or on publishers' websites, they had to have a registered identity to log in (e.g. MyMaths and MathsWatch), which was provided by their schools; in other words, schools normally bought access for their students to use teaching videos and e-learning systems. In fact, students had mathematics lessons in a computer-supported classroom every two weeks according to the interviews, in which case they were regularly exposed to an e-learning environment in mathematics.

Textbooks are not a commonly used resource in mathematics for English students, which echoes Bokhove and Jones' (2014) finding that the term "textbook" less frequently appeared in Ofsted reports as there was a considerable decrease of textbook use in England since 2004. The results in this study show that a few students gained access to textbooks within classrooms about once a week for a short amount of time, and used them under teacher instruction mainly for in-class learning and exercises. According to classroom observations, those students actually did not own the textbooks; instead, they borrowed different series of textbooks from the classroom based on their learning needs, read concepts and questions in the books under the teacher's guidance, worked out solutions in their exercise books, and had to return them before they left the classroom, just as Haggarty and Pepin (2002; 2001) described in their studies. Also, it is interesting to see that the helpfulness of textbook use in improving their ability in problem solving was highly rated by students though it was not a frequently used resource, ranking as the second most helpful resource and was just one place below the rating of exercise books. It might reveal that textbooks have the potential to positively influence English students' learning of mathematics in some ways.

The use of reference books and e-books was rarely mentioned by English students and teachers in their questionnaires and interviews and were hardly perceived in classroom observations. It probably suggests that those two resources are hardly incorporated in English students' learning of mathematics in years 7 and 8, but caution is needed in generalizing how they use the two resources because of the lack of responses to them.

9.2 What are the similarities and differences in students' resource use in mathematics learning between Shanghai and England?

The results suggest significant differences in students' resource use in many respects between Shanghai and England. This section firstly discusses general similarities and differences as summarized in Chapter 8 along with some possible explanations, and then goes further into details related to specific resources in terms of how they can be comparable to each other between the two places.

In general, English students use e-resources significantly more than Shanghai students, and the latter almost completely rely on paper-based resources. The immediate cause of the differences in using e-resources might be school support. In England, all three sampled schools had computer laboratories, and their students were supposed to have mathematics lessons in those rooms every two weeks, in which case students usually completed some personalized tasks with e-learning systems on computers. However, in Shanghai, many students did not have the opportunity to use any e-resources by themselves within schools according to their responses in interviews. The results are consistent with the PISA report showing that the number of Shanghai students per school computer was more than twice the number of England's, and students' ICT use in Shanghai significantly lowered the OECD average (OECD, 2015). However, as explained in the PISA report, students' infrequent use of ICT did not suggest that no ICT equipment is used in schools in Shanghai; in fact, teachers use computers, projectors, and smartboards very often, which is also confirmed through classroom observations in this study.

Therefore, the second reason for the difference in using e-resources might be related to teacher mediation. In the PISA findings, Shanghai students who reported that only the teacher used the computer during mathematics lessons accounted for the largest proportion among all the participating countries and regions, which implies that a teacher-centred approach to integrating ICT is applied to mathematics education in Shanghai (OECD, 2015). Indeed, it seems easier for teachers to control the class when ICT equipment is only operated by them rather than students, which also reflects the whole-class pedagogy emphasized in Chinese classrooms (Biggs, 1998; Stevenson & Lee, 1995; Wang & Lin, 2005). However, in England, teachers pay more attention to the individual's learning experience (Frederick K S Leung, 1995), and they are more likely to let students work on different tasks and help them individually during lessons; thus, they could be more willing to encourage students to use ICT equipment by themselves. In fact, English teachers showed more affection than worries when it came to students' use of computers in interviews and recognized the importance and convenience of e-resources in teaching and learning.

The other possible interpretation for the finding that Shanghai students seldom use e-resources in mathematics might be parental control of using e-devices. In students' interviews, many of them said that they could not, or had limited time to use computers, mobile phones, and other e-devices at home, which could be also connected to the PISA result that Shanghai students spent significantly less time on the internet at home and outside school compared to the OECD average (OECD, 2015).

Secondly, Shanghai students incorporate the resources in more varied situations and learning activities compared to how English students use the resources. The first possible explanation might be the difference of time spent on homework. Both students and teachers from Shanghai and England were asked how much time it took to complete mathematics homework. Their answers suggested that it was around 40 minutes in Shanghai while no more than 30 minutes in England, which seemed to be not a big difference. However, the frequency of doing homework in mathematics was almost every day in Shanghai while once a week in England. It implies that compared to English students, Shanghai students spend much more time on school-related work in mathematics at home, which is in accordance with the PISA report showing that students from Shanghai spend the most time on homework or other study set by their teachers of all the participants (OECD, 2013a; Zhou & Wang, 2016). Therefore, it seems not surprising that English students have fewer opportunities to use learning resources beyond classrooms, probably involving some after-class learning activities, such as previewing the knowledge before a lesson and doing exercises not assigned by teachers.

The other plausible interpretation for the finding that English students are less likely to use the resources after class and for the relevant purposes might be related to how the resources are kept. According to classroom observations in England, exercise books and textbooks were usually kept by teachers in classrooms. English students would go to different classrooms for lessons in different subjects. Teachers distributed the resources to students when they came to have mathematics lessons, asked students to stick the used worksheets into exercise books during lessons, and collected all the books back when lessons finished. Indeed, some students might bring worksheets and exercise books home for doing homework once a week, but in most cases, it was the teachers who took care of the most commonly used resources instead of students themselves, and therefore, English students could hardly use them after leaving the classroom.

Thirdly, Shanghai students conveyed a stronger sense of self-regulation compared to English students. Specifically, "*I keenly know that it can improve my mathematics mark*" or "*I think it can help me better understand mathematics knowledge and skills, and enhance my mathematical abilities*" were the most cited motives of why Shanghai students used a learning resource, while in England, "*my teacher usually asks me to use it according to his/her instructions*" was the primary reason for students' resource use in mathematics. The first possible explanation of this difference could be related to students' expectations of educational achievement. Many comparative studies mentioned Chinese high expectations for children's education (Frederick K S Leung, 1995, 2001; Frederick Koon Shing Leung et al., 2006; OECD, 2013b). Specifically, one study focusing on Chinese students' expectation on the level of education indicated that, on average, they were willing to spend 14 years on schooling, which was 5 years longer than the number of the years of compulsory education in China and 2 years beyond the starting point of higher education (Chinese students normally take 12 years to complete their study in primary and secondary schools) (Y. Zhang, 2014); one study, referring to Chinese reports regarding Shanghai students' aspirations for future life, shows that career aspiration, especially for the high-paying professions, such as doctor and manager of foreign-funded enterprises, received the most attention (Tan, 2012a). Therefore, the high expectation of education and further careers related to mathematics might make Shanghai students clearly aware of the importance of mathematics learning, so that they express a strong sense of self-regulation for their resource use in mathematics.

Another potential reason why Shanghai students had such a perception of self-regulation might be the perceived self-responsibility of learning outcomes. The PISA 2012 results provide empirical evidence implying that, compared to students from the UK, Shanghai students showed more consistency in the responses that success in mathematics was under their control instead of the teacher's or family's (OECD, 2013b). Thus, Shanghai students tend to take their own responsibility for the learning outcomes in mathematics, which might be reflected in a stronger sense of self-regulation behind their resource use.

Fourthly, compared to Shanghai students, English students are more likely to change their way of using textbooks, worksheets, and teaching videos in a new academic year. A plausible reason could be related to how classes are organized and assigned to mathematics teachers. In Shanghai, students are usually grouped into classes once they enter a school, and stay in that setting till they graduate from the school. Teachers are grouped by grade level and also stay in that setting once allocated to classes, which means that they often teach and follow the same classes during the years that those students study in the school. Therefore, Shanghai students are kept in a relatively stable learning environment, which probably led to minor changes in how they use learning resources. However, in England, though students are also grouped into classes after their entrance, they may be changed to a different class set based on their performance at the end of a term. Teachers are usually grouped by subject and teach several year levels with high mobility, which means that they could be assigned to different classes at multiple year levels when a new academic year begins. In this case, it is more possible for English students to have a different mathematics teacher at different year levels who might incorporate different resources in their mathematics learning, which was also pointed out by the students in interviews explaining why they used textbooks differently compared to the previous year level. Accordingly, the higher mobility of students and teachers could be the reason why English students had significantly more changes in using some resources.

Finally, the findings show that, in Shanghai, the defined resources always positively influenced mathematics learning from students' perspectives, while English students seemed to hold a more critical view on whether the resources were helpful to their learning of mathematics. It might suggest that, compared to English students, Shanghai students benefit more from using the resources, or have more awareness of the positive impact of the resources on mathematics learning. However, it could also because of the emphasis on propriety in Chinese culture (e.g.

Chan 2008; Fan 2000), in which case Chinese students might be more likely to give a non-negative evaluation to avoid offending anyone. Moreover, the significant and strong correlation between the ratings of the three aspects of mathematics learning implies that it could be hard for most students to distinguish the terms *knowledge and skills*, *reasoning ability*, and *problem-solving ability* from each other in mathematics.

When it comes to the differences in resource use regarding each specific resource, the use of mathematics textbooks comes first. As elaborated earlier, Shanghai students used textbooks much more frequently and spent more time studying with textbooks beyond the classroom in various learning activities compared to English students. The primary explanation might be reflected in how students gain access to textbooks. In Shanghai, the government buys textbooks for every student studying at compulsory education stage, in which case the students are supposed to have textbooks for every compulsory subject including mathematics. However, in England, it is a tradition that schools provide students learning resources (Haggarty & Pepin, 2002; Pepin & Haggarty, 2001), including textbooks, and it will cost a great deal for schools to afford textbooks for every student; thus, textbooks are usually available for students to borrow and use within classrooms only, rather than to possess and take back home, which definitely restrict how students use them.

Then it is worth mentioning that Shanghai's textbooks are much thinner than England's, and aim to provide the students with learning themes, essential outlines, and the structure of knowledge in mathematics, instead of a great number of practice exercises (Ministry of Education of the People's Republic of China, 2011). The use of mathematics textbooks in Shanghai consistently represents these design principles; teachers emphasize the concepts and definitions in textbooks, and students are supposed to learn and understand all the contents in textbooks (K. Park & Leung, 2006), in which case they treat textbooks like a dictionary for knowing and revising knowledge, a standard reference for solving problems and a guideline for passing examinations as discussed in the previous section; thus, they seem to clearly know the helpfulness of using textbooks in improving their learning of mathematics and are more likely to use textbooks with the motive of self-regulation.

In England, textbooks are regarded rather as an "encyclopaedia" containing various concepts and numerous exercises for teachers to choose from when delivering a certain topic (K. Park & Leung, 2006). The use of mathematics textbooks in England reflects this point to a great extent: the teacher who incorporated textbooks in his teaching practice mainly asked students to work on selected exercises in textbooks, another teacher highlighted her desire for "better" textbooks providing more exercises under one topic, and students usually were not expected to have a precise understanding and holistic view of what a whole textbook actually presented, at least for the students in years 7 and 8. Therefore, it could be hard for English students to be aware of the influence of using textbooks on mathematics learning. In fact, English teachers and students are struggling with using textbooks because students cannot "really", or "directly" use textbooks. Sometimes students photocopied a few pages of textbooks so that they could use the selected exercises and examples, and sometimes they needed to write down the full questions by themselves and write their answers in exercise books. Furthermore, though it was a particular case that students in school B followed their teacher to summarize concepts and the key explanations under a topic, in "another" exercise book (e.g. "star book", as they call it according to classroom observations), in which way they composed their own "textbook" in the sense of combining the contents in the two exercise books, it suggests the appeal to them of a book containing essential knowledge and definitions in mathematics.

Secondly, the findings confirm that it is not common for English students to use commercial workbooks in mathematics; exercise books are the ones mainly used for doing practice, which could be seen as an integration of Shanghai's workbooks and notebooks in terms of what and how the contents are written. Therefore, the use of exercise books in England was compared to the use of workbooks and notebooks in Shanghai, which showed more similarities between the use of exercise books and workbooks than between the use of exercise books and notebooks. In fact, in both Shanghai and England, they were the frequently used resources, but exercise books were more likely to be used only within classrooms, which might because of the storage of the resource as discussed earlier.

Next, both exercise books and workbooks were mainly used for in-class learning, revision, and doing homework, the percentages regarding which were roughly distributed in a similar shape according to Figures 17 and 34. Compared to those resources, Shanghai's notebooks were used more widely for various purposes, which could be comparable to how Shanghai students used textbooks as mentioned in the previous section. Therefore, England's exercise books and Shanghai's workbooks seem to play a similar role in students' mathematics learning in terms of what learning activities they are usually incorporated in.

Also, it is worth mentioning that English students spend much longer time on exercise books compared to not only how Shanghai students use workbooks but also the time that they spend on other resources. According to classroom observations and interviews, exercise books were the resource used daily by English students as standard work for mathematics learning under teacher instruction, which actually coincides with the construct of textbook described in Chapter 3 apart from the publishing part. Therefore, in one sense, exercise books are also expected to play some role of textbooks in terms of the content as mentioned above and the dominant position in students' mathematics learning.

Thirdly, the findings show that, on average, worksheets were used more frequently and for a longer time in a day in Shanghai than in England, and compared to English students, Shanghai students were more likely to incorporate worksheets in various learning activities. The possible explanation of this difference might be related to the content of the worksheets. Based on classroom observations, in England, worksheets used for in-class learning usually were divided into several small pieces of paper, and each contained one series of exercises under a specific topic. After completing all the tasks on a worksheet, students were supposed to stick the sheet into their exercise books, which suggests that worksheets are regarded as a supplement to exercise books. However, in Shanghai, worksheets used for in-class learning are treated as an alternative to notebooks, which means that they might be used every day but hardly be used with notebooks at the same time in a lesson. Therefore, the worksheets used in Shanghai usually contain the introduction of a topic, key concepts with some blanks for students to fill in, examples, tasks and exercises, and also summaries, which can be seen as a simplified teaching plan of the lesson, so that students will have a whole picture of what the lesson is about and what they need to do during the lesson. Accordingly, Shanghai students use worksheets more often and spend a longer time working on them, and it is possible for them to use worksheets as an independent resource after class for various purposes, such as looking up for definitions since concepts are included in those sheets. Also, some Shanghai students also receive worksheets from their parents and are required to do extra exercises when studying with them; thus, parental involvement could be another reason for the difference in using worksheets between Shanghai and England, which will be further discussed in the following section.

Moreover, many Shanghai students have reference books in mathematics for self-improvement and therefore mainly use them when revising and doing extra exercises, which is not the case in England. The immediate cause might be the higher level of parental involvement by providing learning resources not required by schools, which is reflected in the high percentage of students who used reference books bought by parents, and one of the defined factors relating to parental support in learning resources. Another plausible interpretation might have been revealed in the discussion of Shanghai students' stronger sense of self-regulation. In fact, the use of reference books could be seen as a practical embodiment of the perceived self-responsibility of learning outcomes. However, their quest for "extra" learning hiding behind the use of "extra" resources might be related to Chinese high expectations of educational achievements and the fierce competition for the future that Shanghai students are facing (Qiu, 2006; T. Wang, 2010). As Tan (2012a) elaborates in her study, many Shanghai parents endeavour to ensure that their children are ahead of the "ordinary starting point" in life, or in a more feasible way, at least ahead of their children's classmates. Hence, it seems reasonable for Shanghai parents and students to seek something beyond "ordinary" learning in schools, which could include "extra" resources, such as reference books bought by parents, and out-of-school lessons as discussed in the next section.

Finally, compared to Shanghai students, English students are more likely to use teaching videos and e-learning systems in mathematics. The findings show that the proportion of English students who used the e-resources was approximately twice the percentage of Shanghai students, though most of the English students used them only once a week for in-class learning and exercise. Then, English students accessed the e-resources mainly via the school website, teacher-made sources, and search engines (e.g. Google), while Shanghai students rarely used school access and teacher-made videos, since their schools did not provide the support in mathematics, based on what the students' and teachers said in interviews. As discussed earlier, those differences in using e-resources could be due to the school ICT infrastructure, teacher mediation, and parents' control.

Also, English students seem to use e-resources in a similar way to how they use paper-based resources in terms of the purpose of use and the situations, i.e. mainly for in-class learning and exercises, revision, and doing homework. Indeed, as students said in interviews, they usually watched videos to clarify the steps of solving a question and logged into e-learning systems to complete in-class tasks and also homework. However, in Shanghai, students are more likely to use the e-resources as ancillary materials after class for preview, looking up information, and doing extra exercises. In interviews, one student mentioned that she sometimes used an e-learning system to search and check the answers to her homework.

In short, it seems that all four frequently used resources in England play a similar role, which could be comparable to how Shanghai students use worksheets and workbooks in terms of the purposes that they are mainly used for, namely, in-class learning and exercises, revision and doing homework. However, in that sense, the roles that textbooks, notebooks, and reference books play in Shanghai students' learning are nearly missing in England, though exercise books used by English students could be understood as notebooks or some kind of textbooks, according to the constructs in this study. In fact, the dominant position of exercise books in England is essentially founded on the multiple roles that they play in students' learning of mathematics: they exist as notebooks since the contents are written by students themselves, they sometimes take the role of textbooks as the contents are used as standard work for mathematics learning, and they are commonly used for doing exercises, which is embodied in what they are called and the function for which Shanghai workbooks are designed. Therefore, compared to that, the most-used resources in Shanghai, i.e. paper-based, seem to have a relatively independent function to each other in students' learning of mathematics.

9.3 What are the factors that influence students' use of learning resources in England and Shanghai?

According to the conceptual framework and literature review, this study constructs social, didactical, and cultural factors including four aspects, i.e. out-of-school lessons, parental involvement, teacher mediation, and beliefs regarding mathematics learning and learning resources, to tentatively interpret students' resource use in mathematics and the result of comparisons between Shanghai and England. Some of the aspects have been mentioned and simply discussed above in terms of their impacts on students' resource use, while this section will go beyond those arguments and intend to make some remarks based on the findings.

Out-of-school lessons

The results show that many Shanghai students attended out-of-school lessons in mathematics and it was more popular to study in cram school than to study with a private tutor, whereas only a few English students had the experiences of attending out-of-school lessons, the difference of which is statistically significant. The PISA report (OECD, 2013a) has the same finding, though the difference in the proportion of students who attended after-school lessons in mathematics between UK and Shanghai was not as considerable as the figures shown in this study. It might because that PISA 2012's target samples in the UK were 15-year-old students from three countries (England, Wales, and Northern Ireland) and four types of school (OECD, 2014), which aimed at students at a higher learning stage and covered more areas and school types than the design of this study.

Moreover, there existed significant associations between attending out-of-school lessons organized by commercial companies and how Shanghai students used reference books and worksheets. As elaborated earlier, many Shanghai students and parents look for learning in addition to the school's regular timetable to ensure that their children are ahead of their classmates while attending lessons organized by commercial companies, or in other words, going to cram schools, is a popular choice (Tan, 2012a). Many studies have paid attention to such kind of lessons with the increasing popularity of the lessons (Aronson, Zimmerman, & Carlos, 1999; Baker, Akiba, LeTendre, & Wiseman, 2001; Bodilly & Beckett, 2005), especially in East Asia (Bray, 2009; Byun, 2009, 2014; Zhang & Bray, 2015). Those lessons aim to improve students' proficiency in test-taking and usually provide mock problems for students to practise (H M Huang, 2004; Kuan, 2011; OECD, 2016). According to students' interviews in Shanghai, reference books and worksheets are the two types of resources that cram schools usually supply. Thus, it seems natural that students who attended the lessons were more likely to use reference books for doing extra exercises and believed in the helpfulness of reference books in improving their learning of mathematics since they were designed to prepare students for examinations, and students who benefitted from such extra learning could be more willing to use worksheets bought by their parents with the intention to improve more.

Parental involvement

Firstly, it seems interesting that the Shanghai parents' response rate was 94%, which was even more than the number of their children' replies, while 74 English parents gave their answers back, which was less than half of the questionnaires sent out. The low response rate in England could be complicated. As teachers mentioned after distributing parent questionnaires in class, some students would not care about them and not pass the letters to their parents, and some probably forgot to bring them back. Thus, though it might not fair to blame all unreturned questionnaires on parents' neglect, the response rates to some extent still reveal the difference of parental involvement in children' learning between the two places.

Back to the findings of parental involvement in this study, it implies a more frequent involvement of Shanghai than English parents in children's mathematics learning, by way of checking children's learning progress, assisting with homework, assigning extra exercises, and buying learning resources on their own initiative. However, the PISA report indicates that there are no significant differences in parents' interest in children's school activities and parents' support when children face difficulties at school, between the UK and participating cities from mainland China including Shanghai (OECD, 2017), and particularly, the figures for after-school study time with parents in UK and Shanghai were also close (OECD, 2016), which suggest that there might not be a significant difference in parental involvement in children's homework between the two places. In fact, it should be noticed that the significant differences found in this study reveal the frequencies, rather than the amount of time, with which parents got involved in some aspects of mathematics learning including assisting with homework, and Shanghai students apparently had mathematics homework more frequently than English students as discussed previously; thus, it will not be seen as conflicting with the PISA results.

Supporting children in doing homework was the most mentioned form of parental involvement according to English students' responses in interviews, which is also one of the most common ways that parents can help with children's learning (H. Cooper, Steenbergen-Hu, & Dent, 2012; Núñez et al., 2015). Indeed, English parents' assistance with homework is a boost for their children to benefit from resource use: frequent involvement in children's homework seems to encourage students to overcome difficult problems and revise what they have done on worksheets, reduce the time that students spend on exercise books, and believe in the helpfulness of worksheets and e-learning systems in improving their learning of mathematics. It might suggest that parental involvement by assisting with children's homework plays a positive role in English students' mathematics learning, which has been reported by many researchers (H. Cooper, Jackson, Nye, & Lindsay, 2001; Pomerantz & Eaton, 2001; Voorhis, 2011). However, such associations were not found in Shanghai's results, which shows that the influence of parents' assistance with homework is not unanimous (Dumont et al., 2012).

Shanghai students' resource use is more likely to be influenced by other forms of parental involvement. Checking children's learning progress moderately frequently might help students better understand textbooks since it shortened the time that students spent on textbooks and made students perceive the helpfulness of textbooks in improving their problem-solving ability in mathematics; assigning extra exercises to children at a high frequency seems to drive students to spend more time on worksheets and reference books, while recognizing the positive impact of the two resources on the improvement of mathematics learning, and students could be more willing to use reference books and worksheets if their parents bought those resources moderately frequently. The latter two forms of parental involvement echo Shanghai students' and parents' quest for learning beyond schoolwork as mentioned above, and the results imply that Shanghai students would be better engaged in learning activities incorporating resource use if their parents rationally emphasized "extra learning" and intervened appropriately in children's after-school study.

Teacher mediation

According to the results, teachers play a considerable role in which resources students use the most frequently and in which situations students use learning resources, since students are supposed to complete teacher-assigned tasks presented in the resources in many cases (Rezat, 2012). Specifically, English students' use of learning resources is more likely to be dependent on teacher instruction given the fact that teacher mediation was the most cited reason for using many resources, and students had fewer out-of-school lessons, and less frequently received parent-assigned exercises and parent-paid learning resources compared to Shanghai students. Moreover, teachers from the same school usually instruct students to use learning resources similarly while teachers from different schools have different preferences of what students are supposed to use in their learning of mathematics, which is reflected in students' report that the resource use in different schools is significantly different.

In fact, Shanghai teachers appear to teach mathematics in a similar way to their colleagues. As discussed in the previous section, Shanghai mathematics teachers are usually grouped by grade level and stay with the set once they are allocated to classes; thus, it is convenient for them to communicate teaching progress and share resources with each other in a fixed group (Wong, 2010). In particular, there are Collective Lesson Planning Groups for different subjects at each grade level, in which all teachers teaching the same subject meet regularly, prepare lessons together, observe each other's lessons, reflect and comment on observations collectively, and conduct public lessons in turn (Lianghuo Fan, Miao, & Mok, 2015). In this study, the teachers who frequently incorporated worksheets in students' mathematics learning pointed out that the worksheets were usually designed and shared by all mathematics teachers at the same year level and passed to the teachers in a lower grade when they moved up. Accordingly, the emphasis on communication, collaboration, and inheritance between teachers could explain the similar methods of mathematics teaching, and ultimately mathematics learning including resource use, within a school.

However, in England, all the teachers interviewed said that they usually prepared lessons on their own and barely had time to observe colleagues' lessons though they had the desire to share ideas with each other, which suggests that the differences in mathematics teaching between different teachers working in the same school could be also considerable. Webb et al.'s (2004) study also reveals that English teachers' participation in collaborative whole-school lesson planning decreased with increased use of government-approved schemes of work for the national curriculum. The schemes list the content that teachers are supposed to teach, while they can still use different resources and employ different teaching approaches to deliver lessons, which means that there is little need for teachers to make the decision together on what to teach as they usually did before. Therefore, the pattern of resource use in an England school might be the result of a combination of various teaching styles within the school, which shows that the consensus of which resources should be used in mathematics learning and teaching within an England school is not as strong as Shanghai schools.

Beliefs

The findings of students' beliefs regarding the authority of mathematics textbooks, doing exercises, and the attribution of success and failure in mathematics learning provide data-based evidence supporting the fact that, compared to English students, Chinese students are more likely to endow textbooks with high authority, take doing exercises and "practice makes perfect" as the principle of mathematics learning, and believe that hard work is the key to be successful in their learning of mathematics, which are concerned by many researchers when it comes to the comparison of mathematics education between East and West (e.g. Leung et al. 2006).

Next, how do the beliefs influence students' resource use in mathematics? In general, the results indicate that beliefs about the authority of textbooks, doing exercises, the pressure of examinations, and the attribution of success and failure in mathematics learning have greater effect on Shanghai students' resource use compared to England, which might partly because that Shanghai students tend to incorporate resources in mathematics learning more consciously, e.g.

use resources out of the motive of self-regulation, hence it could be easier to find associations between their beliefs and resource use.

To be specific, Shanghai students who had greater trust in textbooks were more likely to find them interesting and helpful in mathematics learning, incorporate them in various situations and learning activities, and use them for self-improvement, while there were no associations between the belief about textbooks and students' textbook use in England. The plausible interpretation could be students' different perceptions of textbooks between the two places. As argued in the previous section, Shanghai students appear to be more familiar with textbooks, in which case they usually clearly know how to use them and perceive the importance of textbook use in their learning of mathematics. However, English students seem to have an ambiguous image of what a textbook is as their responses to the belief related to textbooks contained paradoxes and some of them even did not give their opinions on the statements. Thus, it might be less possible for English students to use textbooks based on how they understand them.

Secondly, Shanghai students who thought highly of doing exercises were more likely to challenge themselves with difficult problems in workbooks, worksheets, and reference books, use them for self-regulation, find worksheets and reference books interesting and helpful in improving their learning of mathematics, and use worksheets frequently for in-class learning and exercises but for a short period in a day. Most English students recognized the importance of doing exercises in mathematics learning as well: they seemed to use exercise books more frequently, be more willing to cope with difficult problems in worksheets, and perceive the influence of using the two resources on their mathematics learning positively. It confirms the Chinese emphasis on "practice makes perfect" in mathematics education (Frederick K S Leung, 1995; S. Li, 1999, 2006) while implying a contrast to the impression of western people's contempt for doing exercises in mathematics learning (Hiebert & Carpenter, 1992; S. Li, 2006), and it further suggests that looking on the bright side of doing exercises could be a boost in both Shanghai and English students' learning of mathematics.

Thirdly, the findings reveal that Shanghai and English students were statistically facing the same amount of pressure to pass examinations, which echoes the fact that revision was one of the most frequently mentioned purposes of using learning resources in both places. Moreover, Shanghai students who felt more stressed before mathematics examinations tended to work on worksheets for a longer time and used notebooks not only in class but also after class and for doing extra exercises. It seems that the pressure of examinations drives Shanghai students to engage in learning activities including resource use beyond schools, which has been discussed earlier referring to out-of-school lessons and parent-assigned exercises. However, English students who worried more about their examination performance were more likely to use worksheets for self-regulation. In fact, the use of worksheets could explain English students' participation in school-related learning activities beyond the classroom to a certain extent, since worksheets were the resources received from teachers and schools, and were most used after class and for doing homework, which suggests that the perceived stress of examinations might encourage English students to be aware of self-responsibility in mathematics learning, and possibly be more willing to complete teacher-assigned work at home.

Finally, the results reflecting students' attribution of success and failure in mathematics learning suggest that both effort and personal interests and abilities seem important to Shanghai and English students, though Shanghai students appear to be more faithful to effort, which is in accordance with the common image that Chinese put heavy emphasis on hard work in learning (Frederick K S Leung, 1995; J. Li, 2004; H. Stevenson & Stigler, 1992). For the influence of the belief on resource use, Shanghai students who would rather attribute the success of mathematics learning to effort were more likely to challenge themselves with difficult problems in workbooks and worksheets and use them for self-regulation, work on worksheets almost every school day, use reference books for a longer period of time per day, change their ways of using worksheets and reference books at the new year level, and perceive the helpfulness of the three resources in their mathematics learning. It actually could be seen as the embodiment of effort to improve mathematics learning from a Chinese view, which was also pointed out by Shanghai students in interviews, that effort to them meant doing more exercises and seeking "extra" learning. English students who tended to ascribe the success of mathematics learning to effort were more inclined to change how they used worksheets compared to the previous year level, which was usually related to an increase in frequency and amount of time, and watch teaching videos beyond teacher instruction. Therefore, it seems that both in- and after class learning should be counted as effort to English students, though the latter aspect did not come up in interviews.

From the findings and discussions above, it is clear that all the factors constructed by this study do play some role in students' interaction with learning resources, although they might contribute differently to the results in a different context, which suggests that the factors should be taken into consideration when explaining students' resource use in mathematics learning.

Indeed, this study benefits from Vygotsky's Activity Theory, which is the theoretical underpinning of the relationship between students, learning resources, and mathematics learning while emphasizing the cultural–historical contexts of learning. Just as Rezat and Sträßer (2012) said, it is optimistic and positive to take mathematics as the object and artefacts as the instrument of the learning activity in schools, while the reverse proposed by Engeström (1998) might not be essential according to the findings of this study, since many students have intrinsic motivations, e.g. *enjoyment* and *challenge*, to use the resources in their mathematics learning; in other words, to produce school text showing the experiences and abilities in solving assigned problems is not always the only objective of learning for these students. Moreover, different from Rezat and

Sträßer's socio-didactical tetrahedron, the conceptual framework of this study does not aim to structure the components or characters, such as teacher, family, and tutor, of mathematics learning, but to focus on students' resource use in mathematics learning, namely the *student–learning resource–mathematics* triangle, and construct the possible factors influencing the interactions between students and learning resources. This study shows that the factors must be more specific than the components that Rezat and Sträßer assembled, which can be linked to resource use in a given context. Therefore, although the social, didactical, and cultural factors constructed by this study do explain students' resource use to a great extent, they could be in a different form of expression when it comes to other educational systems or contexts, especially for the cultural part, i.e. beliefs about learning resources and mathematics learning.

9.4 Summary

Firstly, in Shanghai, mathematics textbooks and notebooks present the essential content and key points that students are supposed to know and refer to when needed, workbooks and worksheets are taken as the main source of selective exercises, and reference books are usually used as a supplement to the resources mentioned above and beyond school learning. In England, exercise books are the dominant resource in students' mathematics learning and play multiple roles including presenter of knowledge, source of exercises and place of reflection; worksheets could be regarded as complementary to exercise books supporting students' in- and after class learning; and teaching videos and e-learning systems are mainly used as an alternative and extension of exercise books and worksheets.

Secondly, the comparisons reveal many differences in students' resource use in mathematics between the two places. In short, the use of learning resources in Shanghai seems to be "multithreading", which means that different resources have their own position in students' mathematics learning, while the resource use in England looks "radial", centred on exercise books. The reasons for the differences could be various and rooted in not only teaching practice but also social ideology and culture.

Finally, the constructed factors perform differently in different contexts. The social and cultural factors play a great role in Shanghai. Shanghai students and parents are more likely to appeal to learning beyond school including attending out-of-school lessons, doing exercises not assigned by teachers, and buying learning resources not required by schools, which influence students' use of worksheets, workbooks, and reference books. Also, their emphasis on the authority of textbooks, doing exercises, and effort to succeed in mathematics also impact how they use the relevant learning resources to a certain extent. Compared to that, teacher mediation seems to be more influential to students' resource use in England as their learning of mathematics, including resource use, depends more on school-related activities, i.e. the didactical dimension.

Chapter 10 Conclusions, Implications, and Recommendations

The final chapter of this study consists of three sections. The first section summarizes the study and draws conclusions based on the main findings. The second section discusses some implications for those who are relevant to students' learning of mathematics including teachers, parents, school administrators, and policymakers. The third section suggests several potential directions of students' resource use that researchers can go into further.

10.1 Summary and conclusions

This study is a comparative study between Shanghai and England, and the basic research question is, How do secondary school students use learning resources in mathematics? Since it is implemented in Shanghai and English settings, the second research question is, What are the differences and similarities of students' resource use between the two places? And to tentatively interpret the resource use and results of the comparison, it also asks, What are the factors that influence students' resource use in mathematics in Shanghai and England?

A conceptual framework is established to address the research questions. Learning resources in this study refer to the objects presenting mathematics which can be utilized by students in their learning of mathematics in school education. Following this concept, eight resources, namely textbooks, workbooks, worksheets, notebooks, reference books, e-books, teaching videos, and e-learning systems, are defined as the embodiments of learning resources, which are further classified into two categories, i.e. paper-based resources and e-resources. Originating from Vygotsky's Activity Theory, students' resource use in mathematics is described as a dynamic relationship between students, learning resources, and mathematics, in which case the use of a resource is defined as the activity primarily related to paper-based and electronic resources in students' mathematics learning. Eight indicators are constructed to represent students' resource use, including three measures related to time: frequency, duration, and timing; two aspects reflecting reasons of resource use: purpose and motivation; and three other aspects: the access to different learning resources, the change in resource use compared to the previous academic year, and the influence of resource use on students' mathematics learning. Based on Rezat and Sträßer's socio-didactical tetrahedron evolved from Engström's work, social, didactical, and cultural factors are taken into account to better understand resource use in Shanghai and English contexts. The social factor includes out-of-school lessons and parental involvement in children's mathematics learning, the didactical factor refers to teacher's teaching incorporating students' resource use, and the cultural factor is understood as beliefs related to learning resources and mathematics learning involving students' resource use; particularly, this study focuses on students' beliefs about the authority of textbooks, doing exercises, the pressure of examinations, and the attribution of success and failure in mathematics learning.

The main subjects of this study consist of 161 Shanghai students in grades 7 and 8 and 206 English students in years 7 and 8 from three state-funded secondary schools in each place, which are multistage-cluster convenient samples from the urban district of Shanghai and south-west of England. Also, 6 mathematics teachers from each place and 161 Shanghai parents and 206 English parents were involved in the investigation, which are the nested samples of student participants.

Six instruments were designed and developed to collect data from the research samples. The primary one is the student questionnaire covering all the information needed in this study except for the didactical factor. Shanghai students contributed 144 valid responses while English students gave back 178 valid replies, which account for 89.4% and 86.4% of the distributed questionnaires respectively. The student focus group interview was employed as a complement to the questionnaires and was also used to identify the association between their beliefs and resource use. The 22 Shanghai students were divided into four groups and 27 English students in five groups were interviewed in the sampled schools. The teacher questionnaire was designed to collect data relating to teaching practice incorporating students' resource use and beliefs about the resources and mathematics learning, the response rate of which was 100% in both Shanghai and England. The teacher interviews were conducted with 6 Shanghai teachers and 4 English teachers to obtain details of the information collected from the questionnaires. The classroom observation was applied to 4 Shanghai lessons and 14 England lessons as the triangulation of the data collected above, focusing on the interactions between the sampled students, their teachers, and learning resources in class. The parent questionnaires inquired about their beliefs and involvement in children's mathematics learning and was used as a triangulation of students' answers. In all, 152 valid responses were returned by Shanghai parents while 74 valid replies were received from English parents, which account for 94.4% and 36.0% respectively of the questionnaires sent.

Quantitative methods dominated the data analysis. By processing the data collected from the questionnaires, a general image of how students use learning resources in mathematics and the contextual factors for resource use in Shanghai and England were presented with descriptive statistics, such as percentages and means. Chi-square tests were employed to examine the differences in students' resource use between the two places and the association between resource use and the factors concerned, along with t-tests.

Qualitative methods were applied to the data collected from classroom observations and interviews to enrich the contextual information; namely, which resources students used when attending out-of-school lessons and studies with parents, how teachers instructed students to use learning resources in mathematics, and students' beliefs about learning resources and mathematics learning, which were mainly taken as the clues and evidence to build up the association between the factors and students' resource use.

The findings of this study provide answers to the research questions, which are concluded in the following paragraphs.

How do secondary school students from Shanghai use learning resources in mathematics?

The paper-based resources, including textbooks, workbooks, worksheets, notebooks, and reference books, are the main learning resources used by Shanghai students in mathematics in terms of the frequency of use and duration. Specifically, textbooks supplied by the Shanghai government are used both in and after class for various purposes including preview, revision, in-class learning, and exercises, and looking up definitions, theorems, and formulas as well as examples, references, and answers. Workbooks, provided by the Shanghai government, district-level authority and some schools, are mainly used for in-class learning and exercises, doing homework, and revision. Worksheets, mostly designed by teachers and schools, play a similar role to workbooks in terms of what learning activities they are incorporated in, and are rated by students as the most helpful resource in improving their mathematics learning. Notebooks, usually bought by students themselves, are a personalized resource used for taking down the key points and examples in lessons and later for revising and referring to the contents when needed. Reference books, provided mainly by parents, are used by many students as a supplement to the above resources for revision and doing extra exercises beyond school-related work, and are rated as the second most helpful resource in their learning of mathematics. However, only a few students are exposed to e-resources including e-books, teaching videos, and e-learning systems. Moreover, Shanghai students have a strong sense of self-regulation behind their use of learning resources, do not make many changes in resource use compared to the lower year level, and believe that the resources all positively influence their mathematics learning in varying degrees.

How do secondary school students from England use learning resources in mathematics?

Exercise books, worksheets, teaching videos, and e-learning systems are the commonly used resources in England. To be explicit, exercise books, supplied by schools and existing as a combination of the workbooks and notebooks defined in this study, are the dominant resource and the most helpful one in mathematics learning in the students' views, and are mainly used and kept in classrooms for in-class learning and exercises, while some students also use them for revision and doing homework. Worksheets, designed by teachers and schools, are used both in and after class for in-class learning and exercises, revision, and doing homework, are taken as a complement to exercise books and are the second most helpful resource in improving mathematics knowledge and skills and reasoning ability. English students have mathematics lessons in an e-learning environment regularly, in which case they watch teaching videos and log in to e-learning systems via school-provided access. The two e-resources are usually used in class for learning and exercises as well as revising purposes, while e-learning systems are additionally used by some students after class for doing homework. A few students incorporate textbooks in mathematics learning and use them mostly within classrooms for in-class learning and exercises, since it is a tradition in England that textbooks are provided by schools and available to students to borrow from classrooms during lessons rather than to use as their own possessions. Reference books and e-books are hardly used by English students in their learning of mathematics. Also, English students hold a critical view of how the use of resources influences their mathematics learning except for exercise books; their resource use is led by teachers in most cases, and many of them make some changes in resource use at different year levels.

What are the differences and similarities in students' resource use between Shanghai and England?

Generally speaking, the findings indicate more differences than similarities in students' resource use in their learning of mathematics between the two places. Shanghai students rely heavily on paper-based resources while English students incorporate both paper-based and e-resources in mathematics learning. Most English students only use school-provided and teacher-designed resources, while many Shanghai students also use the resources bought by themselves or their parents. Shanghai students often use the resources both in and after class for various learning purposes, while English students are more likely to use them only within the classroom mainly for in-class learning and exercises as well as revision, and sometimes for doing homework. Shanghai students take their own responsibility for managing learning resources while it is the teachers who usually take care of the resources for their students in England. Accordingly, behind their resource use, Shanghai students have a stronger sense of self-regulation to improve their learning of mathematics, while English students deem that their use of learning resources mainly depends on teachers' instructions. Moreover, Shanghai students believe that all the resources play a positive role in improving their mathematics learning, while English students appear to doubt the helpfulness of the resources except for exercise books, and compared to Shanghai students, it is more likely for English students to change how they use learning resources in a new academic year, especially for textbooks, worksheets, and teaching videos.

What are the factors that influence students' resource use in Shanghai and England?

The defined social, didactical, and cultural factors have different performances in the two places and influence resource use in different ways.

Firstly, it is popular for Shanghai students to attend out-of-school lessons in mathematics, especially for those organized by commercial companies, which has an association with whether they use reference books for doing extra exercises and whether they use worksheets received from their parents. However, it is not the case for English students since few of them have such lessons.

Secondly, Shanghai parents are involved more frequently than English parents in their children's mathematics learning. Shanghai students tend to use worksheets more frequently, incorporate reference books in their learning of mathematics and use them for doing extra exercises, and recognize the helpfulness of the two resources in improving their mathematics learning if their parents frequently assign exercises in addition to school work. They are more likely to use mathematics textbooks efficiently if their parents check their learning progress at a moderate frequency, and engage more in parent-assigned tasks on worksheets and use reference books after class if their parents sometimes buy them learning resources. In England, students could be more willing to solve difficult problems in worksheets, use them for revising purposes, and realize the helpfulness of exercise books and worksheets in improving their learning of mathematics if their parents get more involved by assisting with homework.

Thirdly, in both Shanghai and England, teacher instruction decides which resources students use the most frequently and in which situations students use the resources to a great extent, as "teacher mediation" is one of the main motivations for students' resource use in the two places. In Shanghai, teachers from the same school are likely to instruct students to use learning resources in a similar way due to their emphasis on collaborative work, while teachers from different schools may have different understandings of what and how the resources should be used by their students in mathematics learning; accordingly, their students' use of the resources is significantly different from others. In England, teachers usually work alone and have greater autonomy in resource use, and the change in mathematics teachers can lead to the change in how students use learning resources.

Finally, the results suggest a closer association between students' beliefs and their resource use in Shanghai than in England. Shanghai students who think highly of the authority of textbooks are more likely to find them interesting and helpful, use them both in and after class for various learning purposes, and link textbook use to the improvement of mathematics learning, while English students' beliefs about textbooks are not reflected in how they use the books. For the beliefs about doing exercises, both Shanghai and English students who take them positively are more willing to challenge themselves with difficult problems in the resources used for exercises, use them for self-regulation, and find the resources interesting and helpful to their mathematics learning. Moreover, Shanghai students who perceive more stress of examinations tend to spend more time on worksheets and use notebooks after class and for doing extra exercises, while English students who are under pressure seem to have a relatively strong sense of self-regulation in their use of worksheets. Lastly, Shanghai students who are inclined to attribute the success and failure of mathematics learning to effort use worksheets frequently, spend much time on reference books, have the courage to solve difficult problems in workbooks and worksheets, and are aware of the helpfulness of using those resources in mathematics learning. However, English students who believe more in effort incorporate teaching videos in their learning of mathematics on their own initiative and adapt themselves to learning at a higher year level by using worksheets frequently and for a longer period of time.

10.2 Implications for teachers, parents, school administrators, and policy makers

This study is about students' use of learning resources in mathematics, which reveals how students could better engage in mathematics learning with different resources. The findings of this study contain several implications for teachers, parents, school administrators, and policymakers, who all take part in students' resource use in mathematics, and ultimately, students' learning of mathematics.

In Shanghai's case, teachers have an essential and standardized textbook to follow, a strong consensus of how the resources should be incorporated into students' mathematics learning, relatively substantial sources of exercises designed by different panels for their students, and the tradition emphasizing whole-class teaching (Biggs, 1998; J. Wang & Lin, 2005). It should be kept in mind that students could have different learning needs; hence it is important for teachers to provide their students with choices and leave room for students with different demands in terms of how to use learning resources, which might also help to relieve some students' and parents' anxiety about being ordinary and seeking extra learning beyond normal school work.

Shanghai parents do pay much attention to their children's mathematics learning, including resource use. The findings suggest though, that by intensively assigning extra exercises, parents force their children to spend more time working with learning resources; it will make students' learning more efficient if they get involved more reasonably by way of checking learning progress and buying resources not required by schools. However, in Shanghai, the role of parental involvement by assisting with homework in students' mathematics learning is still unclear according to this study, which might be implied in the discrepant results relating to different types of parental homework involvement found by other researchers (Patall, Cooper, & Robinson, 2008).

School administrators in Shanghai could take it into consideration to provide students with more opportunities to be exposed to e-learning environments, given the fact that well-integrated ICT and easy access to sources for research are related to students' well-being at schools (Cuyvers, Weerd, Dupont, Mols, & Nuytten, 2011), which is also the situation that students are supposed to adapt to at colleges and universities. In fact, many school principals from Shanghai agree that the shortage of e-resources and devices might hinder students' mathematics learning (OECD, 2013a). Thus, enabling students to incorporate e-resources in their learning in schools is something worth the school administrators' endeavour; for instance, by investing in ICT equipment and software for students and encouraging teachers to introduce e-resources to students.

The results of this study also imply that though the education system in China has become increasingly decentralized from the central government to local authorities during these decades (Pan et al., 2015), the system within a region, such as Shanghai, is still centrally controlled by the local administration to a great extent, especially for curricula and learning resources, which is partly revealed in the PISA report (OECD, 2013a). Although the PISA report presented a trend that the more autonomy schools have, the better in students' mathematics performance across all the participants, Shanghai appeared to be an outlier. Therefore, it is not the case to simply advise further decentralization for Shanghai policymakers, but to remind them to think about it and provide more choices of teaching and learning resources (e.g. textbooks and their accessories) if possible.

For the situation in England, teachers have their own understanding of students' resource use in mathematics and are usually confident about the pedagogies; however, the lack of collaborative work with others could make the decision-making subjective and biased. Hence, it would be helpful to improve students' experience with learning resources if teachers could exchange ideas about teaching and resource use regularly, since there is evidence that communication between teachers is one of the most important sources for developing their pedagogical knowledge (Lianghuo Fan, 2014), which ultimately benefits students' learning experience.

Secondly, English teachers pay much attention to students' individual work in class according to the observations, while it often takes much time to get students back concentrating on the teacher's demonstration once they are set free, which lowers the efficiency of teaching. Leung's (1995) study supports this point of view that more individual activities along with more off-task activities are conducted in England mathematics classrooms, compared to Chinese classrooms. Thus, students might be more efficiently engaged in academic-oriented activities if teachers balance the proportions better between whole-class teaching and students' individual work.

Also, English students' learning of mathematics seems to depend heavily on their teachers since most of them use learning resources only under teacher's requirements, a few of them learn mathematics beyond classrooms on their own initiative, and it is the teacher who takes care of the primary resource, namely, exercise books, for students. Teacher interviews disclose that they do not think students can keep their own resources well and complete non-task-specified work at home, like preview the knowledge before a lesson, while the findings of this study suggest that the constraint of access to learning resources hinders how students can use them in various situations. English students could be more aware of their own responsibility of learning in schools if their teachers expect more of them, for instance, let students manage their own resources and teach them to do some learning beyond classrooms.

To English students, this study shows evidence that at the current stage, parental involvement by assisting with homework is a boost for them to benefit from resource use in their learning of mathematics. Hence, English parents are supposed to be conscious of their role as assistant or helper in their children's learning and be more involved when children need them, just as they do in other aspects to foster children.

School administrators in England have great autonomy over curricula and assessments and take strong responsibility of performance (OECD, 2013a), and they also give their teachers great autonomy in their teaching, including resource use. However, they seem to neglect the differences in the choice of resources caused by teachers' teaching abilities, and students needing to know the whole picture of their mathematics learning, which could enhance their motive for self-regulated learning if they know what they are going to do and see the goal clearly (Urdan & Schoenfelder, 2006). A solution to the former issue could be organizing discussion groups and classroom observations for teachers to communicate and reflect with each other, and another measure that may solve the two issues at the same time is to provide teachers and students with a thin but essential book addressing the basic knowledge and examples that they are about to go through during a term, which could save the time of composing such content in class. The cost could be reduced if schools write and print the books by themselves.

Lastly, two questions are raised by this study to the policymakers in England. In a highly decentralized system, who should take the main responsibility to supply rich and reliable resources for students to use at schooling stage? And how can the resources be reliable? At present, it is the teachers who take the position by helping students compose the primary learning resource, i.e. exercise books, in mathematics. Given the fact that there not much collaborative work between teachers, the quality of learning resources should receive more attention from policy makers; further measures, for example, by organizing schools by region to write books for students guided by specialists, are needed to support schools in improving students' learning experiences working with learning resources.

10.3 Recommendations for further study

This study aims to investigate how students use learning resources in mathematics and takes into account the social, didactical, and cultural contexts in Shanghai and England. It would be also feasible and interesting to apply the study to other regions in China and UK, which would provide knowledge from a more holistic view and allow comparisons between different places within the countries; it could also be applied to other countries to draw a picture of the interactions between students and learning resources in mathematics, and to make comparisons between different countries and regions.

Another obvious extension of this study is to transfer it from mathematics to other subjects since the main structure is not subject-specific. For instance, learners' use of materials in language learning has been a concern to researchers for many years as mentioned in the literature review, and this study sheds valuable light on the application to learners at schooling stage.

Moreover, although this study only focuses on the students at lower year levels in state-run secondary schools, it would be significant to look at students at primary or senior secondary stage and students in private schools.

Finally, the discussion in this study suggests that it seems hard for students to distinguish between knowledge, skills, reasoning abilities, and problem-solving abilities as they gave similar answers to the influence of resource use on those aspects in their mathematics learning. It might be possible for students to think more deeply if they have to answer a series of questions corresponding to every aspect. It also implies that further study could investigate one or several indicators of resource use constructed by this study, such as students' motivation for resource use and the influence of resource use on students' learning, with more and specific measures, which could extend the depth of the results presented by this study

Appendix A

Student Questionnaire

Introduction

This survey is about your use of **mathematics learning resources**, which consists of five parts. Please read each question carefully and answer as accurately as you can. You will normally answer the items by ticking a box except for a few questions, in which you will need to write a short answer.

Be assured that all answers you provide will be kept in the **strictest confidentiality** and will only be used for research purposes.

This survey defines **nine** types of mathematics learning resources. Please read the explanation of each resource in the following table before answering any question.

learning resources		**Definition**
Paper-based resources	Textbook	The book authorized by your school to be used as a standard work in mathematics learning.
	Exercise book	The book for you to take notes and **do exercises** in mathematics.
	Worksheet	A piece of paper containing teachers' guides, tasks and questions for learning mathematics, which may be **designed by teachers**. Thus in most cases, it is non-publications.
	Reference book	Any books you personally selected to help with mathematics.
	Others	Other paper-based resources that you cannot categorize into any of the above.
E-resources	E-book	Any **books** online used/downloaded to help with mathematics. (i.e. e-textbooks, e-reference books and e-magazines for mathematics learning)
	Teaching video	Videos used to learn mathematics.
	E-learning system	Any software, programmes, web-based platforms (e.g. mymaths.co.uk), applications (e.g. "FX math solver" on smart phone) etc. **designed for learning**.
	Others	Other e-resources (i.e. Google Image, Wikipedia).

Please remember your **identity number** ________, you will be required to provide the number on the second section.

Section 1. Part 1: Yourself

Your school name ______________________	You are in □ **year 7** / □ **year 8**
Your name ____________________ (Optional)	You are a □ **girl** / □ **boy**

Section 1. Part 2: Your use of mathematics learning resources

*This part consists of seven questions. Please answer the questions as accurately as you can by ticking **one box** for every resource unless it notes that "**Please tick all the boxes that are applicable**".*

*If you **do not use** some resources in your learning of mathematics, please tick "**N.A.**"(not applicable) for the corresponding items.*

*When answering, consider the situation **in this academic year** and **include** the time spend on the **weekend** too.*

1. On average, how often do you use the following resources in your learning of mathematics?

Resources		Frequency of use				
		N.A.	1day per week	2-3 days per week	4-5 days per week	6-7 days per week
Paper-based resources	Textbook	□	□	□	□	□
	Exercise book	□	□	□	□	□
	Worksheet	□	□	□	□	□
	Reference book	□	□	□	□	□
	Others___________	□	□	□	□	□
E-resources	E-book	□	□	□	□	□
	Teaching video	□	□	□	□	□
	E-learning system	□	□	□	□	□
	Others___________	□	□	□	□	□

2. When do you usually use the following resources in your learning of mathematics? (***Please tick all the boxes that are applicable***)

Resources		Timing of use		
		N.A.	In class	After class
Paper-based resources	Textbook	□	□	□
	Exercise book	□	□	□
	Worksheet	□	□	□
	Reference book	□	□	□
	Others____________	□	□	□
E-resources	E-book	□	□	□
	Teaching video	□	□	□
	E-learning system	□	□	□
	Others____________	□	□	□

3. On average, how long does it take for you to use the following resources for mathematics learning **in a day that you have maths lessons**?

Resources		Duration of use				
		N.A.	< 15 min	15-30 min	30-45 min	> 45 min
Paper-based resources	Textbook	◻	◻	◻	◻	◻
	Exercise book	◻	◻	◻	◻	◻
	Worksheet	◻	◻	◻	◻	◻
	Reference book	◻	◻	◻	◻	◻
	Others____________	◻	◻	◻	◻	◻
E-resources	E-book	◻	◻	◻	◻	◻
	Teaching video	◻	◻	◻	◻	◻
	E-learning system	◻	◻	◻	◻	◻
	Others____________	◻	◻	◻	◻	◻

4. How do you usually gain access to the following resources in you learning of mathematics?

Resources		Access to learning resources							
		N.A.	Parents buy for me.	School or other sponsor buys for me.	Borrow from the library.	Borrow from the classroom.	My teacher makes them for me.	Borrow from peers	Other. (please tell me in detail)
Paper-based resources	Textbook	◻	◻	◻	◻	◻	◻	◻	_______
	Exercise book	◻	◻	◻	◻	◻	◻	◻	_______
	Worksheet	◻	◻	◻	◻	◻	◻	◻	_______
	Reference book	◻	◻	◻	◻	◻	◻	◻	_______
	Others	◻	◻	◻	◻	◻	◻	◻	_______
		Access to learning resources							
		N.A.	Parents buy for me.	Google them directly or search on publisher's website.	Access through school's website.	It is an accessary of the other resource.	My teacher makes them for me.	Borrow from peers	Other. (please tell me in detail)
E-resources	E-book	◻	◻	◻	◻	◻	◻	◻	_______
	Teaching video	◻	◻	◻	◻	◻	◻	◻	_______
	E-learning system	◻	◻	◻	◻	◻	◻	◻	_______
	Others	◻	◻	◻	◻	◻	◻	◻	_______

5. For what purposes do you usually use the learning resources? (***Please tick all the boxes that are applicable***)

Resources		Purpose of use								
		N.A.	Preview (obtain the knowledge in advance)	In-class learning and exercises	Revision	Looking up definitions, theorems and formulas	Looking up examples, references and answers	Doing homework	Doing extra exercises (not assigned by school teachers)	Other purposes (please specify)
Paper-based resources	Textbook	☐	☐	☐	☐	☐	☐	☐	☐	________
	Exercise book	☐	☐	☐	☐	☐	☐	☐	☐	________
	Worksheet	☐	☐	☐	☐	☐	☐	☐	☐	________
	Reference book	☐	☐	☐	☐	☐	☐	☐	☐	________
	Others________	☐	☐	☐	☐	☐	☐	☐	☐	________
E-resources	E-book	☐	☐	☐	☐	☐	☐	☐	☐	________
	Teaching video	☐	☐	☐	☐	☐	☐	☐	☐	________
	E-learning system	☐	☐	☐	☐	☐	☐	☐	☐	________
	Others________	☐	☐	☐	☐	☐	☐	☐	☐	________

6. In general, what are the reasons for you to use the learning resource in mathematics learning? (***<u>Please tick all the boxes that are applicable</u>***)

Resources		Motivation of use								
		N.A.	It is **enjoyable** for me to use it.	I always feel **fulfilled** when I solve some **difficult problems** in it.	I keenly know that it can **improve my mathematics marks**.	I think it can help me **better understand** mathematics knowledge and skills, and **enhance** my mathematical **abilities**.	My **teacher** usually asks me to use it according to his/her instructions.	My **parent** usually asks me to use it when I study with him/her.	It is the **fastest way** to get the information I need.	Other motivations (Please tell me in detail)
Paper-based resources	Textbook	☐	☐	☐	☐	☐	☐	☐		________
	Workbook	☐	☐	☐	☐	☐	☐	☐		________
	Notebook	☐	☐	☐	☐	☐	☐	☐		________
	Worksheet	☐	☐	☐	☐	☐	☐	☐		________
	Reference book	☐	☐	☐	☐	☐	☐	☐		________
	Others________	☐	☐	☐	☐	☐	☐	☐		________
E-resources	E-book	☐	☐	☐	☐	☐	☐	☐	☐	________
	Teaching video	☐	☐	☐	☐	☐	☐	☐	☐	________
	E-learning system	☐	☐	☐	☐	☐	☐	☐	☐	________
	Others________	☐	☐	☐	☐	☐	☐	☐	☐	________

7. (a) Compared to **<u>the previous year level</u>**, are there any changes in the way you use the learning resources (e.g. the frequency and duration)?

Resources		Change of use		
		N.A.	No	Yes
Paper-based resources	Textbook	☐	☐	☐
	Exercise book	☐	☐	☐
	Worksheet	☐	☐	☐
	Reference book	☐	☐	☐
	Others__________	☐	☐	☐
E-resources	E-book	☐	☐	☐
	Teaching video	☐	☐	☐
	E-learning system	☐	☐	☐
	Others__________	☐	☐	☐

7. (b) Please tell me briefly about the change and why.

Resources	Specify the change and why

Your **identity number** is ___________ and your name is _______________.

Section 2. Part 1: Your experiences about the influences of resource use on your mathematics learning

This part consists of three questions. Please answer the questions as accurately as you can by ticking ***one box*** *for each question.*

If you ***do not use*** *some resources in your learning of mathematics, please tick "****N.A.****"(not applicable) for the corresponding items.*

When answering, consider the situation ***in this academic year****.*

1. How helpful are the learning resources in improving your mathematics ***knowledge and skills***? (e.g., know the differences and relationships between different mathematics concepts, such as fraction and division, and master the related calculation and plotting.)

Resources		The relationship between the use and mathematics learning					
		N.A.	Not helpful	Slightly helpful	Somewhat helpful	Helpful	Very helpful
Paper-based resources	Textbook	□	□	□	□	□	□
	Exercise book	□	□	□	□	□	□
	Worksheet	□	□	□	□	□	□
	Reference book	□	□	□	□	□	□
	Others_________	□	□	□	□	□	□
E-resources	E-book	□	□	□	□	□	□
	Teaching video	□	□	□	□	□	□
	E-learning system	□	□	□	□	□	□
	Others_________	□	□	□	□	□	□

2. How helpful are the learning resources in improving your ***ability in mathematical reasoning***? (e.g. the ability of justifying and showing evidences for your conclusion)

Resources		The relationship between the use and mathematics learning					
		N.A.	Not helpful	Slightly helpful	Somewhat helpful	Helpful	Very helpful
Paper-based resources	Textbook	□	□	□	□	□	□
	Exercise book	□	□	□	□	□	□
	Worksheet	□	□	□	□	□	□
	Reference book	□	□	□	□	□	□
	Others_________	□	□	□	□	□	□
E-resources	E-book	□	□	□	□	□	□
	Teaching video	□	□	□	□	□	□
	E-learning system	□	□	□	□	□	□
	Others_________	□	□	□	□	□	□

3. How helpful are the learning resources in improving your ***ability in problem-solving***? (e.g. the ability of solving real-world problems)

Resources		The relationship between the use and mathematics learning					
		N.A.	Not helpful	Slightly helpful	Somewhat helpful	Helpful	Very helpful
Paper-based resources	Textbook	□	□	□	□	□	□
	Exercise book	□	□	□	□	□	□
	Worksheet	□	□	□	□	□	□
	Reference book	□	□	□	□	□	□
	Others__________	□	□	□	□	□	□
E-resources	E-book	□	□	□	□	□	□
	Teaching video	□	□	□	□	□	□
	E-learning system	□	□	□	□	□	□
	Others__________	□	□	□	□	□	□

Section 2. Part 2: Your out-of-school study in mathematics

*This part consists of six questions. Please answer the questions as accurately as you can by ticking **one box** for each question.*

*When answering, consider the situation **in this academic year** and **include** the time spend on the **weekend** too.*

1. On average, how many hours do you spend on mathematics lessons with a **private tutor every week**?

□ N.A. □ ≤0.5 hour □ 0.5 to 1 hour □ 1 to 1.5 hours □ 1.5 to 2 hours □ ≥2 hours

2. On average, how many hours do you spend in mathematics class **organised by commercial companies** after normal school **every week**?

□ N.A. □ ≤0.5 hour □ 0.5 to 1 hour □ 1 to 1.5 hours □ 1.5 to 2 hours □ ≥2 hours

3. In general, how often do your parents **check or discuss with you about** your learning progress in mathematics **every week**?

□ Never □ < once a week e.g. every two weeks □ Once a week □ 2-3 times a week □ 4-5 times a week □ More than 5 times

4. In general, how often do your parents **assist** your mathematics homework **every week**?

□ Never □ < once a week e.g. every two weeks □ Once a week □ 2-3 times a week □ 4-5 times a week □ More than 5 times

5. In general, how often do your parents ask you to do extra exercises in mathematics **every week**?

□ Never □ < once a week e.g. every two weeks □ Once a week □ 2-3 times a week □ 4-5 times a week □ More than 5 times

6. In general, how often do your parents buy learning resources (not required by the school) for you to learn mathematics?

□ Never □ < once month e.g. every two months □ Once a month □ 2-3 times a month □ 4-5 times a month □ More than 5 times a term

Section 2. Part 3: Your beliefs about learning resources and mathematics learning

This part consists of four questions. Please answer the questions as accurately as you can by ticking one box for every statement in each question.

	1. How much do you agree with these statements about mathematics textbooks?	Strongly disagree	Disagree	Agree	Strongly agree
a)	Textbooks always present the most elegant and simplest, namely, the best way in solving problems.	□	□	□	□
b)	Textbooks always present the right things therefore they are trustworthy.	□	□	□	□
c)	Textbooks always follow essentially the curriculum, which is a guideline for passing examinations.	□	□	□	□
d)	The teacher seems unreliable if she/he always follows the instructions posed in textbooks.	□	□	□	□
e)	Textbooks are just a source of exercises, I do not care about what textbooks say about mathematics in other parts.	□	□	□	□

	2. How much do you agree with these statements about doing exercises in mathematics learning?	Strongly disagree	Disagree	Agree	Strongly agree
a)	Doing maths exercises is boring.	□	□	□	□
b)	Doing exercises is just a repeat of practice with fixed steps.	□	□	□	□
c)	Doing exercises is an efficient way that helps me better understand mathematics knowledge.	□	□	□	□
d)	Practice makes perfect.	□	□	□	□
e)	Doing exercises is not good for developing creativity.	□	□	□	□

3. How much do you agree with these statements about the pressure of examination?

	Strongly disagree	Disagree	Agree	Strongly agree
a) I have to work hard because there are lots of examinations ahead of me.	□	□	□	□
b) Achieving good grades in examinations means everything in the learning of mathematics at schools.	□	□	□	□
c) It will upset me very much if I do not do well in mathematics examinations.	□	□	□	□
d) A good grade is the only pass to a bright future.	□	□	□	□
e) Others (e.g. peers, teachers, and parents) are likely to value me with my examination performances.	□	□	□	□

4. How much do you agree with these statements about the attribution of success and failure in the learning of mathematics?

	Strongly disagree	Disagree	Agree	Strongly agree
a) Hard work can make up the lack of natural ability in mathematics.	□	□	□	□
b) Everyone is born with different gift and talent, so it seems fine if mathematics is not one of the things that I am good at.	□	□	□	□
c) A success or failure in the learning of mathematics mainly depends on how hard one works.	□	□	□	□
d) A success or failure in the learning of mathematics mainly depends on one's ability and interests.	□	□	□	□
e) The most important thing in schools is to develop one's gift and talent rather than to focus on the things that I am not good at.	□	□	□	□

Appendix B

Teacher Questionnaire

Introduction

This survey is about students' use of **mathematics learning resources**, which consists of three parts. Please read each question carefully and answer as accurately as you can. You will normally answer the items by ticking a box except for a few questions, in which you will need to write a short answer.

Be assured that all answers you provide will be kept in the **strictest confidentiality** and will only be used for research purposes.

This survey defines nine types of mathematics learning resources. Please read the explanation of each resource in the following table before answering any question.

learning resources		**Definition**
Paper-based resources	Textbook	The book authorized by your school to be used as a standard work in mathematics learning.
	Exercise book	The book for students to take notes and **do exercises** in mathematics.
	Worksheet	A piece of paper containing teachers' guides, tasks and questions for learning mathematics, which may be **designed by teachers**. Thus in most cases, it is non-publications.
	Reference book	Any books you or students personally selected to help with mathematics.
	Others	Other paper-based resources that you cannot categorize into any of the above.
E-resources	E-book	Any **books** online used/downloaded to help with mathematics. (i.e. e-textbooks, e-reference books and e-magazines for mathematics learning)
	Teaching video	Videos used to learn mathematics.
	E-learning system	Any software, programmes, web-based platforms (e.g. mymaths.co.uk), applications (e.g. "FX math solver" on smart phone) etc. **designed for learning**.
	Others	Other e-resources (i.e. Google Image, Wikipedia).

Part 1. Yourself

Your school name ______________________	You are teaching __________year level
You are a □ **Female** / □ **Male**	You have taught maths for ______ years

Part 2. Your instructions related to students' use of learning resources

This part consists of four questions. Please recall your instructions in ***this academic year*** *and answer the questions as accurately as you can by ticking* ***one box*** *for every resource in each question.*

If you ***do not ask students to use*** *any of the resources in your instructions, please tick "****N.A.****"(not applicable) for the corresponding items.*

1. On average, how often do you ask your students to use the following resources in your teaching of mathematics?

Resources		Frequency of use				
		N.A.	Rarely 1day per week	Occasionally 2-3 days per week	Frequently 4-5 days per week	Very frequently Almost everyday
Paper-based resources	Textbook	□	□	□	□	□
	Exercise book	□	□	□	□	□
	Worksheet	□	□	□	□	□
	Notebook	□	□	□	□	□
	Reference book	□	□	□	□	□
	Others	□	□	□	□	□
E-resources	E-book	□	□	□	□	□
	Teaching video	□	□	□	□	□
	E-learning system	□	□	□	□	□
	Others	□	□	□	□	□

2. When do you usually ask your students to use the following resources in your teaching of mathematics?

Resources		Timing of use		
		N.A.	In class	After class
Paper-based resources	Textbook	□	□	□
	Exercise book	□	□	□
	Worksheet	□	□	□
	Reference book	□	□	□
	Others___________	□	□	□
E-resources	E-book	□	□	□
	Teaching video	□	□	□
	E-learning system	□	□	□
	Others___________	□	□	□

3. How do you usually ask your students to access to the following resources in your teaching of mathematics?

Resources		Access to learning resources							
		N.A.	Students buy it.	School or other sponsors buy it for students.	Borrow from the library.	Borrow from the classroom.	I make it for my students.	Borrow from peers	Other. (please tell me in detail)
Paper-based resources	Textbook	☐	☐	☐	☐	☐	☐	☐	______
	Exercise book	☐	☐	☐	☐	☐	☐	☐	______
	Worksheet	☐	☐	☐	☐	☐	☐	☐	______
	Reference book	☐	☐	☐	☐	☐	☐	☐	______
	Others_____	☐	☐	☐	☐	☐	☐	☐	______
		Access to learning resources							
		N.A.	Students buy it.	Google them directly or search on publisher's website.	Access to them through school's website.	It is an accessary of the other resource.	I make it for my students.	Borrow from peers	Other. (please tell me in detail)
E-resources	E-book	☐	☐	☐	☐	☐	☐	☐	______
	Teaching video	☐	☐	☐	☐	☐	☐	☐	______
	E-learning system	☐	☐	☐	☐	☐	☐	☐	______
	Others______	☐	☐	☐	☐	☐	☐	☐	______

4. For what purposes do you usually ask your students to use the learning resources? (***Please tick all the boxes that are applicable***)

Resources		Purpose of use							
		N.A.	Preview (Obtain the knowledge in advance)	In-class exercises	Revision	Looking up definitions, theorems and formulas	Looking up examples, references and answers	Doing homework	Other purposes (please specify)
Paper-based resources	Textbook	☐	☐	☐	☐	☐	☐	☐	________
	Exercise book	☐	☐	☐	☐	☐	☐	☐	________
	worksheet	☐	☐	☐	☐	☐	☐	☐	________
	Reference book	☐	☐	☐	☐	☐	☐	☐	________
	Others________	☐	☐	☐	☐	☐	☐	☐	________
E-resources	E-book	☐	☐	☐	☐	☐	☐	☐	________
	Teaching video	☐	☐	☐	☐	☐	☐	☐	________
	E-learning system	☐	☐	☐	☐	☐	☐	☐	________
	Others______	☐	☐	☐	☐	☐	☐	☐	________

Part 3. Your beliefs about learning resources and mathematics learning

This part consists of four questions. Please answer the questions as accurately as you can by ticking one box for every statement in each question.

1. How much do you agree with these statements about mathematics textbooks?

		Strongly disagree	Disagree	Agree	Strongly agree
a)	Textbooks always present the most elegant and simplest, namely, the best way in solving problems.	□	□	□	□
b)	Textbooks always present the right things therefore they are trustworthy.	□	□	□	□
c)	Textbooks always follows essentially the curriculum, which is a guideline for my instruction.	□	□	□	□
d)	People will doubt about my teaching ability if I always follows the instructions posed in textbooks.	□	□	□	□
e)	Textbooks are just a source of exercises for students, I do not care about what textbooks say about mathematics in other parts.	□	□	□	□

2. How much do you agree with these statements about doing exercises in mathematics learning?

		Strongly disagree	Disagree	Agree	Strongly agree
a)	Doing exercises makes students feel mathematics is boring.	□	□	□	□
b)	Doing exercises is just a repeat of manipulation with fixed procedures.	□	□	□	□
c)	Doing exercises is an efficient way to help students better understand concepts and procedures.	□	□	□	□
d)	Practice makes perfect.	□	□	□	□
e)	Doing exercises constrains creativity.	□	□	□	□

3. How much do you agree with these statements about the pressure of examination?

	Strongly disagree	Disagree	Agree	Strongly agree
a) Students must work hard because there are lots of examinations ahead of them.	□	□	□	□
b) Achieving good grades in examinations is the most important thing in the learning of mathematics at schools.	□	□	□	□
c) It will upset me very much if my students do not do well in mathematics examinations.	□	□	□	□
d) For students, a good grade is the only way to a bright future.	□	□	□	□
e) Others (e.g. peers, school governors, and parents) are likely to judge me with my students' examination performances.	□	□	□	□

4. How much do you agree with these statements about the attribution of success and failure in the learning of mathematics?

	Strongly disagree	Disagree	Agree	Strongly agree
a) Hard work can make up the lack of natural ability in mathematics.	□	□	□	□
b) Everyone is born with different gift and talent, so it seems fine if mathematics is not one of the things that my students are good at.	□	□	□	□
c) A success or failure in the learning of mathematics mainly depends on how hard one works.	□	□	□	□
d) A success or failure in the learning of mathematics mainly depends on one's ability and interests.	□	□	□	□
e) The most important thing in schools is to develop one's gift and talent rather than to focus on the things that s/he is not good at.	□	□	□	□

Appendix C

Parent Questionnaire

Introduction

This survey is about children's use of **mathematics learning resources**, which consists of three parts. Please read each question carefully and answer as accurately as you can. You will normally answer the items by ticking a box except for a few questions, in which you will need to write a short answer.

Be assured that all answers you provide will be kept in the **strictest confidentiality** and will only be used for research purposes.

Part 1. Yourself and your family

Your child who give you this questionnaire is in □ **Year 7** / □ **Year 8**

How many children do you have in your family? _________ (please give a number)

You are a □ **Mother (or other female guardian)** / □ **Father (or other male guardian)**

Your years of age	□ <35	□ 35-40	□ 40-45	□45-50	□ >50

Part 2. Your involvement in child's mathematics learning

*This part consists of four questions. Please answer the questions as accurately as you can by **ticking one box** for each question.*

Cautions: *Your answers should be related to **the child** who gave you this questionnaire. Please consider the situation **in this academic year** and **include** the time spent on the **weekend** too.*

1. In general, how often do you **check or discuss** with your child about his/her learning progress in mathematics **every week**?

□ Never	□ < once a week e.g. every two weeks	□ Once a week	□ 2-3 times a week	□ 4-5 times a week	□ More than 5 times

2. In general, how often do you **assist** your child's mathematics homework **every week**?

□ Never	□ < once a week e.g. every two weeks	□ Once a week	□ 2-3 times a week	□ 4-5 times a week	□ More than 5 times

3. In general, how often do you ask your child to **do extra exercises** (not assigned by school teachers) in mathematics **every week**?

□ Never	□ < once a week e.g. every two weeks	□ Once a week	□ 2-3 times a week	□ 4-5 times a week	□ More than 5 times

4. In general, how often do you buy learning resources (not required by the school) for your child to learn mathematics?

□ Never	□ < once month e.g. every two months	□ Once a month	□ 2-3 times a month	□ 4-5 times a month	□ More than 5 times a term

Part 3. Your beliefs about learning resources and mathematics learning

This part consists of four questions. Please answer the questions as accurately as you can by ticking one box for every statement in each question.

1. How much do you agree with these statements about mathematics textbooks?	Strongly disagree	Disagree	Agree	Strongly agree
a) Textbooks always present the most elegant and simplest, namely, the best way in solving problems.	□	□	□	□
b) Textbooks always present the right things therefore they are trustworthy.	□	□	□	□
c) Textbooks always follow essentially the curriculum, which is a guideline for children to learn mathematics.	□	□	□	□
d) I will doubt about the teacher's ability if she/he always follows the instructions posed in textbooks.	□	□	□	□
e) Textbooks are just a source of exercises for children, I do not care about what textbooks say about mathematics in other parts.	□	□	□	□

2. How much do you agree with these statements about doing exercises in mathematics learning?	Strongly disagree	Disagree	Agree	Strongly agree
a) Doing exercises makes children feel mathematics is boring.	□	□	□	□
b) Doing exercises is just a repeat of manipulation with fixed procedures.	□	□	□	□
c) Doing exercises is an efficient way to help children better understand concepts and procedures.	□	□	□	□
d) Practice makes perfect.	□	□	□	□
e) Doing exercises constrains creativity.	□	□	□	□

3. How much do you agree with these statements about the pressure of examination?

	Strongly disagree	Disagree	Agree	Strongly agree
a) My children have to work hard because there are lots of examinations ahead of them.	◻	◻	◻	◻
b) Achieving good grades in examinations means everything in children's learning of mathematics at schools.	◻	◻	◻	◻
c) It will upset me very much if my children do not do well in mathematics examinations.	◻	◻	◻	◻
d) For my children, a good score is the only pass to a bright future.	◻	◻	◻	◻
e) Others (e.g. peers and friends) are likely to value my children with their examination performances.	◻	◻	◻	◻

4. How much do you agree with these statements about the attribution of success and failure in the learning of mathematics?

	Strongly disagree	Disagree	Agree	Strongly agree
a) Hard work can make up the lack of natural ability in mathematics.	◻	◻	◻	◻
b) Everyone is born with different gifts and talents, so it seems fine if mathematics is not one of the things that my children are good at.	◻	◻	◻	◻
c) A success or failure in the learning of mathematics mainly depends on how hard one works.	◻	◻	◻	◻
d) A success or failure in the learning of mathematics mainly depends on one's ability and interests.	◻	◻	◻	◻
e) The most important thing in schools is to develop one's gift and talent rather than to focus on the things that s/he is not good at.	◻	◻	◻	◻

Appendix D

Student Focus Groups Protocol

Date: Time:
School: Number of students:
Taping number:

1. **Overall, how do you feel about the importance of different learning resources in your learning of mathematics? Why is a resource important to you and why not?**

2. **Do you think learning resources help you to improve your mathematics knowledge and skills, ability in reasoning, and ability in problem-solving?**
   Have a learning resource ever played a negative role in your learning of mathematics? Can you give a specific example of that?

3. **How do your parents usually help you with your learning of mathematics? What specific learning resources did your parents buy for you in this/the previous term?**

4. **How do you learn mathematics in math-related lessons after school or with tutors? What learning resources do you usually use in the out-of-school class or when study with a tutor?**

5. **How do you think the role of mathematics textbooks in your learning of mathematics? What about other resources?**

6. **How do you think about doing exercises in mathematics learning? What learning resources do you usually use for doing exercises and how do you use them? (give some specific examples)**

7. **Do you worry about your performance in the next examination? What do you do when you prepare for an examination? Do you feel using learning resources can relieve the stress? (give some specific examples)**

8. **What will happen if you have a good/bad performance in mathematics? What makes you the success or failure and how do you make it work (e.g. do more exercises, buy various reference books, explore your own interests)?**

Appendix E

Teacher Interview Protocol

Date: Time:
School: Teacher's code:
Taping number:

1. **Overall, how do you feel about the importance of learning resources** (textbooks, workbooks, worksheets, reference books, e-books, teaching videos, e-learning systems, and others) **in students learning of mathematics? Why is a resource important to students and why not?**

2. **Do you think learning resources help your students to improve their mathematics knowledge, skills, ability in reasoning, and ability in problem-solving?**

3. **On average, how much time do you think students spend on the mathematics homework that assigned by you?**

4. **How did you teach mathematics in the previous academic year? Compared to that, are there any changes in this term in terms of the resources you ask students to use according to your instruction?**

5. **How do you think the role of mathematics textbooks in students' learning of mathematics? What about other resources?**

6. **How do you think about doing exercises in mathematics learning? Which are the learning resources that you usually ask students to use for doing exercises?**

7. **Do you worry about your students' performances in mathematics examinations, why? How do you help them prepare for an examination? Do you think using learning resources can help them perform well in examinations?**

8. **What makes students' success or failure in mathematics learning? How do you help them make it work (e.g. assign more exercises, recommend various reference books, let them find their own interests)?**

Appendix F

Classroom Observation Protocol

Date:	Time:
School:	Class number:
Number of students:	Teacher's code:
Type of lesson: Introducing new content/ Reviewing	Video number:

Classroom activities related to mathematics learning resources

Resources	Frequency	Timing	Purposes	Access	Duration
Textbook Exercise book Worksheet Reference book E-book Teaching video E-learning system		In After	Preview Revision In-class exercises Looking up 1 (df) Looking up 2 (ex) Doing homework	Own 1 (buy) Own 2 (free) Borrow 1 (library) Borrow 2 (class) Borrow 3 (peers) Teacher-made Google/Pub's web School's web Accessary	

Note

Resources	Frequency	Timing	Purposes	Access	Duration

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