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How do students evaluate learning mathematics with digital textbooks? An exploratory study in a Chinese secondary school

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With the rapid development of digital technology, mathematics education researchers have paid increasing attention to the development of digital mathematics textbooks (DMTs) and the effect of DMTs on mathematics teaching and learning, but empirical research in this area, especially in China, has been overdue. In this study, we aimed to investigate how Chinese students evaluated learning mathematics with DMTs in classrooms. The data were collected using a questionnaire from 84 students in a secondary school in an eastern metropolitan city of China, interviews with 12 of them and nearly three-week classroom observations of teaching and learning with a DMT. Results showed that students overall had a positive attitude towards learning mathematics with the DMT. Meanwhile, they also had some concerns about using DMTs, which merits further attention.

Keywords: Chinese mathematics education, digital mathematics textbooks, teaching and learning, secondary school, students' evaluation¹.

Introduction

Over the past decade or so, with the rapid development of digital technology, mathematics education researchers have paid increasing attention to the issues related to the development, use and effects of digital mathematics textbooks in classrooms (Fan et al., 2013; Pepin et al., 2017; Rezat et al., 2021). Many researchers have discussed the development and research on DMTs from a theoretical or policy perspective (Bokhove, 2017; Choppin et al., 2014), while empirical studies centring on teachers and students' use of DMTs for mathematics teaching and learning are still relatively few, which is particularly the case in China, an area of research just starting to emerge.

Arguably, students are the most important users of DMTs and to investigate students' experience and views of using DMTs to learn mathematics has fundamental importance to examine the effect of using DMTs on mathematics teaching and learning. As a part of a larger project on DMT research and development, this study aims to answer the overarching research question: How do secondary students evaluate the use of a DMT for learning mathematics in Chinese classrooms?

Literature review

Related to the effect of DMTs on mathematics teaching and learning, there have been some empirical studies on the use of digital curriculum resources or digital platforms. Some studies focused on teachers' use of digital textbooks (e.g., Gueudet et al., 2016; Remillard et al., 2021). For instance,

¹ In this article, evaluation includes perception, attitude, disposition, view and so on.

Gueudet et al. (2016) explored the process of a group of French mathematics teachers' collectively designing Sésamath e-textbook with focus on the chapter "function" in Grade 10.

Some researchers have investigated the influence of DMTs on students' mathematics learning. Rezat (2021) used two case studies to examine how automated feedback on students' solutions from a DMT affected German primary students' learning processes and conceptual development. The study focused on student' processes of learning, especially in thinking and using the DMT. Similarly, Thomas (2013) examined the processes of Algebra 1 students' using a digital textbook in comparison with the process of those students' using printed textbooks in USA, with the data collected from lesson observations and interview with students and the participating teacher. Different from the two studies mentioned earlier, Reinhold et al. (2020) conducted an intervention-based study to explore the effect of a DMT on high-achieving and low-achieving primary students' learning of fractions in comparison with the students who used a printed version, in which, the results of the pre-test and post-test were analysed to examine the effect.

Concerning the effect of DMTs or digital platforms on students' learning, some researchers have paid attention to issues about students' perceptions. Knapp (2020) used action research to explore the effect of the technology strategies on secondary students' engagement and development of content knowledge when learning mathematics. The study was carried out by employing five technology tools for two weeks during a geometry unit on quadrilaterals. A daily student questionnaire was administered to investigate the effect of e-learning environment on student engagement, student self-efficacy and the usefulness of the technology, and interviews were conducted to gather further information. Chiu (2016) designed a digital chemistry textbook for secondary school and conducted an experimental study to examine the effect of the digital book on students' learning of chemistry in two schools in Hong Kong SAR. In the study, Chiu also used a questionnaire to investigate students' perceptions of using the digital chemistry textbook from the following aspects: students' attitude towards using the digital textbook, perceived usability of digital textbook, mobile computing self-efficacy and mobile computer anxiety. Chiu also used semi-structured interviews to collect the students' and the teacher's views of using the digital textbook. The findings showed that most of the students evaluated the digital textbook positively, and on the other hand, there were also some concerns proposed by the teacher and students.

Guo (2014) designed a DMT based on two geometric chapters in junior secondary mathematics textbooks published by Beijing Normal University Press. In the study, students used the DMT for preparing for learning relevant lessons. Guo examined the effect of the DMT on students' mathematics achievement by setting a pre-test and post-test for students in experimental classes where students used the DMT and a class where students used printed textbooks, and he also investigated students' perceptions of using the DMT by a questionnaire addressing the following aspects: satisfaction, usefulness and ease of use. The findings showed that the digital textbook helped students perform better in mathematics achievement than the printed textbooks; moreover, students were satisfied with using the digital textbook and thought it was easy to operate and useful for learning mathematics. Nevertheless, it should be noted that the students did not use the DMT in mathematics classrooms, instead, they used it for preparation before the lessons, as aforementioned.

Overall, as mentioned earlier, there have been very few empirical studies exploring the effect of DMTs on mathematics teaching and learning in Chinese context. In particular, the effect of DMTs on students' learning of mathematics in mathematics classroom remains to be unexplored. According to the literature as reviewed earlier, we can see that relevant research mainly focused on the following aspects: students' academic achievement, students' learning processes, students' views about usefulness and easiness of DMTs for learning mathematics and dispositions towards using DMTs to explore the effect of DMTs on mathematics learning. In the current study, we hope to fill the gap by investigating Chinese junior secondary students' evaluation about using a DMT for mathematics learning in mathematics classroom in terms of the effect of using the DMT on students' mathematics achievement, the technical usability of the DMT, the usefulness of the DMT for learning mathematics, students' dispositions towards the use of the DMT in mathematics classrooms and students' dispositions towards using the DMT in learning mathematics in future.

Methods

In this section, we will introduce the participants, research tools and data collection and analysis. This study is an empirical study, relying on a DMT developed by the Asian Centre for Mathematics Education, East China Normal University based on junior secondary school mathematics textbooks published by Zhejiang Education Publishing House following Chinese *Mathematics Curriculum Standards for Compulsory Education (2011 Edition)* (in short, national curriculum standards). The DMT consists of teaching resources published by Zhejiang Education Publishing House based on mathematics textbooks with some interactive features (e.g., adding, presenting and sharing dynamic teaching resources in modularized textbooks, making notes, providing users with answers to questions, etc.).

A nearly three-week classroom teaching and learning study was conducted in a public junior secondary school in a metropolitan city in a Chinese eastern province in December 2021. A mathematics teacher and his two classes with a total of 85 students in Grade 9 participated in the study, and the mathematics lessons covered in the study included 22 new lessons covering a chapter "Similar Triangles" (11 lessons in each class) and a review lesson on "Quadratic Function". It needs to be noted that the sample was not randomly selected.

The study used a combination of classroom observation, questionnaire survey, and interview to collect research data. The questionnaire mainly consists of 24 four-point Likert scale items and five open-ended items. The Likert scale items were divided into two parts: the first is about the effect of using DMTs on students' mathematics achievement and the second is about students' attitude towards using DMT. The first part included four items designed according to the description of the overall goals in the national curriculum standards, i.e., knowledge and skills, mathematical thinking, problem solving and emotional attitude (MOE, 2012). The second part consisted of twenty items, partly adapted from Chiu (2016) and partly new covering the features of the DMT. Those items addressed four aspects: the technical usability of the DMT, the usefulness of the DMT for learning mathematics, students' dispositions towards the use of the DMT in mathematics classrooms and towards using the DMT in learning mathematics in future. The open-ended questions were intended to further know the students' views of using the DMT. The Cronbach's alpha coefficients in the first part and the four

aspects in the second part were calculated, which were 0.90, 0.66, 0.89, 0.80 and 0.84. The semi-structured interview questions for students were also designed to further understand students' views of using the DMT in learning mathematics adapted from Fan et al. (2008).

The questionnaire was administered to 85 students in the last two lessons, and returned by 84 students. The interviews with students were conducted in the second and third teaching week, with six students participating in the interview each time. The means (Ms) and standard deviations (SDs) of Likert-scale items in the questionnaire were calculated, and the answers to open-ended questions in the questionnaire and interview data were analysed according to the five aspects in the Likert-scale items mentioned above and student's views about the improvement of the DMT. The lessons were observed to triangulate the other two types of data collected.

Results

In this section, we will report the results about the effect of the DMT on students' mathematics achievement first, then we will report the results in the following aspects: the technical usability of the DMT, the usefulness of the DMT for learning mathematics, students' dispositions towards the use of the DMT and students' dispositions towards using the DMT for learning mathematics in future, and finally, we will introduce students' views about the improvement of the DMT.

As shown in Table 1, most of the students agreed that the DMT was very helpful for their mathematics achievement. In particular, students believed that the use of the DMT in classroom teaching was most helpful to cultivate their interest in mathematics learning, which was verified by students' answers during the interview. Here come translated transcripts from two students.

- Student 1: (It's) playful and (I) can learn things, which I can't experience as usual.
 Student 2: It makes me more interested in it (than using printed textbooks) firstly, so I am more interested in (mathematics) classrooms and then rarely wanders when taking mathematics classrooms.

Table 1: Results on the effect of the DMT on their mathematics achievement

| Item (n=84) | <i>M</i> | <i>SD</i> |
|--|----------|-----------|
| How helpful is the DMT for you to cultivate your interest in mathematics learning? | 3.81 | 0.50 |
| How helpful is the DMT for you to cultivate your mathematical thinking ability? | 3.63 | 0.66 |
| How helpful is the DMT for you to cultivate your problem-solving ability? | 3.63 | 0.64 |
| How helpful is the DMT for you to learn mathematics knowledge and skills? | 3.62 | 0.64 |

Notes: 4-point Likert scale is from 1=no helpful to 4=very helpful.

During the interview, 50% of the students pointed out that the novelty of using the DMT or the new form had increased their learning interest for the mathematics classroom, and some students gave examples of using GeoGebra files to explore and find mathematics definitions or theorems. In addition, some students also pointed out that compared with the previous classes, when using the DMT, they needed to concentrate on listening to the teacher's lectures, and some students also pointed out that using the DMT in the classroom can increase their engagement in classroom.

In terms of the technical usability of the DMT, the results indicate that most students thought the DMT was easy to operate and could be used confidently, as shown in Table 2. This was also confirmed during the interview. Here comes a transcript from a student.

Student 3: (I) can confidently handle it, (and) classmates like it very much.

Table 2: Results on the technical usability of the DMT

| Item | <i>M</i> | <i>SD</i> |
|--|----------|-----------|
| For me, I can quickly learn to operate this digital textbook. (n=84) | 3.86 | 0.35 |
| The operation of this digital textbook is simple and easy to understand. (n=83) | 3.76 | 0.43 |
| I think I can easily use this digital textbook to learn the math content I want to learn. (n=83) | 3.69 | 0.68 |
| It takes a lot of energy to interact with this digital textbook. (n=84) | 1.30 | 0.82 |
| I think the interactive function of this digital textbook is very rigid. (n=83) | 1.30 | 0.87 |
| Operating this digital textbook is often frustrating. (n=84) | 1.02 | 0.73 |

Notes: 4-point Likert scale is from 1=strongly disagree to 4=strongly agree.

Regarding the usefulness of the DMT for learning mathematics, Table 3 showed that students agreed with the effect of DMTs on their mathematics learning was positive. They felt most satisfied with the help of dynamic geometry software files for their learning of mathematics, which was consistent with the findings from the open-ended question “how helpful were the complimentary resources for you to learn mathematics?” to which most students answered GeoGebra files were helpful for their leaning of mathematics and gave examples to show the advantages of the GeoGebra files, for example, it aroused students’ interest and made the process of changing geometric shapes visual.

Table 3: Results on the usefulness of the DMT for learning mathematics

| Item | <i>M</i> | <i>SD</i> |
|--|----------|-----------|
| The dynamic geometry software files in the DMT are very helpful for me to learn mathematics. (n=84) | 3.83 | 0.38 |
| In the DMT, curriculum resources provided by teachers are very helpful to learn mathematics. (n=83) | 3.75 | 0.46 |
| I think that I can apply math knowledge and skills taught by this digital textbook in the future. (n=83) | 3.71 | 0.46 |
| The DMT presents information in a format that makes it easy for me to learn mathematics. (n=83) | 3.66 | 0.48 |
| The way the teacher controls the display of the answers to the questions provided by the DMT is very helpful for me to learn mathematics. (n=80) | 3.64 | 0.48 |
| The DMT shows/hides answers to worked examples, which is very helpful to learn mathematics. (n=83) | 3.63 | 0.48 |
| Comparing with traditional teaching and learning, using the DMT to learn mathematics is more effective. (n=83) | 3.61 | 0.49 |
| When I use the DMT, I think I can control it, rather than it control me. (n=84) | 3.61 | 0.62 |
| I think I can learn more quickly with this digital textbook than with printed textbooks. (n=84) | 3.49 | 0.70 |

Notes: 4-point Likert scale is from 1=strongly disagree to 4=strongly agree.

When it turns to students’ dispositions towards the use of the DMT to learn mathematics, as shown in Table 4, students put “it is interesting to use this digital textbook to learn mathematics” in the first place. In the interview, some students indicated that the DMT was a novel format of mathematics textbooks so it could increase their interest in learning mathematics, some students agreed exploring in the GeoGebra files could help them develop their mathematics concept and thinking from many aspects. In contrast, students had a low degree of agreeing that the DMT was better than printed mathematics textbooks and that using the DMT is the most preferred learning method.

About students’ dispositions toward using the DMT to learn mathematics in future, Table 4 showed that most students would like to continue to use the digital textbook. In fact, most students answered in the open-end question that the DMT was more convenient, environmentally friendly, novel in

format and helpful to increase students' learning interest. Nevertheless, some of students also expressed their concerns about issues related to eyesight, self-regulation and Internet connection.

Table 4: Results on students' dispositions towards the use of the DMT and using it in future

| Item | <i>M</i> | <i>SD</i> |
|---|----------|-----------|
| Dimension 1: students' dispositions towards the use of the DMT to learn mathematics | | |
| It is interesting to use this digital textbook to learn mathematics. (n=83) | 3.75 | 0.44 |
| Compared with traditional textbooks, I prefer to use digital textbooks to learn mathematics. (n=83) | 3.52 | 0.67 |
| Using this digital textbook is one of my favourite ways to learn mathematics. (n=83) | 3.52 | 0.74 |
| Dimension 2: students' dispositions towards using the DMT to learn mathematics in future | | |
| If I have the opportunity, I would like to use this digital textbook more. (n=84) | 3.65 | 0.61 |
| I am willing to spend more time reading this digital textbook. (n=84) | 3.48 | 0.81 |

Notes: 4-point Likert scale is from 1=strongly disagree to 4=strongly agree.

With regard to the improvement of the DMT, students put forward a number of suggestions from the processes of using the DMT and previous experience of using other software when they answered the open-ended questions and were interviewed, which can be summarized into the following aspects: (1) increasing the interaction between students and the DMT, such as marking on the web, taking photos of answers and uploading them, etc.; (2) increasing the interaction between students and teachers through the DMT, for example, teachers can assign questions to students online, and students can submit their answers to teachers and share them with other students; (3) enlarging graphics; (4) blocking other irrelevant web pages; (5) making further improvement in the designing of problems, e.g., dividing the questions according to the difficulty, and adding more explanations about the processes of analysis for the problems.

Concluding remarks

This study explored how Chinese students evaluated their learning of mathematics with a DMT. The results revealed that students generally had a positive attitude towards using the DMT to learn mathematics in classroom. Moreover, the results were in a sense consistent with results from relevant studies conducted earlier in other areas including other mathematics domains, digital textbooks and subjects (e.g., Guo, 2014; Chiu, 2016; Reinhold et al., 2020).

With regard to the extent to which the DMT helped improve students' mathematics learning achievement, most students believed that the use of the DMT was very helpful in learning mathematical knowledge and skills, cultivating mathematical thinking ability, problem-solving ability and, especially, in increasing students' mathematical learning interest. The main reason was that the DMT provided opportunities for using new learning method and mathematical exploration in the classroom to enhance students' interest and improve their engagement in mathematical learning.

About the technical usability of the DMT, students generally believed that the DMT was easy to operate, but they hoped to add more real-time interactive functions for teachers and students in the DMT. As for the usefulness of the DMT for learning mathematics, students generally believe that the DMT was useful for mathematics learning. In addition, regarding students' dispositions towards the use of the DMT, students agreed most that the use of the DMT could increase their interest in

mathematics learning. Moreover, the majority of the students also supported the continuation to use the DMT for mathematics classroom teaching in future.

At the same time, the students also expressed concerns on the use of DMTs in their learning of mathematics, such as long-term use might affect their eyesight and distract learners' attention from learning. They merit serious attention from researchers, developers and teachers in relation to the research, development and use of DMTs in the future.

To end this paper, we should point out there are limitations in the study. First, restricted by the internet network and equipment conditions, students only used the DMT in the observed classrooms. Further research in using DMTs in more different learning settings is needed. In addition, the participants in the study were from a convenient sample, and there was only one teacher. Whether other students from other schools or educational settings would also have the same evaluation of using the DMT merits further study. Finally, the topic of mathematics contents taught in observed lessons only included new lessons in the chapter "similar triangle" and a review lesson of "quadratic function", and moreover, the lessons observed used many GeoGebra applications as additional instructional resources, which was closely related to the selected topics in the DMT. In that sense, how students would evaluate using DMTs in learning other mathematics topics also remains to be further explored.

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