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Chinese mathematics teachers' use of digital technologies for instruction: A survey study

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Abstract

The rapid development of education informatization provides more and more K-12 Chinese mathematics classrooms access to digital technologies. As a result, it is important to understand Chinese mathematics teachers' practices of technology integration in order to better support them. A questionnaire containing close and Likert-scale questions was distributed to 1,083 Chinese mathematics teachers to understand their usage of a list of commonly available technologies and demographic factors related to their technology usage. Results from the survey showed that search engines, self-accumulated digital resources, courseware, and smartboard were frequently used by the majority of participants. Other commonly available technologies were only frequently used by less than half of the participants. In lesson preparation the majority of participants used technologies to download resources, make courseware, and search for practicing problems. Most participants used technologies to motivate students and present knowledge and information during classroom instruction. The impact of age, grade levels, years of teaching with technology, and teacher beliefs on the participants' technology usage was also analyzed. Implications of the findings from this study were discussed.

Keywords: Chinese mathematics teachers, lesson preparation, classroom instruction, technology use

INTRODUCTION

In the past few decades, education researchers have recognized the potential for mathematics teaching and learning to be transformed by the availability of digital technologies such as education resource platforms, courseware software, smart whiteboard, presentation software, graphing calculators, dynamic geometry software, and web-based interactive mathematics applications (Heid, 1997; Pierce & Stacey, 2010). Despite the early optimism for the future of technology integration in mathematics education, findings from studies conducted in several countries (e.g., Australia, United States, and South Africa) has implied that technology has not brought substantial change in mathematics teaching and that access to digital technologies and resources, educational policies, and institutional support are not sufficient for ensuring effective integration of technology into teaching practices (Goos & Bennison, 2008; McCulloch et al., 2018; Umugiraneza et al., 2018). Teacher plays a critical role in technology integration and decides not only whether and what technology is used in the classroom but also how technology is integrated. Researchers in the United States have found that many mathematics teachers and their students primarily use technology to carry out simple calculations, store data, and display static materials, which are unlikely to develop student understanding, stimulate their interests, or increase their mathematical proficiencies (Ertmer, 2005). Most existing studies on mathematics teachers' use of digital technologies were conducted prior to COVID-19. Given that the pandemic has reshaped the territory of technology usage in PreK-12 schools (Borba, 2021; Engelbrecht et al., 2020), it is important to understand mathematics teachers' usage of commonly available digital technologies in the post-pandemic era. Moreover, there has been very limited empirical research to investigate Chinese mathematics teachers' use of digital

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Contribution to the literature

- This study identified Chinese mathematics teachers' most frequently used digital technologies and their activities with them in lesson preparation and classroom instruction.
- The study examined the impact of age, grade levels, years of teaching with technology, and teacher beliefs on Chinese mathematics teachers' technology usage.
- Implications of the findings from this study were discussed.

technologies and factors that support or hinder their effective integration into classroom practices.

In 1995 the China education and research network (CERNET) was connected to the international network, which started the process of education informatization in China. Although starting late, education informatization in China has developed rapidly in the past two decades through a series of government-led initiatives, among which include *school link network* project that aimed to ensure that 90% of Chinese teachers can have access to online education resources and the *three links and two platforms* project that aimed to ensure that each school connects to the broadband network, each class connects to high-quality education resources, and each individual in schools connects to online learning space, and to develop online platforms for education resources and online platforms for education management. These initiatives focused on developing infrastructure and improving access to information and communication technologies (ICTs) and digital resources in K-12 schools. A recent report has shown that by the end of 2020 all K-12 Chinese schools had internet connection (Cyberspace Administration of China, 2021). Given that access to computers and the internet is no longer a serious issue for most schools, the Chinese Ministry of Education (MOE) launched education informatization 2.0 action plan in 2018 that aims to further promote the integration of ICTs in teaching and learning and the development of digital competencies of all teachers and students. Chinese national mathematics curriculum standards also promote teachers' use of ICTs to support students' learning and to develop their understanding of mathematical concepts (MOE, 2011). Given that access to digital technologies and resources, educational policies, and institutional support are not sufficient for ensuring effective integration of technology into teaching and learning of disciplinary knowledge, it is important to understand how teachers integrate technology into their practice in order to better support them.

The study reported here aimed to understand Chinese mathematics teachers' use of a list of commonly available digital technologies and resources in lesson preparation and classroom instruction in the post-pandemic era. More specifically, it was guided by the following four questions:

1. How frequently do Chinese mathematics teachers use a list of commonly available digital technologies and resources in lesson preparation and classroom instruction?
2. How do age, years of teaching with technology, grade level, and beliefs affect Chinese mathematics teachers' frequency of using digital technologies and resources for instruction?
3. What are Chinese mathematics teachers' specific pedagogical activities of using these digital technologies and resources in lesson preparation and classroom instruction?
4. How do age, years of teaching with technology, grade level, and beliefs affect Chinese mathematics teachers to use a particular technology for specific activities?

LITERATURE REVIEW & CONCEPTUAL FRAMING

While the use of technology for teaching and learning mathematics has been widely researched in various countries and the field has agreed that incorporating technology into the teaching and learning of mathematics is important, there is still relatively little research that examines Chinese teachers' use of commonly available technologies for mathematics instruction. This section briefly summarizes existing research on types of technology used in mathematics teaching, factors that influence technology integration in mathematics teaching, and the ways technology is positioned and used in mathematics teaching and learning.

Types of Technology Used in Mathematics Teaching

A large number of hardware, software, and web-based technologies are now available for teaching mathematics. Each technology has inherent affordances and constraints. These technologies have been categorized into different types. Li and Ma (2010) identified four computer technology types in mathematics learning: tutorial, communication media, tools, and exploratory environment. *Tutorial technologies* are computer programs that directly teach mathematics by setting up a stimulating environment where information, demonstration, drill, and practice are provided to students. Examples of this type of technology are computer-assisted instruction (CAI), various computer-based mathematics games and numerous drill and practice software. *Communication* *media* are tools that enable effective communication and information sharing. *Exploratory environments* are technologies that seek to encourage active learning through discovery and exploration. *Tools* serve the technological purpose to make teaching and learning fun, effective, and efficient. Examples of this type of technology are Geometer's Sketchpad, data analysis software, and various virtual manipulatives. McCulloch et al. (2018) interviewed 21 early-career secondary mathematics teachers and found that the technologies that these teachers used included *mathematical action technologies* (e.g., GeoGebra, Desmos, and interactive mathematics applets), *collaboration technologies* (e.g., Padlet and Google documents), *assessment technologies* (e.g., Kahoot!, Plickers, and Quizlet), and *communication technologies* (e.g., document cameras and projectors). Alabdulaziz (2021) examined the use of digital technologies in Saudi Arabia during COVID-19 shutdown and identified different types of technologies used by mathematics teachers to facilitate learning, including mobile technologies, touchscreens and pen tablets, massive open online courses (MOOCs) in mathematics, and computer algebra systems. The COVID-19 pandemic has popularized the use of various types of communication technologies (e.g., Facebook, YouTube, Zoom, Google documents, and Yahoo answers) in mathematics teaching and learning (Marbán & Mulenga, 2022; Mulenga & Marbán, 2020). The use of various types of technology in mathematics teaching suggests that it is necessary to consider a wide range of technologies when surveying the landscape of technology usage in mathematics teaching particularly in the post-pandemic era. The categorizations of technology from the literature were used to inform our identification and organization of commonly available technologies used by mathematics teachers. Some researchers have also found that mathematics teachers focus on presentation technologies (e.g., document camera and interactive whiteboard) more than dynamic mathematics software or interactive mathematics applets (Polly, 2014), which implies that some technologies align well with teacher-centered pedagogies while others provoke learner-centered pedagogies.

Factors Influencing Technology Integration in Mathematics Teaching

Although research on how teachers choose and integrate a particular technology in mathematics instruction is limited, there has been an increasing number of research studies examining factors that affect teachers' use of technology. Teacher beliefs are often considered as a factor that limits meaningful integration of technology in mathematics teaching and learning–specifically, beliefs about the nature of mathematical knowledge (Kim et al., 2013), beliefs about the nature of teaching and learning (Ertmer, 2005; Kim et al., 2013; Li et al., 2019), beliefs about the role of the teacher (Tweed, 2013), and beliefs about their own technological skills (Goos & Bennison, 2008; Li et al., 2019). Thurm and Barzel (2022) have argued with empirical evidence that self-efficacy beliefs, epistemological beliefs, and beliefs about teaching with technology are crucial factors for teaching mathematics with technology. Teacher knowledge is another commonly suggested factor, including technological knowledge, pedagogical knowledge, content knowledge, and the intersection of these areas of knowledge (e.g., Koehler & Mishra, 2009; Loong & Herbert, 2018; Pierce & Stacey, 2013). Additional factors suggested by researchers include but are not limited to gender (Li et al., 2019; Perienen, 2020), years of teaching (Perienen, 2020; Tweed, 2013), adequate preparation or professional development of teachers (Afshari et al., 2009; Perienen, 2020; Winter et al., 2021), teaching styles (Marbán & Mulenga, 2019), computer skills (Perienen, 2020), time since adoption of the technology (Ertmer, 2005), accessibility to appropriate hardware and software (Goos & Bennison, 2008; Winter et al., 2021), openness towards technology (Li et al., 2019), perceived ease of use for both teachers themselves and their students (McCulloch et al., 2018; Perienen, 2020), and alignment with the goals of the lesson (McCulloch et al., 2018). While most classrooms in China have computers and internet access, alleviating the issue of accessibility, many other factors remain to be barriers to technology integration. Therefore, there is a need to understand how factors other than access to hardware and software impact mathematics teachers' use of technologies for instruction. Moreover, existing studies have reported contradicting results on factors that contribute to teachers' use of technology. For instance, some studies have reported a negative relationship between the number of years of teaching and technology use (Inan & Lowther, 2010; Perienen, 2020; Umugiraneza et al., 2018), but other studies have challenged this negative relationship (e.g., Hermans et al., 2008; Li et al., 2019; Tweed, 2013). As a result, more empirical studies are needed to further examine how relevant factors impact teachers' use of technology. This study aimed to contribute to this strand of inquiry.

Teacher's Use of Digital Technologies in Mathematics Teaching

Researchers have identified a wide range of pedagogical activities afforded by digital technologies.

Some activities are not discipline-specific while others are specific to mathematics teaching and learning. Examples of general pedagogical activities afforded by digital technologies are motivating students, presenting knowledge and information, supporting students' communication and collaboration, providing timely feedback for students, and collecting data about student learning (e.g., McCulloch et al., 2018; Pierce & Ball, 2009). Mathematics-specific pedagogical activities include but

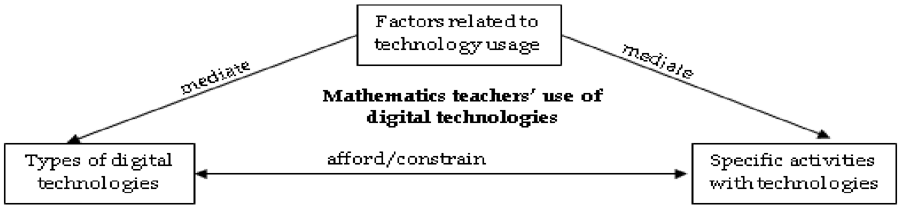

Figure 1. Conceptual framing of this study

are not limited to delegating procedures, providing opportunities to practice concepts, making sense of mathematical ideas or procedures, supporting student task exploration, modeling problem situations dynamically, and creating and manipulating dynamic mathematical representations (e.g., Drijvers et al., 2018; Polly, 2014). Although technologies afford a wide range of pedagogical activities, teacher's use of digital technology for specific pedagogical activities is not only constrained by the inherent affordances of technology but also is influenced by factors discussed above. Some researchers have found that many teachers use technology for low-level tasks and high-level uses are still very limited (Ertmer, 2005). A US Department of Education survey found that only 20% of teachers report using software to extend their students' learning on a weekly basis (Bakia et al., 2009). Only a small number of Mauritians mathematics teachers in Perienen's (2020) study used technology in their teaching practices, although they were regular users of computers and perceived technology as useful for enhancing mathematic teaching and learning. While more and more Chinese mathematics teachers have access to digital technologies, it remains unclear what type of digital technological tools that Chinese mathematics teachers actually use in lesson preparation and classroom instruction and what activities these technologies are used for. It is this gap of knowledge that this study aimed to narrow.

Review of the above literature resulted in a conceptual framework that guided the design of our study (**Figure 1**). It shows that the design of a survey study on mathematics teachers' use of digital technologies for instruction should at least consider the types of digital technologies that are used, the specific activities that technologies are used for, and the factors that mediate teachers' use of technologies.

METHODOLOGY

Participants

The participants of this study were Chinese mathematics teachers in Tianjin who had used some sort of digital technologies and resources in lesson preparation and/or classroom instruction. Mathematics teachers in Tianjin were chosen because education informatization development in Tianjin represented the current development of education informatization in many Chinese provinces. Like many other Chinese provinces, Tianjin currently belongs to the second tier in education informatization and is behind the first-tier cities in China (i.e., Beijing, Shanghai, Shenzhen, Guangzhou, Wuhan, and Hangzhou). Zhang et al. (2019) reported that 99.93% of schools in Tianjin have access to the internet (national average was 99.7% in 2020), 96.12% of schools have a multimedia classroom (national average was 95.2% in 2020), 66% of schools are equipped with an interactive whiteboard (national average was over 50% in 2020), and 68.3% schools have complete sets of supporting digital resources for mathematics textbooks (national average was over 67% in 2020). These data indicate that education informatization in Tianjin represents the national average.

Instrument

A survey was used to study Chinese mathematics teachers' use of digital technologies and resources for instruction. The survey consisted of three parts. The first part was about the demographic information of the participants, including age, the highest degree in education, years of teaching, years of using digital technologies for instruction, grade level, and accessibility to commonly used instructional technologies. The second part was about teachers' use of commonly available technologies in lesson preparation and classroom instruction. Questions on this part focused on not only teachers' frequency of using a list of commonly available technologies but also their specific activities with each of them. For lesson preparation, the list of technologies included online supporting resources from textbook publishers, national and provincial education resources platforms, search engines, platforms and software programs for creating courseware, self-accumulated digital resources, mathematics-specific technologies, online teaching platforms and apps. Regarding the specific activities of using these technologies in lesson preparation, the list included analyzing learning and students, downloading resources for lesson preparation, downloading or creating courseware, searching for or making mini-lesson videos, searching for practicing problems, searching for inquiry-based learning activities, and searching for or making interactive mathematics applets. For classroom instruction, the list of technologies included courseware, mini-lesson videos, smartboard, dynamic mathematics software, and interactive mathematics applets. The list of activities of using these technologies during instruction included ones that are not subject-specific (i.e., motivating students, presenting knowledge and information, assisting group work, supporting students' demonstration and communication, collecting data about student learning, providing timely feedback for students, and supporting self and peer evaluation) and ones that are more specific to mathematics (i.e., modeling problem situations dynamically, supporting mathematical abstraction and induction, supporting conjecturing and exploration, and carrying out mathematical actions, and visualizing mathematical concepts and relations).

The third part of the survey was the mathematics teachers' beliefs scale (MTBS), a valid and reliable instrument developed by Xie and Cai (2021) to measure mathematics teachers' belief system. The instrument consists of five subscales with 26 items to measure teacher beliefs about mathematics, mathematics learning, mathematics teaching, students, and teachers. The dimension on beliefs about mathematics considers teacher beliefs on the source, nature, development, and value of mathematics as a discipline. The dimension on beliefs about mathematics learning measures teacher beliefs about the process, speed, and impact factors of mathematics learning. The dimension on beliefs about mathematics teaching takes account of teacher beliefs on the fundamental antagonisms, curriculum material, process, strategy, organizational form, and evaluation in mathematics teaching. The dimension on beliefs about student considers teacher beliefs on the intellectual and nonintellectual factors and individual differences in student development. The dimension on beliefs about teachers focuses on their perceived motivation to teach, self-efficacy, and teaching style. The five subscales belong to two second-order factors, namely, beliefs about mathematics pedagogy (MTBS-mathematics pedagogy) and beliefs about students and teachers (MTBS-students and teachers). A higher score on an MTBS subscale indicates more productive beliefs that have closer alignment with reform-oriented views of mathematics instruction.

Procedures

Since the third part of the survey consisted of an existing survey instrument, this section mainly describes the process of developing the second part of the survey in this study, which consists of three stages. Firstly, based on existing literature on mathematics teachers' use of technology for instruction and our own knowledge of Chinese mathematics teachers' pedagogical practices with technology, we generated a list of commonly available technologies and teachers' specific activities with them in lesson planning and classroom instruction. The list of commonly available technologies was divided into technologies used in lesson preparation and technologies used during classroom instruction. It is worth noting that the same technology might be used at different stages of instruction (e.g., dynamic mathematics software can be used both in lesson preparation and during instruction). Secondly, the draft of the survey was first reviewed by 32 K-12 mathematics teachers from nine provinces (10 elementary teachers, 13 middle school teachers, and 9 high school teachers). Their feedback included

(1) adding or removing a particular technology,

(2) adding, rewording, or combining specific activities with technology, and

(3) changing the wording or format of survey questions.

The revised survey was then reviewed by a teaching-research officer who was familiar with teachers' use of ICTs in Tianjin, a mathematics education researcher, and an educational technology researcher. The survey was further revised based on their feedback. Thirdly, the revised survey was tested with 10 mathematics teachers in Tianjin for feedback on clarity of the survey questions and length of the survey. The survey was then finalized based on their feedback. This three-stage process was to establish face validity and content validity for the survey. The final version of the survey can be accessed at https://www.wjx.cn/vm/OjdzIAf.aspx.

The survey was distributed through an online survey platform. Under the assistance of three teaching-research officers, the research team sent out the survey link in early November of 2021 to all mathematics teachers in Tianjin through WeChat, a very commonly used social platform in China. We chose WeChat over other media (e.g., email) because WeChat is frequently used by many Chinese teachers at work. As a result, it allowed us to distribute the survey efficiently to a large number of K-12 mathematics teachers in Tianjin. The teachers were given about one week to complete the survey. A reminder was also sent out after a few days followed by the initial survey distribution.

Data Processing and Analysis

The online survey platform recorded 1465 mathematics teachers' responses to the survey, which was about 8.6% of the total number of mathematics teachers in Tianjin. These responses were imported into SPSS 28.0.1. Since the data quality of an online survey is subject to the effects of respondents who do not give the required attention to survey questions and who speed through the survey (Vriesema & Gehlbach, 2021), responses that meet one of the following three criteria were excluded:

(1) a response that spent less than five minutes on the survey,

(2) an incomplete response (i.e., more than 10% of the survey questions is not responded), and

(3) a response that reported no technology usage in teaching.

This process excluded 382 responses and left 1,083 (73.9%) responses for further analysis.

Among the 1,083 teachers, 225 (18.6%) were male and 982 (81.4%) were female, which was consistent with the gender distribution of the teacher population in Tianjin. The average age of the 1,083 teachers was 38.6. 178 (16.4%) teachers were less than 30 years old, 372 (34.3%) teachers were between the ages of 30~39, 382 (35.3%) teachers were between the ages of 40~49, and 151 (13.9%) teachers were 50 years old or above. 992 (77.4%) had bachelor's degrees as their highest degree and 838 (77.4%) has a degree in mathematics or mathematics education. 284 (26.2%) teachers had less than five years of teaching experience with technology, 335 (30.9%) teachers had 5~9 years of teaching experience with technology, and 464 (42.8%) teachers had 10 or more years of teaching experience with technology. 322 (29.7%) were elementary teachers, 192 (17.7%) were middle school teachers, and 569 (52.5%) were high school teachers. The demographic characteristics of the teachers in this study were a good representation of the mathematics teacher population in Tianjin. The Cronbach's alpha for the survey is 0.945, indicating a high level of internal consistency of this survey with this specific sample.

To answer the first and the third research questions, descriptive statistics (i.e., frequency tables and cross-tabulations) were used to analyze teachers' frequencies and the specific activities of using the list of commonly available technologies during lesson preparation and classroom instruction. Logistic regression analysis was conducted to answer the other two research questions. More specifically, a cumulative odds ordinal logistic regression with proportional odds was conducted to determine the effect of age, years of teaching with technology, grade levels, and the two second-order factors in the MTBS on how often ("rarely", "semesterly", "monthly" "weekly", "daily") teachers used a particular technology. Similarly, a binary logit model was estimated to investigate whether age, years of teaching with technology, grade levels, and the two second-order factors in the MTBS predict whether a teacher used a particular technology-supported activity. For each logistic regression analysis, the predictor variables were tested a priori to verify there was no violation of the assumptions. Years of teaching was not included in these logistic models because of its high correlation with age (r=0.861). The two second-order factors of MTBS were used because the subscales within each of the second-order factors were highly correlated (r>0.8).

RESULTS

Teacher's Frequency of Using Digital Technologies and Resources

The survey results showed that among the given list of technologies search engines and self-accumulated digital resources were frequently used by most teachers in lesson preparation. About 70% percent of the teachers in this study indicated that they had used search engines and self-accumulated digital resources on a weekly or daily basis in lesson preparation. Only a very small percent of them indicated that they rarely used search engines or self-accumulated digital resources in lesson preparation. The percent of teachers who reported to frequently (weekly or daily) use online supporting resources from textbook publishers, courseware creation platforms and software (e.g., Microsoft PowerPoint, 101 Education PPT, Focusky), mathematics-specific technologies (e.g., GeoGebra), and online teaching platforms and apps (e.g., Rain Classroom, Seewo, Xuexitong) ranged between 42.2% and 45.8%. Meanwhile, there were substantial percentages (ranging from 15.6% to 26.6%) of teachers who had rarely used the above digital technologies or resources in lesson preparation. Only around 33% to 37 % of the teachers in this study had used on a weekly or daily basis national education resource platform (https://www.eduyun.cn) and provincial or local education resources platforms (http://tjedu.tjjy.com.cn).

The survey results also revealed that more than 70% of the teachers in this study reported using courseware on a weekly or daily basis for classroom instruction. There was only a very small percentage (4.7%) of the teachers who had rarely used courseware during classroom instruction. Nearly 60% of the teachers in this study reported using smartboard weekly or daily during classroom instruction. Meanwhile, there were only about 32% to 34% percent of the participants who had used dynamic mathematics software (e.g., GeoGebra, Geometer's Sketchpad), interactive mathematics applets, and mini-lesson videos on a weekly or daily basis. More than 40% of the teachers had rarely used them or only used them a few times a semester.

Table 1 provides more information about teachers' frequency of using commonly available technologies in lesson preparation and instruction.

Factors Affecting Teacher's Frequency of Using Digital Technologies and Resources

Results from the ordinal logistic regressions showed that grade level, age, years of teaching with technology, teacher's beliefs accounted for a significant amount of variance in their frequency of using a particular technology in lesson preparation. In general, an increase in age (expressed in years) was associated with a statistically significant decrease in the odds of more

Table 1. Teachers' frequency of using digital technologies/resources in lesson preparation & classroom instruction (n=1,083)

		Rarely	Semesterly	Monthly	Weekly	Daily
Lesson preparation	Search engines	64 (5.9%)	75 (7.0%)	158 (14.7%)	344 (31.9%)	437 (40.5%)
	Self-accumulated digital resources	46 (4.3%)	117 (10.8%)	178 (16.5%)	389 (36.0%)	352 (32.5%)
	Online resources from textbook publishers	237 (22.1%)	16 (15.0%)	18 (17.1%)	304 (28.4%)	187 (17.4%)
	Courseware creation platforms and software	219(20.2%)	171(15.8%)	211(19.5%)	278(25.7%)	203(18.8%)
	Math-specific technologies	169 (15.6%)	216 (20.0%)	221 (20.4%)	295 (27.3%)	180(16.7%)
	Online teaching platforms and apps	288 (26.6%)	173 (16.0%)	163 (15.1%)	236 (21.8%)	221(20.4%)
	National education resources platform	167 (15.5%)	251(23.3 %)	256 (23.8%)	309 (28.7%)	92 (8.6%)
	Provincial or local education resources platform	206 (19.2%)	252 (23.5%)	260 (24.2%)	286(26.6%)	70 (6.5%)
Instruction	Courseware	51(4.7%)	112 (10.4%)	159 (14.7%)	340 (31.4%)	420(38.8%)
	Smartboard	150 (13.9%)	150 (13.9%)	141 (13.0%)	229 (21.2%)	412(38.1%)
	Dynamic math software	246 (22.7%)	227 (21.0%)	242 (22.3%)	255 (23.5%)	113(10.4%)
	Mini lesson videos	212 (19.7%)	246 (22.9%)	249 (23.1%)	279 (25.9%)	90(8.4%)
	Interactive math applets	302 (28.1%)	209 (19.5%)	219 (20.4%)	243 (22.6%)	101 (9.4%)

frequent use of digital technologies or resources with the exception of using online supporting resources from textbook publishers. Except for the use of self-accumulated digital resources and mathematics-specific technologies, years of teaching with technology was not a statistically significant predictor of teachers' frequency of using digital technologies or resources.

Although the scores on MTBS-mathematics pedagogy was not a statistically significant predictor of teachers' frequency of search engines, online teaching platforms and apps, national education resources platforms, and provincial or local education resources platforms, an increase in scores on MTBS-students and teachers was often associated with a statistically significant increase in the odds of more frequent use of digital technologies or resources. Mathematics teachers in lower grade levels were more likely to have an increased frequency of using digital technologies and resources in lesson preparation. In particular, the odds of elementary school mathematics teachers reporting more frequent use of technologies were often statistically significantly higher than that of the high school mathematics teachers.

Table 2 provides more detailed information about the results of the logistic regression analysis of teachers' frequency of using commonly available digital technologies and resources in lesson preparation.

Results from the ordinal logistic regressions revealed that grade level, age, years of teaching with technology, teacher's beliefs accounted for a significant amount of variance in their frequency of using a particular technology during classroom instruction. In general, an increase in age was associated with a statistically significant decrease in the odds of more frequent use of

Table 2. Logistic regression analysis of teacher's frequency of using technologies in lesson preparation

	Variable	β	S.E. β	Wald's χ^2	df	p	e^{β}
Search engines (χ^2(6)=133.599, p<0.001)[b]	Grade level: Elementary (1-6)[a]	.495	.1387	12.722	1	<.001	1.640
	Grade level: Middle school (7-9)[a]	.098	.1590	.380	1	.538	1.103
	Age	-.055	.0080	46.941	1	<.001	.947
	Years of teaching with technology	.008	.0175	3.264	1	.071	1.008
	MTBS-mathematics pedagogy	.006	.0044	1.702	1	.192	1.006
	MTBS-students & teachers	.103	.0164	39.379	1	<.001	1.109
Self-accumulated digital resources (χ^2(6)=91.652, p<0.001)[b]	Grade level: Elementary (1-6)[a]	.279	.1365	4.192	1	.041	1.322
	Grade level: Middle school (7-9)[a]	.316	.1573	4.028	1	.045	1.371
	Age	-.039	.0079	24.944	1	<.001	.961
	Years of teaching with technology	.051	.0171	8.837	1	.003	1.052
	MTBS-mathematics pedagogy	.007	.0042	2.491	1	.114	1.007
	MTBS-students & teachers	.094	.0158	35.146	1	<.001	1.098
Online resources from textbook publishers (χ^2(6=174.176, p<0.001)[b]	Grade level: Elementary (1-6)[a]	1.571	.1410	124.138	1	.000	4.811
	Grade level: Middle school (7-9)[a]	.515	.1545	11.101	1	<.001	1.673
	Age	-.013	.0078	2.849	1	.091	.987
	Years of teaching with technology	.006	.0169	.108	1	.742	1.006
	MTBS-mathematics pedagogy	.011	.0042	6.692	1	.010	1.011
	MTBS-students & teachers	.052	.0163	10.162	1	.001	1.053
Courseware creation platforms & software (χ^2(6)=111.343, p<0.001)[b]	Grade level: Elementary (1-6)[a]	.866	.1346	41.350	1	<.001	2.377
	Grade level: Middle school (7-9)[a]	.282	.1534	3.384	1	.066	1.326
	Age	-.039	.0077	26.296	1	<.001	.961
	Years of teaching with technology	.017	.0168	1.035	1	.309	1.017
	MTBS-mathematics pedagogy	.010	.0042	5.954	1	.015	1.010
	MTBS-students & teachers	.036	.0157	5.316	1	.021	1.037

Table 2 (Continued). Logistic regression analysis of teacher's frequency of using technologies in lesson preparation

	Variable	β	S.E. β	Wald's χ²	df	p	e^β
Math-specific technologies (χ^2(6)=97.655, p<0.001)[b]	Grade level: Elementary (1-6)[a]	.399	.1337	8.898	1	.003	1.490
	Grade level: Middle school (7-9)[a]	.401	.1537	6.814	1	.009	1.494
	Age	-.047	.0078	36.876	1	<.001	.954
	Years of teaching with technology	.043	.0167	6.539	1	.011	1.044
	MTBS-mathematics pedagogy	.011	.0042	6.969	1	.008	1.011
	MTBS-students & teachers	.060	.0160	13.933	1	<.001	1.061
Online teaching platforms & apps (χ^2(6)=156.740, p<0.001)[b]	Grade level: Middle school (7-9)[a]	.401	.1537	6.814	1	.009	1.494
	Age	-.047	.0078	36.876	1	<.001	.954
	Years of teaching with technology	.043	.0167	6.539	1	.011	1.044
	MTBS-mathematics pedagogy	.011	.0042	6.969	1	.008	1.011
	MTBS-students & teachers	.060	.0160	13.933	1	<.001	1.061
	MTBS-students & teachers	.039	.0158	6.193	1	.013	1.040
National education resources platform (χ^2(6)=86.653, p<0.001)[b]	Grade level: Elementary (1-6)[a]	.811	.1337	36.746	1	<.001	2.249
	Grade level: Middle school (7-9)[a]	.367	.1550	5.611	1	.018	1.444
	Age	-.264	.0775	11.646	1	<.001	.768
	Years of teaching with technology	.059	.0845	.487	1	.485	1.061
	MTBS-mathematics pedagogy	-.006	.0042	2.100	1	.147	.994
	MTBS-students & teachers	.052	.0160	10.626	1	.001	1.054
Provincial or local education resources platform (χ^2(6=61.479, p<0.001)[b]	Grade level: Elementary (1-6)[a]	.597	.1331	20.121	1	<.001	1.817
	Grade level: Middle school (7-9)[a]	.024	.1556	.024	1	.876	1.025
	Age	-.232	.0765	9.161	1	.002	.793
	Years of teaching with technology	.095	.0840	1.288	1	.256	1.100
	MTBS-mathematics pedagogy	-.004	.0043	1.000	1	.317	.996
	MTBS-students & teachers	.055	.0160	11.670	1	<.001	1.056

Note. [a] High school (10-12) is the reference variable & [b] Result of likelihood ratio test that compares the fitted model to a model with varying location parameters

digital technologies. In contrast, an increase in years of teaching with technology was associated with a statistically significant increase in the odds of more frequent use of digital technologies (except the case of using interactive mathematics applets).

An increase in the scores on MTBS was often associated with a statistically significant increase in the odds of more frequent use of digital technologies (except MTBS-mathematics pedagogy in the use of smartboard). Mathematics teachers in lower grade levels were more likely to have an increased frequency of using courseware, smartboard, and mini-lesson videos during classroom instruction. Grade level was not a statistically significant predictor of teachers' frequency of using dynamic mathematics software.

Table 3 provides more detailed information about the results of the logistic regression analysis of teacher's frequency of using commonly available technologies during instruction.

Teachers' Specific Activities of Using Digital Technologies and Resources

The survey results showed that downloading resources for lesson preparation, downloading or

Table 3. Logistic regression analysis of teacher's frequency of using technologies during instruction

	Variable	β	S.E. β	Wald's χ²	df	p	e^β
Courseware (χ^2(6)=398.149, p<0.001)[b]	Grade level: Elementary (1-6)[a]	2.517	.1686	222.930	1	.000	12.394
	Grade level: Middle school (7-9)[a]	.989	.1643	36.265	1	<.001	2.690
	Age	-.053	.0083	40.918	1	<.001	.948
	Years of teaching with technology	.059	.0176	11.427	1	<.001	1.061
	MTBS-mathematics pedagogy	.012	.0046	6.531	1	.011	1.012
	MTBS-students & teachers	.079	.0165	22.775	1	<.001	1.082
Smartboard (χ^2(6)=78.462, p<0.001)[b]	Grade level: Elementary (1-6)[a]	.706	.1380	26.182	1	<.001	2.026
	Grade level: Middle school (7-9)[a]	.309	.1572	3.852	1	.050	1.361
	Age	-.028	.0078	13.143	1	<.001	.972
	Years of teaching with technology	.050	.0169	8.653	1	.003	1.051
	MTBS-mathematics pedagogy	.005	.0042	1.255	1	.263	1.005
	MTBS-students & teachers	.062	.0157	15.760	1	<.001	1.064
Mini lesson videos (χ^2(6=62.104, p<0.001)[b]	Grade level: Elementary (1-6)[a]	1.332	.1392	91.537	1	.000	3.787
	Grade level: Middle school (7-9)[a]	.399	.1566	6.500	1	.011	1.491
	Age	-.032	.0077	17.061	1	<.001	.969
	Years of teaching with technology	.047	.0166	8.187	1	.004	1.049
	MTBS-mathematics pedagogy	.012	.0042	7.650	1	.006	1.012
	MTBS-students & teachers	.057	.0158	13.033	1	<.001	1.059

Table 3 (Continued). Logistic regression analysis of teacher's frequency of using technologies during instruction

	Variable	β	S.E. β	Wald's χ^2	df	p	e^{β}
Dynamic mathematics software (χ^2(6=42.709, p<0.001)[b]	Grade level: Elementary (1-6)[a]	-.148	.1360	1.177	1	.278	.863
	Grade level: Middle school (7-9)[a]	.076	.1506	.257	1	.612	1.079
	Age	-.030	.0077	14.842	1	<.001	.971
	Years of teaching with technology	.040	.0165	6.042	1	.014	1.041
	MTBS-mathematics pedagogy	.011	.0042	6.494	1	.011	1.011
	MTBS-students & teachers	.055	.0155	12.419	1	<.001	1.056
Interactive math applets (χ^2(6)=165.268, p<0.001)[b]	Grade level: Middle school (7-9)[a]	.076	.1506	.257	1	.612	1.079
	Age	-.030	.0077	14.842	1	<.001	.971
	Years of teaching with technology	.040	.0165	6.042	1	.014	1.041
	MTBS-mathematics pedagogy	.011	.0042	6.494	1	.011	1.011
	MTBS-students & teachers	.055	.0155	12.419	1	<.001	1.056
	MTBS-students & teachers	.053	.0158	11.106	1	<.001	1.054

Note. [a] High school (10-12) is the reference variable & [b] Result of likelihood ratio test that compares the fitted model to a model with varying location parameters

Table 4. Teacher's specific activities of using digital technologies/resources in lesson preparation

	n	Analyze learning and students	Download resources for lesson preparation	Download or create courseware	Search for practicing problems	Search for inquiry-based learning activities	Search for or create interactive math applets
Search engines	1,014	257 (25.3%)	547 (53.9%)	488 (48.1%)	542 (53.5%)	321 (31.7%)	281 (27.7%)
Self-accumulated digital resources	1,036	284 (27.4%)	560 (54.1%)	536 (51.7%)	505 (48.7%)	310 (29.9%)	258 (24.9%)
Online resources from textbook publishers	835	244 (29.2%)	490 (58.7%)	437 (52.3%)	379 (45.4%)	232 (27.8%)	261 (31.3%)
Courseware creation platforms and software	863	186 (21.6%)	407 (47.2%)	425 (49.2%)	315 (36.5%)	227 (26.3%)	237 (27.5%)
Math-specific technologies	912	204 (22.4%)	384 (42.1%)	405 (44.4%)	330 (36.2%)	242 (26.5%)	245 (26.9%)
Online teaching platforms and apps	793	206 (26.0%)	407 (51.3%)	420 (53%)	326 (41.1%)	242 (30.5%)	262 (33.0%)
National education resources platform	908	216 (23.8%)	487 (53.6%)	453 (49.9%)	399 (43.9%)	270 (29.7%)	259 (28.5%)
Provincial or local education resources platform	868	201 (23.2%)	452 (52.1%)	437 (50.3%)	398 (45.9%)	254 (29.3%)	240 (27.6%)

creating courseware, and searching for practicing problems were consistently the major activities for using the list of technologies in lesson preparation. In contrast, only less than 1/3 of the teachers had used the list of technologies to analyze learning and students, to search for inquiry-based mathematics activities, or to search for or make interactive mathematics applets. For instance, 547 (53.9%) teachers used search engines to download resources for lesson preparation, 488 (48.1%) teachers used it to download courseware, 542 (53.5%) teachers used it to search for practicing problems. However, only 257 (25.3%) teachers used it to learn more about learning and students, 321 (31.7%) teachers used it to locate inquiry-based learning activities, and 281 (27.7%) teachers used it to search for interactive mathematics applets. Similarly, 490 (58.7%) teachers used online supporting resources from textbook publishers to download resources for lesson preparation, 437 (52.3%) teachers used it to download courseware, 379 (45.4%) teachers used it to search for practicing problems. On the contrary, only 244 (29.2%) teachers used it to analyze learning and students, 232 (27.8%) teachers used it to locate inquiry-based learning activities, and 261 (31.3%) teachers used it to search for interactive mathematics applets. This pattern extended to their use of mathematics-specific technologies. 384 (42.1%) teachers used mathematics-specific technologies to download resources and 330 (36.2%) teachers used it to search for practicing problems. However, 242 (26.5%) teachers used it to locate inquiry-based learning activities and 245 (26.9%) teachers used it to search for interactive mathematics applets.

Table 4 contains the numbers and percentages of teachers who used the list of technologies for different activities. It is important to note that the total number of teachers under each technology excluded the teachers who reported rarely using the technology in lesson preparation. Therefore, the percentages are substantially smaller in relation to the total number of teachers in this study, especially for digital technologies and resources outside search engines and self-accumulated digital resources.

Results from the survey also revealed that motivating students and presenting knowledge and information were consistently the most frequently selected non-

Table 5. Teacher's specific activities of using digital technologies during classroom instruction

	n	Non-mathematics-specific activities							Mathematics-specific activities				
		Motivate students	Present knowledge& information	Assist group work	Support students' demonstration and communication	Collect data about student learning	Providing timely feedback for students	Support self & peer evaluation	Model problem situations dynamically	Support mathematical abstraction and induction	Support conjecturing and exploration	Carry out mathematical actions	Visualize mathematical concepts and relations
Courseware	1,031	693 (67.2%)	635 (61.6%)	393 (38.1%)	430 (41.7%)	349 (33.9%)	381 (37.0%)	326 (31.6%)	592 (57.4%)	609 (59.1%)	481 (46.7%)	498 (48.3%)	611 (59.3%)
Smartboard	932	464 (49.8%)	508 (54.5%)	363 (38.9%)	423 (45.4%)	356 (38.2%)	389 (41.7%)	302 (32.4%)	420 (45.1%)	461 (49.5%)	432 (46.4%)	454 (48.7%)	484 (51.9%)
Mini lesson videos	864	517 (59.8%)	476 (55.1%)	282 (32.6%)	291 (33.7%)	256 (29.6%)	246 (28.5%)	201 (23.3%)	450 (52.1%)	428 (49.5%)	367 (42.5%)	326 37.7(%)	393 (45.5%)
Dynamic math software	837	503 (60.1%)	475 (%)	287 (34.3%)	305 (36.4%)	226 (27.0%)	258 (30.8%)	201 (24.0%)	456 (54.5%)	424 (50.7%)	401 (47.9%)	381 (45.5%)	380 (45.4%)
Interactive math applets	772	335 (46.0%)	364 (47.2%)	256 (33.2%)	276 (35.8%)	237 (30.7%)	248 (32.1%)	188 (24.4%)	342 (44.3%)	344 (44.6%)	328 (42.5%)	319 (41.3%)	331 (42.9%)

mathematics specific activities for using courseware, smartboard, mini video lessons, dynamic mathematics software, and interactive mathematics applets. In contrast, a much smaller percentage of teachers had used these technologies for other non-mathematics specific activities such as assisting group work, supporting students' demonstration and communication, collecting data about student learning, providing timely feedback for students, and supporting self and peer evaluation. Although teachers' use of these technologies for mathematics-specific activities is more evenly distributed (mostly between 40% and 60%), particular activities were more prominent in some technologies. For instance, a relatively larger number of teachers used courseware and mini-lesson videos to model problem situations dynamically and to support mathematical abstraction and induction compared with the teachers who used these two technologies to support conjecturing and exploration and to carry out mathematical actions (e.g., numerical calculation, graphing, symbolic manipulation, geometric construction, and data display and analysis).

Table 5 presents the numbers and percentages of teachers who used the five technologies for different activities during classroom instruction. Since the total number of teachers under each technology excluded the teachers who reported rarely using the technology during classroom instruction, the percentages are smaller in relation to the total number of teachers in this study, especially for technologies other than courseware. Less than half and sometimes even less than 1/3 of the teachers in this study had used smartboard, mini-lesson videos, dynamic mathematics software, and interactive mathematics applets for the list of activities during instruction.

Factors Affecting Teacher's Engagement with Technology-Supported Activities

Results from the binary logistic regressions revealed that higher scores on the two subscales of MTBS, especially the subscale of MTBS-students and teachers, often had a statistically significant positive effect on the use of technologies to analyze learning and students, to download resources for lesson preparation, to download or create courseware, to search for practicing problems, to search for inquiry-based learning activities, and to search for or create interactive mathematics applets. Only in a small number of instances such a positive effect was not statistically significant. Although the odds that middle school mathematics teachers who used the listed technologies for the above activities were not statistically significantly different from that of the high school mathematics teachers, mathematics teachers in elementary school often had statistically significant higher odds than high school mathematics teachers to engage in the above activities when using the above list of technologies in lesson preparation. Only in a small number of instances the higher odds held by the elementary school mathematics teachers did not reach a statistically significant level. Age mostly had a negative but non-statistically significant effect on teacher's engagement in a particular activity with technology in lesson preparation. Meanwhile, years of teaching mostly had a positive but non-statistically significant effect on teachers' engagement in a particular activity with technology in lesson preparation.

Table 6 provides more detailed information about the results of the logistic regression analysis of teacher's activities of using the eight technologies in lesson preparation.

Table 6. Logistic regression analysis of teacher's specific activities of using eight technologies in lesson preparation

		Analyze learning & students	Download resources for lesson preparation	Download or create courseware	Search for practicing problems	Search for inquiry-based learning activities	Search for or create interactive math applets
Search engines	Grade level: Elementary (1-6)	+**(1.680)		+***(1.740)		+***(2.247)	+**(1.583)
	Grade level: Middle school (7-9)						
	Age			-***(.964)			-*(.974)
	Years of teaching with tech						+*(1.047)
	MTBS-mathematics pedagogy		+***(1.017)		+**(1.015)		
	MTBS-student & teachers	+**(1.062)	+**(1.059)			+***(1.091)	+***(1.063)
Self-accumulated digital resources	Grade level: Elementary (1-6)	+***(2.009)	+*(1.047)	+***(1.916)		+***(2.097)	+***(2.300)
	Grade level: Middle school (7-9)						+*(1.644)
	Age		-**(.974)	-**(.973)		-*(.975)	
	Years of teaching with tech					+*(1.050)	+*(1.058)
	MTBS-mathematics pedagogy		+*(1.016)	+***(1.018)	+*(1.011)		
	MTBS-student & teachers			+***(1.058)		+***(1.074)	+***(1.147)
Online resources from textbook publishers	Grade level: Elementary (1-6)	+***(1.943)	+**(1.641)	**(1.610)		+**(1.830)	+**(1.643)
	Grade level: Middle school (7-9)						
	Age		-*(.970)	-**(.973)			
	Years of teaching with tech						+*(1.053)
	MTBS-mathematics pedagogy		+**(1.018)	+*(1.011)			
	MTBS-student & teachers		+**(1.062)		+*(1.048)	+**(1.080)	+***(1.116)
Courseware creation platforms and software	Grade level: Elementary (1-6)	+***(2.117)		+**(1.599)		+**(1.658)	+***(1.862)
	Grade level: Middle school (7-9)						
	Age			-***(.962)		-*(.971)	
	Years of teaching with tech			+*(1.049)			
	MTBS-mathematics pedagogy			+**(1.015)			
	MTBS-student & teachers			+**(1.060)		+***(1.103)	***(1.151)
Math-specific technologies	Grade level: Elementary (1-6)	+*(1.572)				+***(1.820)	+***(2.043)
	Grade level: Middle school (7-9)						
	Age			-*(.977)			
	Years of teaching with tech						
	MTBS-mathematics pedagogy		+*(1.011)				+**(1.016)
	MTBS-student & teachers	+**(1.074)	+*(1.054)	+*(1.050)		+***(1.103)	+***(1.142)
Online teaching platforms and apps	Grade level: Elementary (1-6)		+**(1.569)	+**(1.746)		+***(2.095)	+***(1.826)
	Grade level: Middle school (7-9)						
	Age		-*(.979)	-**(.967)			-*(.976)
	Years of teaching with tech						+*(1.053)
	MTBS-mathematics pedagogy			+*(1.011)			
	MTBS-student & teachers		+*(1.050)			+***(1.094)	+***(1.137)
National education resources platform	Grade level: Elementary (1-6)	+**(1.683)		+***(1.896)		+***(1.892)	
	Grade level: Middle school (7-9)						
	Age			-*(.979)			
	Years of teaching with tech						+*(1.061)
	MTBS-mathematics pedagogy		+**(1.015)				
	MTBS-student & teachers	+**(1.072)	+**(1.056)		+**(1.057)	+*(1.053)	+***(1.151)
Provincial or local education resources platform	Grade level: Elementary (1-6)	+*(1.575)				+**(1.762)	+*(1.593)
	Grade level: Middle school (7-9)						
	Age		-*(.976)	-*(.974)		-*(.973)	
	Years of teaching with tech						+**(1.070)
	MTBS-mathematics pedagogy		+*(1.013)				
	MTBS-student & teachers	+**(1.076)	+*(1.050)	+**(1.071)	+*(1.049)	+***(1.096)	+***(1.118)

Note. "+" means positive relationship and "-" means negative relationship; ***means p<.001, ** means p<.01, and * means p<.05; the number in the parenthesis is the odds ratio

Results from the binary logistic regressions showed that the teachers with higher scores on the two subscales of MTBS were often more likely to use courseware, smartboard, mini-lesson videos, dynamic mathematics software, and interactive mathematics applets to motivate students, to present knowledge and information, to model problem situations dynamically, to support mathematical abstraction and induction, to support conjecturing and exploration, to carry out mathematical actions, and to visualize mathematical concepts and relations. Only on a very small number of occasions higher scores on the two subscales of MTBS

Table 7. Logistic regression analysis of teacher's specific activities of using the five technologies during instruction

		Motivate students	Present knowledge & information	Model problem situations dynamically	Support math-al abstraction & induction	Support conjecturing & exploration	Carry out math-al actions	Visualize math-al concepts & relations
Courseware	Grade level: Elementary (1-6)	+*** (2.204)	+*(1.465)	+*** (1.971)	+*** (1.770)	+***(2.222)	+***(1.900)	+*(1.429)
	Grade level: Middle school (7-9)							
	Age		-**(.970)				-**(.970)	
	Years of teaching with tech					+**(1.063)	+**(1.056)	**+(1.069)
	MTBS-mathematics pedagogy	+*** (1.027)	+*** (1.041)	+*** (1.033)	+***(1.018)	+**(1.010)	+**(1.015)	+*** (1.031)
	MTBS-student & teachers	+*** (1.029)	+*** (1.071)	+*** (1.067)	+*** (1.069)	+***(1.077)	+***(1.079)	+*** (1.089)
Smartboard	Grade level: Elementary (1-6)	+**(1.545)		+***(2.042)	+**(1.644)	+***(2.329)	+** (1.596)	+**(1.652)
	Grade level: Middle school (7-9)							
	Age					-*(.975)		
	Years of teaching with tech					+*(1.046)		+*(1.043)
	MTBS-mathematics pedagogy	+**(1.013)	+***(1.021)	+** (1.015)	+***(1.017)			+*(1.012)
	MTBS-student & teachers	+**(1.060)	+*(1.048)	+***(1.091)	+**(1.056)	+**(1.504)	+**(1.063)	+**(1.067)
Mini lesson videos	Grade level: Elementary (1-6)	+***(1.848)	+*(1.430)	+**(1.705)		***+(1.902)	+**(1.561)	+*(1.403)
	Grade level: Middle school (7-9)							
	Age		-*(.979)					
	Years of teaching with tech							
	MTBS-mathematics pedagogy	+***(1.028)	+***(1.022)	+***(1.029)				
	MTBS-student & teachers	+**(1.070)	+**(1.056)	+***(1.088)	+**(1.062)			+*(1.051)
Dynamic math software	Grade level: Elementary (1-6)				+*(1.502)		+*(1.631)	+**(1.593)
	Grade level: Middle school (7-9)							
	Age		-*(.975)		-*(.980)		-**(.969)	-*(.974)
	Years of teaching with tech						+**(1.061)	+*(1.045)
	MTBS-mathematics pedagogy	+***(1.034)	+***(1.031)	+***(1.025)	+*(1.013)			+**(1.016)
	MTBS-student & teachers	+**(1.059)	+*(1.044)	+***(1.086)	+**(1.059)	+*(1.048)	+*(1.041)	+***(1.072)
Interactive math applets	Grade level: Elementary (1-6)	+**(1.669)		+**(1.632)			+*(1.566)	+**(1.711)
	Grade level: Middle school (7-9)							
	Age		-*(.978)					
	Years of teaching with tech			+*(1.057)		+*(1.061)		
	MTBS-mathematics pedagogy	+**(1.018)	+***(1.020)	+**(1.018)				+*(1.013)
	MTBS-student & teachers	+**(1.061)	+*(1.057)	+**(1.073)	+**(1.061)			+***(1.090)

Note. "+" means positive relationship and "-" means negative relationship; ***means p<.001, ** means p<.01, and * means p<.05; the number in the parenthesis is the odds ratio; & math-al: mathematical

did not have a statistically significant positive effect on teacher's engagement in the above activities when using the five technologies in classroom instruction.

Compared with high school mathematics teachers, mathematics teachers in elementary school often had statistically significantly higher odds to use courseware, smartboard, mini-lesson videos, dynamic mathematics software, and interactive mathematics applets for each of the activities listed above. Only in a very small number of instances the higher odds held by the elementary school mathematics teachers did not reach a statistically significant level. However, the odds that middle school mathematics teachers engaged in each of the above activities when using the five technologies were not statistically significantly different from that of the high school mathematics teachers. Although age had a negative effect on teacher's engagement in these activities with technology during classroom instruction, it was only in a few instances that the effect was statistically significant. Similarly, although years of teaching with technology had a positive effect, it was only in a few instances that the effect was statistically significant.

Table 7 provides more detailed information about the results of the logistic regression analysis of teacher's activities of using the list of technologies during classroom instruction. Because of limited space, the table only includes the two most frequently selected non-mathematics-specific activities and five mathematics-specific activities.

DISCUSSION AND CONCLUSION

This study has revealed that only search engines and self-accumulated digital resources were frequently (weekly or daily) used by more than half of the participants in lesson preparation. Similarly, only courseware and smartboard were frequently used by more than half of the participants in classroom instruction. Other commonly available technologies (e.g., education resources platforms, courseware creation software programs, mathematics-specific technologies) were not frequently used by the majority of the participants in lesson preparation or classroom instruction. The frequent use of courseware and smartboard over other technologies in classroom instruction is probably because they align with teacher-centered practices (Dishon, 2021; Polly, 2014). A lecture can be easily adapted to include PowerPoint presentations, pictures, and videos, while preserving the overall familiar pedagogical structure. This suggests that new technologies are more likely to be integrated if they align with or are used in ways that align with existing pedagogical practices and technology usage. In other words, the integration of educational technologies is usually cumulative rather than successive in that new technologies are often assimilated with, and not in place of, existing technologies (Dishon, 2021; Friesen, 2011). The dominance of teacher-centered technology usage was also reflected in the specific activities that technologies were used for. Most participants used technologies in lesson preparation to get courseware, resources, and practicing problems rather than to analyze learning and students or to search for inquiry-based learning activities. Motivating students and presenting knowledge and information were consistently the most frequently selected non-mathematics specific activities for technology usage during classroom instruction. Further research is needed to better understand the mechanism for integrating a specific digital technology into mathematics teaching.

Results from this study showed that many mathematics teachers had frequently used self-accumulated digital resources, digital resources obtained from search engines, and national or regional education resource platforms in their lesson preparation. This raises the question of how mathematics teachers select, organize, and integrate digital education resources into their daily lessons. Gueudet and Trouche (2012) proposed a documentational approach to examine the various aspects of the development and use of documents and resources in the field of education. According to this approach, teacher's documentation work includes all facets of activity in which teachers interact with resources (e.g., textbooks, student's work sheet, software programs, and digital resources). One of the pivotal constructs of the documentational approach is documentational genesis, a process of genesis that involves building or adapting schemes of utilization for sets of resources. A utilization scheme of a set of resources has both invisible and observable aspects. The invisible aspect is a cognitive structure that guides teacher's action. The observable part corresponds to the regularities in the teacher's action for a given class of situations. The documentational approach might provide a productive means to examine Chinese mathematics teachers' use of digital resources for instruction.

Although access to technology was less a problem for the mathematics teachers in this study, many general and mathematics specific technologies (e.g., education resources platforms and dynamic mathematics software) were only frequently used by less than a half and sometimes even only one-third of the teachers. This confirms the result from literature, which states that access to technology does not guarantee frequent and meaningful use of technology in mathematics teaching (Goos & Bennison, 2008; McCulloch et al., 2018; Umugiraneza et al., 2018). Many other factors are likely to impact mathematics teachers' technology usage. Some of the demographic factors are discussed below.

Teacher Beliefs and Technology Use

This study has shown that teacher beliefs impacted both how frequently a technology was used and whether the technology was used for a specific activity. More specifically, teachers with higher scores on the MTBS had more frequent use of technology, indicating that teachers who held productive beliefs of mathematics, mathematics learning and teaching, students, and self-efficacy were more likely to have increased frequency of using technology in their lesson preparation and classroom instruction.

This was especially true for teachers with productive beliefs on students (e.g., students' disposition factors such as motivations, attitudes, social relationships, and perseverance can be improved by cultivation) and self-efficacy (e.g., each mathematics teacher has his or her own teaching style). This pattern was observed across a wide range of technologies, including mathematics action technologies (e.g., interactive mathematics applets and dynamic mathematics software), communication technologies (e.g., courseware and smartboard), website platforms for education resources (e.g., online supporting resources from textbook publishers and national education resource platform). Moreover, teachers with productive beliefs were more likely to use technology in their lesson preparation for activities, such as downloading resources for lesson preparation, searching for inquiry-based learning activities, and searching for or creating interactive mathematics applets. They were also more likely to use technology during their classroom instruction for activities, such as motivating students, presenting knowledge and information, modeling problem situations dynamically, visualizing mathematical concepts and relations, supporting mathematical abstraction and induction, and carrying out mathematical actions. While teacher beliefs are often considered as a factor that limits meaningful integration of technology in mathematics teaching and learning, many studies on this topic have been theoretical or qualitative in nature (e.g., Misfeldt et al., 2016; Pierce & Ball, 2009; Thomas & Palmer, 2013; Tondeur et al., 2017). Moreover, there is a paucity of quantitative research that investigates the relationship of teachers' beliefs and the use of technology at a finer-grained level taking into account the multidimensional nature of teacher beliefs (except Thurm & Barzel, 2022). Findings from this study provide quantitative empirical evidence for the effect of different aspects of teacher's beliefs on the frequency of technology usage and on whether technology is used for specific activities. The results imply the importance of supporting mathematics teachers to develop productive beliefs of mathematics, mathematics learning and teaching, students, and self-efficacy through professional learning activities.

Grade Levels and Technology Use

Findings from this study have shown that in general mathematics teachers in lower grades were more likely to have a higher frequency of using technologies in lesson preparation and classroom instruction. In particular, mathematics teachers in elementary schools were more likely to use digital technologies and resources more frequently than mathematics teachers in high school with an exception in their use of dynamic software programs. Moreover, the odds of elementary mathematics teachers' use of digital technologies or resources for specific pedagogical activities (e.g., analyze student learning, search for inquiry-based learning activities, motivate students, support mathematical abstraction and induction, carry out mathematical actions, and visualize mathematical concepts and relations) was often higher than the odds of high school mathematics teachers, though there was no statistically significant difference between middle and high school mathematics teachers' odds of using digital technologies or resources for specific pedagogical activities. These findings imply significant differences between elementary and secondary mathematics teachers' use of digital technologies and resources. Differences across grade levels in technology usage were reported in the United States (Dogan et al., 2021; Ritzhaupt et al., 2012) and other countries or regions (Wu, 2021), but these studies were not specific to mathematics teachers. Since there were no significant differences in access to technology between elementary and secondary mathematics teachers in Tianjin (Zhang et al., 2019), these differences were likely due to internal factors, such as beliefs about the nature of mathematics learning and teaching, perceptions of the values of technology across grade levels, and pressure that college entrance exam places on high school teachers and students. Further research is needed to examine factors that contribute to grade-level differences in Chinese mathematics teachers' use of digital technologies.

Age, Experience, and Technology Use

This study has found that age often had a significant negative impact on mathematics teachers' frequency of technology usage. Older teachers were less likely to use technology more frequently in their lesson preparation and classroom instruction. Moreover, age had a negative impact on whether a technology was used for a specific activity in lesson preparation and classroom instruction, though the impact was only statistically significant on a few occasions. Given that age and years of teaching were highly correlated in this study (r=0.861), it is likely that these findings can be extended to teachers with more years of teaching. Similar results were reported in the literature over the past a few decades. For instance, an earlier report from the US National Center for Educational Statistics (2000) found that teachers with 9 or fewer years of teaching are more likely to integrate computers in their teaching than teachers with 20 or more years of teaching. Inan and Lowther (2010) discovered that age and year of teaching have an indirect negative impact on teacher's computer proficiency and technology usage. More recently, Perienen (2020) found that younger teachers demonstrated more frequent use of ICTs in mathematics teaching. Although many studies have reported a negative relationship between age or the number of years of teaching without technology and technology use, some studies also challenged this relationship (e.g., Hermans et al., 2008; Tweed, 2013). The conflicting results from different studies suggest the importance to examine factors that could possibly mediate the relationship between age or year of teaching and technology usage.

This study also found a statistically significant positive relationship between years of teaching with technology and frequency of technology usage during classroom instruction, but years of teaching with technology only had a statistically non-significant positive impact on teacher's frequency of technology usage in lesson preparation. This is consistent with the result from literature, which states that the more frequently teachers use technology the more likely that they would perceive them as easy to use and integrate them in their teaching (Perienen, 2020; Ritzhaupt et al., 2012). Moreover, years of teaching with technology in general had a positive impact on whether a technology was used for a specific activity in lesson preparation and classroom instruction, though the impact was only statistically significant on a few occasions. This positive relationship suggests the importance of accumulated experience in teaching mathematics with technology.

Limitation

There are several limitations in this study. First, since Tianjin belongs to the second tier in the development of education informatization in China, mathematics teachers in Tianjin might not represent those from tier 1 or tier 3 cities and provinces. Therefore, results from this study might not be generalizable to mathematics teachers from tier 1 or tier 3 cities and provinces. We are in the process of building connections with education agencies in different geographical areas of China. In the near future, we plan to sample mathematics teachers from different tiers of cities and provinces in China so that we can better understand their use of digital technologies for instruction. Second, because the survey was distributed through WeChat, it is possible that only mathematics teachers who were frequently WeChat users had responded. This may have resulted in a lack of inclusiveness among the mathematics teachers who did not use WeChat frequently and thus affected the generalizability of the results in this study. However, WeChat was the most economic approach to distribute the survey to a large number of mathematics teachers in Tianjin. Third, the use of self-reports in this study has its own limitation. The participants might be either consciously or unconsciously provide more socially acceptable responses rather than being truthful given that the current discourses in public policy and school administration promote technology integration in mathematics teaching and learning. Other research methods, such as classroom observations and analysis of videotaped lessons, might be used to understand mathematics teachers' actual use of digital technologies in their practices.

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