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The Use of Open Educational Resources during the COVID-19 Pandemic: A Qualitative Study of Primary School Mathematics Teachers in Hong Kong

Chung-Kwan Lo [1,*], Ahmed Tlili [2] and Xiaowei Huang [1]

[1] Department of Mathematics and Information Technology, The Education University of Hong Kong, Hong Kong 999077, China
[2] Smart Learning Institute, Beijing Normal University, Beijing 100875, China
* Correspondence: chungkwanlo@eduhk.hk

Abstract: During the COVID-19 pandemic, teaching and learning activities had to be conducted fully online. To sustain quality education, teachers could use open educational resources (OERs) available in the public domain to make online mathematics teaching more effective and interactive. However, we currently know little about the use of OERs in primary school settings. Therefore, this study seeks to understand their school policies and guidelines on and teachers' experience of using OERs during the pandemic. Our overarching goal is to provide recommendations on the future development and use of OERs in the context of primary school mathematics education. We employed a qualitative approach and interviewed 13 mathematics teachers from different primary schools. Our findings suggest that teachers tended to rely on OERs more during the pandemic than before. They used OERs to introduce mathematics and to facilitate class interactions in online lessons. However, not all schools had policies and guidelines on the use of OERs in place. Some teachers also encountered challenges when using OERs, such as finding that the resources were unsuitable for school contexts and lower primary school students. Based on the findings, we discuss some possible strategies for the improvement, such as ensuring the suitability of OERs, through developer–teacher collaborations.

Keywords: open educational resources; online learning; mathematics education; primary education

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1. Introduction

The outbreak of the COVID-19 pandemic affected campus operations worldwide. To reduce social contact and minimize the risk of the pandemic spreading, teaching and learning shifted from the face-to-face mode to online and distance modes [1–5]. However, sustaining quality education in a fully online environment was challenging. For example, Roy et al. [6] noted that the non-availability of educational resources (e.g., books) at home was one of the barriers hindering students from keeping up with their learning. Huang et al. [7] therefore encouraged the use of open educational resources (OERs) to overcome the challenge.

In 2019, the United Nations Educational, Scientific and Cultural Organization (UNESCO) recommended the development and use of OERs—teaching and learning materials in any format and medium that reside in the public domain or are under copyright, that have been released under an open license, that permit no-cost access, re-use, re-purpose, adaptation and redistribution by others [8,9]. In mathematics education, OERs range from textbooks, lecture notes, videos, assignments and tests, to technological tools and software packages [10]. With limited or no restrictions, OERs can ensure an equitable access to quality education and thus facilitate the achievement of sustainable development goal 4 (SDG 4), especially during the COVID-19 pandemic [7]. In this context, how do teachers use OERs in real K-12 school settings? Most studies on OERs have been conducted in

higher education (see [11] for a review) and have seldom examined the teaching of mathematics. Therefore, there is little in the literature about how teachers use OERs for teaching mathematics in schools.

This study focuses on the use of OERs in primary school mathematics teaching in Hong Kong, during the COVID-19 pandemic. Specifically, it aims to understand the school policies and guidelines, as well as the teachers' experiences and practices when using OERs, to sustain students' home-based learning. Our research findings are particularly relevant to the status quo in Hong Kong, as the government has recently allocated HKD 500 million (about USD 63.7 million) to support the development of ancillary facilities for the implementation of e-learning in K-12 schools [12]. Hence, this study is timely and possesses the originality needed to provide the recommendations for the development and use of OERs in the context of primary school mathematics education. The following research questions (RQ1 to RQ3) are posed to guide the present study.

- RQ1: What are the school policies or guidelines on the use of OERs in Hong Kong primary schools?
- RQ2: What types of OERs did mathematics teachers use during the COVID-19 pandemic?
- RQ3: What are the challenges concerning the use of OERs in teaching?

2. Conceptual Background

The conceptual background of this study was developed by setting out the major benefits of and challenges to the use of OERs. We then provide an overview of UNESCO's proposed recommendations for an OER policy.

2.1. Benefits of Using OERs

Based on a review of the literature, three major benefits of using OERs can be identified. First, OERs supported teachers in helping to sustain students' home-based learning during the COVID-19 pandemic. For example, Mosquera Feijóo et al. [2] used OERs in their engineering course in response to the closure of classrooms during the first semester of 2020. Their resources included a collection of e-textbooks, pre-recorded videos and short questions, which all played a core role in supporting the students' independent study at home. Their survey results indicated that more than 70% of their students were satisfied with the use of OERs. In their biomedical research course, Vladis and Coleman [13] introduced Python to their students, using a HarvardX online course which included high-quality lecture videos and problem sets. They concluded that the use of these OERs enabled a smooth transition to online teaching that required little content and resources development.

Second, the availability of OERs can support students' self-directed learning. In a study by Bonk and Lee [14], some students appreciated the freedom to learn using OERs. Based on their interest, professional growth needs, and goals for self-improvement, students could choose the relevant OERs to construct their own learning pathways. In the words of one student, "Knowing that I did not need to ask an actual person for help was life changing" [14] (p. 44). During the COVID-19 pandemic, the science teachers in Gerard et al. [15] used OERs to promote students' self-directed learning. Based on their WISE (web-based inquiry science environment) OERs, the teachers adapted the relevant unit content and modified the instructions to increase students' agency in exploration. The majority of the teachers reported that their students took ownership of the knowledge construction.

Finally, UNESCO [8,9] noted that the use of OERs can ensure more equitable access to education and reduce barriers to learning opportunities. Traditionally, most educational materials are developed by commercial publishers. As a result, the high cost of textbooks may limit the proportion of students who can achieve their academic goals [16]. In a survey by Jhangiani and Jhangiani [17], one-third of student respondents attributed their poor performance in a course to high textbook costs. They found that these respondents were more likely to self-identify as members of an economically disadvantaged group. To promote equity and to ensure the quality of teaching and learning during the pandemic,

Rodrigo et al. [3] produced OERs in the form of video lectures and made the resources available online at no cost. Their OERs benefited students regardless of their socioeconomic status and reached over 350,000 viewers across 37 countries in around one year and a half.

2.2. Challenges to the Use of OERs

Despite the benefits of using OERs, Tlili et al. [11] identified multiple challenges related to OERs through a review of the literature. These were classified into five major categories, including learning-related challenges (e.g., content quality), funding-related challenges (e.g., allocated budget), legal-related challenges (e.g., copyright), individual-related challenges (e.g., lack of awareness/skills), and environmental-related challenges (e.g., technological infrastructure). In this section, we focus on three of these challenges related to the use of OERs in teaching practices.

First, finding suitable OERs can be an obstacle to their use. In a study by Christoforidou and Georgiadou [18], both teachers and their students complained that finding OERs was a difficult and time-consuming process. In Hong Kong, Wang et al. [19] surveyed 20 teachers in their technical vocational education training programs. As Christoforidou and Georgiadou [18], they found that the majority of teachers encountered difficulties in finding relevant and appropriate OERs for their students. These findings might indicate the need to create more quality OERs that are easy to find. Some teachers reported that locating video lectures on YouTube was easier than searching on their university OERs websites [3], suggesting that methods of retrieving OERs from repositories need to improve.

Second, the quality of OER content is another major concern. Wiley et al. [20] noted that they could easily find nearly 3 million biology OERs using Google. However, these were of questionable quality and produced by authors of questionable reliability [7]. As one student commented, "Don't be too trusting of the documentation. It's written by humans and has the potential for error" [14] (p. 48). However, as educators, how can we provide our students with OERs without knowing their quality? Huang et al. [7] therefore suggested using the OERs available in well-known national and international repositories, such as the Massachusetts Institute of Technology (MIT).

Third, personalizing OERs for students can be burdensome for teachers. Although teachers may succeed in finding relevant, high-quality OERs, such resources probably need to be adapted before they can be used in the local context [20]. For example, some teachers modified the instructions of their WISE OERs to meet the needs of their students [15]. Several teachers also created videos to guide their students in using these videos. In Hong Kong, Wang et al. [19] found that the language issue was a major challenge to the adoption of OERs. In most popular OER repositories and educational sites (e.g., MIT, YouTube and Khan Academy), many OERs are produced in English and are for university students. Adopting these non-local OERs is not always feasible in Hong Kong because the English language proficiency of some students is unsatisfactory [19]. Considerable effort is thus required to translate these resources for students in Hong Kong.

2.3. UNESCO's Recommendations on an OER Policy

To facilitate the adoption of OERs in teaching and learning, UNESCO has encouraged governments and educational institutions around the world to offer policy support, advocacy, and capacity building [9]. The organization has formulated eight building blocks for an OER policy (Table 1). These building blocks constitute a masterplan for OERs, as they basically cover every aspect of OERs, including the development (building block 3), quality (building block 4), teachers' awareness of using OERs (building block 5), the use of OERs in schools (building block 2), and research into OERs (building block 7), among others.

Table 1. Building blocks for the OER policy and their corresponding objectives [9] (pp. 56–75).

	Building Blocks	Objectives
1.	Adopting an open licensing framework	To enable and simplify the use of open licensing for learning materials.
2.	Integrating OERs into the curriculum	To encourage the use of OERs as a guiding principle in curricula To make available a wide range of generic OERs that can be adapted by any institution.
3.	Ensuring the development, storage and accessibility of OERs	To encourage the development of OERs on all levels. To make OERs easily discoverable, accessible and adaptable through digital storage and editing platforms.
4.	Aligning quality assurance procedures	To ensure appropriate quality assurance procedures, which encourage the continual improvement of learning materials.
5.	Supporting capacity building and awareness raising	To enable users to fully harness the qualities of OERs for teaching and learning. To ensure that all stakeholders are knowledgeable about the qualities of OERs and how they can be used.
6.	Encouraging sustainable business models and launching funding strategies	To ensure that the cycle of the OER production and reuse is sustainable over time for those actors involved in their production and reuse.
7.	Promoting evidence-based research on the impact of OERs	To ensure that continual monitoring of the policy's progress is carried out. To ensure that adequate levels of research on the impact of OER use exist and can be fed back into the OER policy design
8.	Having a governance mechanism for the OER policy	To align the OER policy with existing policies, strategies or relevant regulatory frameworks. To coordinate the adoption of new regulatory frameworks. To prioritize and allocate budgets to various projects for OERs. To develop standards and quality measures for OERs. To monitor the progress of OERs and make course corrections.

Formulating an OEROER policy can help remedy the aforementioned challenges to their use. In view of the difficulty of finding OERs, UNESCO [9] has called for governments to ensure their development, storage and accessibility (building block 3), for example, by providing resources for teachers and OER producers that will incentivize the development and sharing of OERs. OER repositories can also adopt metadata standards to facilitate discoverability. To tackle concerns about content quality, UNESCO [9] suggests aligning both standard-based and user-assessed quality assurance procedures for OERs (building block 4). For example, Lo et al. [21] adopted the standard of Bugler et al. [22] (e.g., accuracy and visual appeal) to guide the development of flipped learning OERs for mathematics teachers. They invited frontline teachers (i.e., the OER users) to evaluate and provide feedback on

the OERs across three iterations of development, which helped the developers improve their OERs accordingly. To overcome the challenge to personalizing OERs, UNESCO [9] emphasizes the importance of making available a wide range of generic OERs that can be adapted by any institution (building block 2). In Hong Kong, OERs in both Chinese and English are necessary because there are both CMI (Chinese as the medium of instruction) and EMI (English as the medium of instruction) schools.

3. Methods

To help readers understand the research findings of this study, we first provide a brief overview of the research context and the relevant e-learning policies in Hong Kong. We then give a description of the teacher participants, followed by the data collection and analysis.

3.1. Research Context and the Relevant e-Learning Policies in Hong Kong

Hong Kong is viewed as a developed region, ranking second globally in the IMD's World Digital Competitiveness Ranking 2021 [23]. Since 1998, the government has invested a total of HKD 14 billion (about USD 1.78 billion) to launch a series of four strategies on information technology in education (ITE1 to ITE4). Taking ITE4 in 2015 [24] as an example, the government aimed to realize the potential for IT to enhance interactive learning and teaching experiences. Accordingly, multiple actions were proposed, such as enriching and updating the free resources on Hong Kong Education City (HKEdCity; an official OER repository for K-12 teachers and students) through partnerships between schools and other organizations.

In recent years, schools' operations in Hong Kong have been affected by the COVID-19 pandemic. Face-to-face classes were suspended from time to time between 2020 and 2022. The Education Bureau announced that face-to-face classes in most schools would be resumed in the 2022/23 school year, but on a half-day basis [25]. Therefore, there is still a considerable need to sustain students' home-based learning using e-resources. However, whether the existing OERs (created before the pandemic) can meet the current demand is questionable.

In the same vein, the Hong Kong government has allocated HKD 500 million (about USD 63.7 million) to set up "The e-Learning Ancillary Facilities Programme" [26]. Schools, tertiary institutions and school sponsoring bodies can apply for funding under this three-year program to develop ancillary facilities for the implementation of e-learning in kindergartens, primary, secondary and special schools. Their deliverables are expected to be launched for trial use in the 2024/25 school year [26]. Efforts are now required to ensure the quality and suitability of the resources as well as the formation of policies on using them in schools. However, there is little information about how teachers in Hong Kong perceive and use OERs, indicating that more research is needed in this regard. Therefore, this study aims to cover this gap and provides more insight into the use of OERs in the context of Hong Kong.

3.2. Participants

Thirteen mathematics teachers (Teachers A to M) from 13 different primary schools in Hong Kong were recruited through prior connections. According to Ando et al. [27], this sample size is sufficient to provide all of the themes with most of the codes necessary for a thematic analysis. Their teaching experience ranged from five to 30 years (M = 12.8; SD = 7.2). All of them taught both lower (Grades 1 to 3) and upper (Grades 4 to 6) primary school students during the COVID-19 pandemic.

3.3. Data Collection and Analysis

We collected the data through semi-structured interviews. The third author conducted the interviews in Chinese via Zoom (a video conferencing platform) during August and early September 2022. The interview topic guide was developed using the OER Hub

Researcher Pack, which was created by a group of OER experts [28]. Based on the aforementioned research questions (see the Section 1), the relevant interview questions, such as the following, were adapted from them:

1. What are the policies or guidelines on using OERs in your school or subject panel? Probe for teachers' views and suggestions.
2. What OERs (if any) did you use during the COVID-19 pandemic? Please rate, from 5 (fully relied on) to 1 (not relied on), the extent to which you relied on the OERs in your teaching (a) during the pandemic and (b) before the pandemic? Probe for teachers' explanations of their ratings.
3. What are the practical challenges to the use of OERs in your teaching? Ask teachers to elaborate.

The interview data were coded and categorized using the qualitative data analysis procedures proposed by Creswell [29]. To ensure that the research progressed, we began with the transcript of the first interview (Teacher A) and assigned codes to each piece of the data. These codes were the wordings of the research participant and concepts from the literature. Following the completion of the coding of the first transcript, all of the codes assigned were reviewed and grouped. The preliminary list of codes was used to analyze the rest of the interview data (Teachers B to M). This allowed us to identify any emerging codes that enriched the list. Finally, similar codes were organized into sub-themes. Some of the interview data (in Chinese) were translated into English for reporting purposes.

The numerical data solicited in the second interview question (Q2), as listed above, were analyzed using the Wilcoxon signed-rank test, which is a non-parametric test used to compare two related conditions (i.e., during the pandemic vs. before the pandemic) [30]. Instead of answering with an integral value, three teachers answered Q2b as a range (i.e., "2 to 3" for Teachers C and H; "3 to 4" for Teacher A). In these cases, we took the mid-value of the range (i.e., 2.5 for "2 to 3" and 3.5 for "3 to 4").

To enhance the consistency of our classification, we used several quotes as examples that clearly illustrated each sub-theme. Multiple reviews of the data were carried out to ensure that we understood each sub-theme. In the event of disagreement, the authors re-examined the interview data in question together to come to a consensus.

4. Findings

4.1. RQ1: What Are School Policies or Guidelines on the Use of OERs in Hong Kong Primary Schools?

We first examined whether there were any policies or guidelines on using OERs in the schools of our teacher participants. As Table 2 shows, more than half reported that there were no such policies or guidelines. Among them, five teachers said that they were encouraged to use OERs without any specific requirements (Teachers B, G, K, L and M). Three other teachers mentioned that there were no policies or guidelines to follow (Teachers A, D and J). As for the five teachers who shared their school policies or guidelines, we found that their focuses were diverse, covering five main aspects, namely: (1) the sources of OERs used (e.g., "the platform of HKEdCity," Teacher F), (2) the topics covered when using OERs (e.g., "teaching 3D figures in Grade 5," Teacher H), (3) the frequency of use (e.g., "once every semester," Teacher C), (4) classroom management (e.g., "controlling the times when students can use their devices," Teacher E), and (5) instructional approaches (e.g., "blended learning," Teacher I).

Table 2. Teachers' responses on the policies and guidelines on using OERs in their schools.

Response	Count (%)	Representative Quotes
Yes	5 (38.5%)	"Mathematics teachers are required to assign exercises for students to do through the platform of HKEdCity regularly" (Teacher F). "My school wants us to use blended learning. That is, to use some e-learning platforms for students' pre-class, in-class and post-class learning" (Teacher I).
No (but teachers were encouraged to use OERs)	5 (38.5%)	"Our panel head encourages us to use [OERs]. But so far, there are no guidelines that govern how we use the resources" (Teacher G). "We encourage teachers to use [OERs], but we do not require them to use the resources in every topic" (Teacher K).
No	3 (23.1%)	"We casually found [some resources] for ourselves or shared with others. There are no guidelines to follow" (Teacher A). "No, we are quite flexible. Teachers can decide how to deliver their lessons" (Teacher D).

We then asked for teachers' suggestions regarding policies or guidelines on using OERs in teaching mathematics. Their ideas were categorized into two main themes. First, teachers should consider the suitability when using OERs for any given topic in mathematics (Teachers C, K, and L). For example, Teacher C noted that "For some algebraic topics, we emphasize students' paper-based calculations. So, we don't want to use those e-platforms." In contrast, for some topics about shape and space, Teachers C, K and L noted that the use of appropriate open e-tools could help visualize abstract concepts (e.g., the nets of cubes) for their students. Second, the use of OERs should not increase teachers' workloads (Teachers B and F). As adapting OER demands teacher effort, Teacher B argued that "Teachers are busy . . . Hoping [the requirements of using OERs] do not cause trouble for my colleagues."

4.2. RQ2: What Types of OERs Did Mathematics Teachers Use during the COVID-19 Pandemic?

The OERs that the teacher participants used can be divided into two categories. The first category is the OERs used to introduce mathematics knowledge and concepts, which includes the free online resources developed by tertiary institutions (n = 13), GeoGebra [31] resources (n = 5), Educational Television (ETV) produced by the government (n = 4), resources on the platform of HKEdCity (n = 2), and YouTube (n = 2). For example, Teachers A and C shared their experience of using GeoGebra resources, whereas Teacher J commented on using ETV and YouTube videos:

- "You simply type the keywords for what you want on the GeoGebra website . . . or google them with 'ggb' [the filename extension of GeoGebra files]. There are a lot of resources" (Teacher A).
- "We used a lot of GeoGebra [resources] to teach students the nets of cubes. These allowed them to explore different figures and discover the rules behind them" (Teacher C).
- "Students might find it difficult to understand [mathematics] in a face-to-screen environment. Because there are sounds and images in the ETV and YouTube videos, it is easier for them to acquire that knowledge" (Teacher J).

The second category concerns the OERs in the form of online applications which could facilitate class interactions in online lessons. Table 3 summarizes the applications, as mentioned by the teacher participants more than once, such as Kahoot! [32] and Nearpod [32]. Other applications, such as Classkick, Pear Deck, Seesaw and Wordwall, appeared once.

Teachers used these for different purposes. For example, Teacher L said that "For revision, I would use Kahoot! [quizzes] to review learning with my students. To guide the progress of my teaching, I used Nearpod to introduce students to mathematics knowledge and monitor their classwork."

Table 3. Main applications used by the teacher participants.

Response	Count [1]	Description
Kahoot! [32]	6	A game-based online learning platform that allows teachers to create quiz-based games for their students
Nearpod [33]	3	An online platform that provides teachers with real-time insights into students' understanding through interactive lessons, interactive videos, gamified learning, formative assessment and activities
Padlet [34]	3	An online collaborative tool that students can use to post and share ideas with others
Quizizz [35]	3	An online platform that allows teachers to create quizzes for their students
Edpuzzle [36]	2	An online platform that allows teachers to create interactive video lessons for their students

[1] Totals are greater than 13 because some teacher participants used multiple applications.

We also asked our teacher participants to rate the extent to which they relied on OERs in their teaching, during the COVID-19 pandemic and before the pandemic, respectively. The results of the Wilcoxon signed-rank test indicated that teacher ratings were significantly higher during the pandemic ($Mdn = 3.0$) than before the pandemic ($Mdn = 2.5$), $z = -2.67$, $p < 0.01$. In other words, our participants tended to rely more on OERs during the pandemic. Table 4 shows their diverse usages of OERs. For example, Teacher J (rated 2) only used the resources at the start of a learning unit, whereas Teacher C (rated 2) only used them when summarizing a chapter.

Table 4. The extent to which the teacher participants relied on OERs during the pandemic.

Rating	Count (%)	Representative Quotes
5 (fully relied on)	1 (7.7%)	"In face-to-face lessons, we can use gestures or instructions to direct students' attention. But it is difficult in online lessons. So, we have to use online applications to gather student responses" (Teacher E).
4	4 (30.8%)	"If we just go through e-textbooks with our students, it is quite boring. So, I would rather play some short videos, such as ETV" (Teacher B). "I relied greatly on an online drawing board . . . Without these kinds of resources, my students cannot stay focused, especially in hour-long double lessons" (Teacher G).

Table 4. *Cont.*

Rating	Count (%)	Representative Quotes
3	5 (38.5%)	"The resources do not seem to be rich enough and I would select the relevant ones [to use]. So, I do not rely on them very much" (Teacher D). "I use the resources for revision . . . When teaching mathematics concepts, I use my own PowerPoint [slides] or demonstrations" (Teacher I).
2	3 (23.1%)	"Usually, I use the resources at the start of a learning unit. I seldom use them at a later stage" (Teacher J). "I usually use the resources to summarize a chapter. In other words, I seldom use them during mathematics lessons "(Teacher C).
1 (not relied on)	0 (0.0%)	N.A.

It is worth noting that apart from OERs, about half of the teacher participants (n = 7) said that during the pandemic they mainly used the e-resources provided by their textbook publishers. These resources included instructional videos, applications and online exercises. However, access to them was restricted to textbook users only.

4.3. RQ3: What Are the Challenges to the Use of OERs in Teaching?

As identified in the interview data, there were three major challenges to the use of OERs (Table 5). These were (1) incomplete resources (Teachers D, G and K), (2) being unsuitable for school contexts (Teachers D, G and J), and (3) being unsuitable for lower primary school students (Teachers A, B and C). Taking unsuitability for lower primary school students as an example, Teacher B said that, "When we use applications like Kahoot! during lessons, it is difficult for Grade 1 students, because they have to log in or turn on the camera to scan QR codes. These are complicated for them." As she recalled, "My Grade 1 students always complain that 'I cannot log in' or 'I do not have the app'." In her opinion, "Unless their parents can assist them, their uses of those applications won't be effective".

As well as the major challenges above, three other issues with the use of OERs are worth noting:

- Difficulties in using the resources. "Some students encountered difficulties when using the applications . . . The interface design is not always comprehensible" (Teacher A).
- Difficulties in adapting the resources. "Sometimes, I would download the resources and incorporate some school-based materials. For example, I would add a button to show a proof, which my students need . . . However, this [editing the resource] cannot be done on some platforms" (Teacher G).
- Language issues. "The biggest issue with Nearpod is that their questions are mostly written in English . . . For Grade 1 students, we have to translate [the questions] to help them" (Teacher B). Nevertheless, the teacher noted that "For Kahoot! and Quizizz, many teachers have written and uploaded their questions in Chinese . . . I can use them with my students, which is very convenient" (Teacher B).

Table 5. Major challenges to the use of OERs.

Challenges	Count [1]	Representative Quotes
Incomplete resources	3	"[Regarding the resources developed by a tertiary institution] Honestly, it seems that the materials in each Grade are not rich enough" (Teacher D). "There are some topics missing on the platform. So, we tend not to use it to conduct our lessons" (Teacher K).
Being unsuitable for school contexts	3	"For example, they teach the multiplication table like [lyrics]. But the use of resources is limited by our school-based curriculum. We teach this in another way . . . Some [resources] are not suitable for us" (Teacher D). "Our experienced teachers have their own ways of demonstrating [mathematics knowledge] . . . So, they would not use many online resources" (Teacher J).
Being unsuitable for lower primary school students	3	"I am not sure whether they can explore and learn [using the resources]. So, we seldom use them in lower primary" (Teacher C). "When we use applications like Kahoot! during lessons, it is difficult for Grade 1 students because they have to log in or turn on the camera to scan QR codes. These are complicated for them" (Teacher B).

[1] Totals are less than 13 because some of the teacher participants did not share any challenges to the use of OERs.

5. Discussion

The COVID-19 pandemic disrupted face-to-face teaching and learning worldwide. At the time of writing, face-to-face classes in Hong Kong continue to be affected and have yet to be fully resumed. Thus, students are still required to learn at home online. The findings suggest that teachers tended to rely on OERs more during the pandemic than before. This could be because OERs are very efficient in reducing the time needed for preparing teaching materials, as well as in reducing the online isolation among students [7]. The teachers used them to introduce mathematics knowledge and concepts (e.g., GeoGebra resources and ETV) and to facilitate class interactions during online lessons (e.g., Kahoot! and Nearpod). However, they generally placed a greater emphasis on using OERs to make the process of teaching mathematics more interactive. Compared with Hilton III et al. [37], the OERs were used for different purposes, such as reducing the cost of mathematics textbooks. As our teachers explained, their textbook publishers provided some teaching and learning resources for them to use during remote teaching.

Nevertheless, we found that some schools did not have policies or guidelines on using OERs, and that some teachers encountered challenges in using them. These factors might have impaired the efficacy of students' home-based learning during the pandemic. Based on the research findings and the literature, we make a contribution to the field by discussing three possible strategies to enhance OER adoption. We then acknowledge the limitations of the present study and make recommendations for future research.

5.1. Ensuring the Suitability of OERs through Developer–Teacher Collaborations

The findings indicate that some OERs did not match the requirements of school curricula or the teaching approaches of some teachers. According to UNESCO [9], it is important to align quality assurance procedures and ensure the continual improvement of OERs (building block 4; Table 1). We therefore recommend that OER developers involve more frontline teachers from different schools in the development process. Through these

collaborations, OER developers can understand the needs of schools and teachers and thus create more suitable resources for them. In Lo et al. [21], for example, frontline teachers were invited to provide feedback on the design of the OERs. Accordingly, developers were able to make improvements and enhance the suitability of their OERs for teaching practices. In addition to the OER development stage, Sapire and Reed [38] involved teachers from various sites in the pilot and revision stages of their OERs. Based on teachers' input and the findings of trial uses, they were able to create appropriate OERs for various students.

Additionally, specific attention should be paid to the development of OERs for lower primary school students. As noted by Wang et al. [19], students might have language issues when using OERs written in English. More resources in Chinese should be developed for the local context. Furthermore, we found that some lower primary school students had difficulties (e.g., logging on to a platform) in using OERs. It is therefore worth the effort to design user interfaces that facilitate the use of OERs without the need for students to rely on parents.

As a sidenote, to ensure that the OERs created can be reused easily in different teaching contexts, for instance by being available in both English and Chinese translations, there needs to be more awareness of the different types of open licenses that teachers can use for their OERs (building block 1; Table 1). Some open licenses limit what a user can (re)use in any given OER.

5.2. Integrating OERs into Selected Topics in Mathematics

The findings show that not all schools had policies or guidelines on using OERs in teaching primary school mathematics, leaving teachers unable to leverage the benefits of OERs. One UNESCO's recommendation [9] is to integrate OERs into the curriculum (building block 2; Table 1), increasing teachers' awareness of OERs and their ability to use them. As a first step, school leaders should encourage the use of OERs in some selected topics in the primary mathematics curriculum. For example, several of the teacher participants stated that the use of the relevant GeoGebra resources was feasible and could facilitate teaching and learning the topics about shape and space, such as the nets of cubes. The dynamic features of the GeoGebra resources (e.g., sliders) allow students to explore mathematical objects in a fully online environment [21,39]. As Teacher A confirmed, teachers can easily find useful resources created and uploaded by other educators using the search function on the official GeoGebra website [31]. In future teacher professional development and education programs, training should be provided to facilitate the integration of OERs into the mathematics curriculum [40,41].

5.3. Building Students' Ability to Use OERs

The interview findings suggest that lower primary school students might not be familiar with operating some online applications, such as Kahoot! and Nearpod. As a result, some teachers were unable to use these applications to promote class interactions in their online lessons. UNESCO [9] recommends building students' ability to use OERs (building block 5; Table 1). Therefore, the various stakeholders (e.g., government officers, school leaders) should consider refining the focus of technology education in schools to support the adoption of OERs (building block 8; Table 1). During computer lessons, for example, teachers could introduce the skills needed to use the applications that are needed for other lessons [42]. Then, teachers from different subject disciplines should use these applications in their day-to-day teaching (e.g., using Kahoot! to conduct quiz-based games [1]; Table 3). This not only creates opportunities for students to practice what they have learned, but also builds their capacity to adjust to online learning in any possible future interruptions to school operations.

5.4. Limiations and Recommendations for Future Research

Although the above recommendations are derived from our research findings, there are several limitations to our study. First, the coding and analysis we conducted could

only be based on what the teacher participants stated. The absence of certain themes in the coding implies that these were not mentioned during the interviews. For example, our teacher participants did not mention any concerns related to open licensing (building block 1; Table 1). In future studies, researchers can explore how well teachers understand open licensing and determine whether there is a need to provide teacher training on this aspect. Second, although the sample size (n = 13) was appropriate for a qualitative study [27], our findings may not capture the whole picture of primary school mathematics education in Hong Kong. Therefore, larger-scale (e.g., territory-wide) studies should be conducted to solicit the voices of more frontline teachers. Third, this study focused on primary school mathematics teaching. The findings may thus be context-specific and cannot be over-generalized. To understand the use of OERs in other contexts, studies of different subject disciplines (e.g., English language teaching) and educational settings (e.g., secondary schools) are required.

6. Conclusions

This study focused on the use of OERs in primary school mathematics teaching during the COVID-19 pandemic in Hong Kong. We interviewed 13 teachers to understand their school policies or guidelines on and their experience of using OERs. Based on the interview findings, we propose several strategies for improvement, including ensuring the suitability of OERs through developer–teacher collaborations, integrating OERs into some selected mathematics topics, and building students' ability to use OERs. For example, school leaders should encourage the use of relevant GeoGebra resources to facilitate the teaching and learning of the topics about shape and space. Nevertheless, we acknowledge that our research findings cannot be over-generalized due to the limited sample size and population (i.e., primary school mathematics teachers). We thus recommend that further research on this topic be scaled up and conducted in other educational contexts.

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