Title	Implementation of online home-based learning and students' engagement during the COVID-19 pandemic: A case study of Singapore mathematics teachers
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Abstract	The COVID-19 pandemic has forced school closure thus shifting teaching and learning towards full home-based learning (HBL). Technology plays a key role but the considerations to design online learning environments that meaningfully engage students are complex. This exploratory, qualitative study attempted to elicit eight mathematics teachers' considerations and perspectives in designing online home-based learning lessons for the engagement of elementary and secondary students. Data were gathered through interviews. Ground-up thematic analyses were conducted. The following implications are derived —(1) student engagement in online learning context is paramount to their learning, (2) there is no one software application for all the learning activities, (3) teacher professional development is necessary to keep them up-to-date, (4) online social networking platforms may be necessary for students' discussion beyond official online lesson time, and (5) students need to be inculcated with more self-directed skills and habits for learning in online and face-to-face contexts. This study gathers evidence-informed considerations for teachers to design lessons and engage students meaningfully in a unique, online HBL environment. While this is an exploratory study, future studies can inform this area of work by including more teachers across subjects, grades, schools, and geographical contexts. Studies involving students and parents would also be meaningful.

1 REGULAR ARTICLE

2 # Implementation of Online Home-Based Learning and Students'
3 # Engagement During the COVID-19 Pandemic: A Case Study
4 # of Singapore Mathematics Teachers

5 Lee Yong Tay[1] · Shu Shing Lee[1] · Kalaivani Ramachandran[1]

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35

Introduction 38

The COVID-19 pandemic has put many societies' capacity 39
and capability in handling the situation to the test. Many 40
schools and institutions of higher learning have shifted 41
their teaching and learning activities online due to school 42
closures and lockdowns to reduce virus transmissions, 43
forcing a change from face-to-face mode of schooling to 44
online home-based learning (HBL). Instead of the sup- 45
portive role, the use of technology has become a core 46
essential for teaching and learning. There are, however, 47
considerations related to issues of using technology for 48
teaching and learning, such as accessibility of hardware 49
and software, screen time, ownership, student engagement 50
and most importantly, pedagogy. In Singapore, despite the 51
short notice and some teething technical and logistical 52
issues, evidences from newspapers (Davie, June 28, 2020; 53
Kurohi, April 14, 2020; Sin, Jun 18, 2020) have shown that 54
the nationwide implementation of online home-based 55
learning was relatively well accepted and implemented. 56

This study seeks to have evidence-informed under- 57
standings by gathering mathematics teachers' considera- 58
tions about how they designed online home-based lessons 59
and their perspectives of students' engagement during the 60
COVID-19 pandemic lockdown. Although the Singapore 61
education system has reaped the benefits of more than two 62
decades of Information and Communication Technology 63
(ICT) Masterplans since 1997 (Koh & Lee, 2008), this 64
period of online HBL presented teachers with different 65
challenges and opportunities to explore new modalities in 66
pedagogy. The experimentations and innovations that took 67

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place during this period are what we believe to be important to document for insights on how teachers designed learning experiences with technology to engage students meaningfully. This paper aims to address this research question, "what are teachers' design of online HBL experiences and how they perceive students' engagement?"

Research Gap—K-12 Student Engagement in an Online Learning Context

There has been a steady growth in the number of students enrolled in online courses in the United States and other countries, such as, Australia, Canada, and New Zealand. This number has been projected to grow further (Barbour, 2013).

Despite the steady growth and enrolment of online courses, the focus of research about student engagement in online courses has been on institutes of higher learning and not on K-12 students—Patrick and Powell (2009) reported that in a meta-analysis of 51 studies by the U.S. Department of Education in 2009, 44 studies were research on older learners. In addition, the high dropout rates for online courses in institutes of higher learning remain a challenge (Henrie et al., 2015). Borup et al. (2014) highlighted that adolescent online enrolments have increased dramatically despite reports of lower student engagement levels and there are higher student attrition rates when compared with typical face-to-face learning environments (Hawkins & Barbour, 2010; Rice, 2006). This research gap of continuous increase in online learning and high dropout rates presents an opportunity to study considerations related to student learning in an online context for K-12 students.

Student engagement is paramount for productive learning (Herrington et al., 2003). The key determinant of students' learning experiences relates to professional learning (Mourshed et al., 2010). A research opportunity would be to examine K-12 students' engagement in online home-based learning environments to inform future training and capacity building of teachers and education institutions, especially at the elementary and secondary school levels (i.e., K-12 equivalent). The study of students' engagement in online environments is important because the pandemic presents first hand professional learning opportunities (Borko, 2004) as teachers find ways to meaningfully engage students, leverage technology and teach them content beyond the face-to-face classroom.

A Theoretical Perspective to Study Student Engagement in an Online Context

A number of studies suggested the importance of taking a sociocultural perspective in looking at students' online engagement (Borup et al., 2014; Burnham & Walden, 1997; Moore, 1989). More recently, Bond and Bedenlier (2019) also proposed a sociocultural perspective of looking at student learning engagement, taking into considerations of the macro, exo, meso, and micro systems. Inevitably, student learning engagement with technology will be influenced by availability of the national network infrastructure and the accessibility to resources. The micro system, which includes the student, learning environment and technology, teacher, learning activities, peers, and family, is of particular interest and direct relevance to student learning engagement with technology. These above-mentioned factors are elaborated in the following sub-sections to include: (1) definition of student engagement; (2) student engagement in an online learning context; and (3) the different sociocultural elements that shape student online engagement.

Definition of Student Engagement

Bangert-Drowns and Pyke (2002) define student engagement as the mobilisation of cognitive, affective, and motivational strategies for interpretive transactions while (Kuh, 2003, 2009) sees engagement as the time and energy students devote to educationally sound activities. Students' engagement in a conventional K-12 classroom and school settings are well documented (Fredricks et al., 2004, 2011) as a multifaceted construct. Fredricks et al. (2004) see student engagement comprising three dimensions—behavioural, emotional and cognitive. *Behavioural engagement* includes forms of positive conduct, such as following of rules, adhering to classroom norms, involvement in learning and academic tasks, and the absence of disruptive behaviours. *Emotional engagement* refers to the students' affective reactions in the classroom, including interest, boredom, happiness, sadness, and anxiety. *Cognitive engagement* describes the investment in learning by the students which involves mental efforts and the use of learning strategies to manage learning tasks.

Student Engagement in an Online Learning Context

Teaching and learning with technology inevitably adds another layer of complexity in understanding student engagement because learning is mediated by both technological hardware and software applications. In studying students' online engagement, Dixson (2015) considers

these four factors: (a) skills (e.g., keeping up with readings, being organised, and listening and reading carefully); (b) emotion (e.g., putting effort and making lessons meaningful and relevant); (c) participation (e.g., engage in online conversations, interact with other students); and (d) performance (e.g., able to do well in tests and assessments). Martin and Bolliger (2018) further stress the importance of three types of interactions inherent in effective online courses: learner-to-learner interaction, learner-to-content interaction, and learner-to-instructor interaction. Technological hardware and software applications, student factors, and types of interactions are considerations that shape the ways teachers design and implement online learning experiences to engage students meaningfully.

The pandemic situation presents an interesting context and dynamics for studying student engagement because teachers and students had to quickly shift from learning in a face-to-face context to an online environment. Teachers had relatively little time to prepare. There are also uncertainties as to how long learning in the online environment would persist with the possibilities of moving back to the face-to-face environment again. Such a context presents an opportunity to study online student engagement, the sociocultural elements that shaped student online learning engagement and the considerations that teachers made to design online learning experiences for students.

Sociocultural Factors that Shape Student Engagement

The teacher, learning environment and technology, learning activities, peers and parents are significant sociocultural elements that shape student online learning engagement.

Teacher

Just like the typical face-to-face classroom learning, students' engagement would be enhanced when student–teacher relationships are strong. There is student engagement when students perceive the teacher to be supportive, effective, and knowledgeable (Baker, 2010; Bond & Bedenlier, 2019). Everett (2015) reviewed several studies related to student engagement in online learning environments and emphasised the importance of teachers designing purposeful interactions (teacher-student and student–student interactions) to facilitate learning. Robinson and Hullinger (2008) suggested that instructors need to purposefully incorporate opportunities for students to learn from one another to create a sense of classroom community, which could potentially enhance students' engagement. Dixson (2010) attempted to examine activities and instructional procedures that might lead to better engagement with students in online learning environment. The findings indicated that there was no particular activity that will automatically facilitate students to be more engaged in online classes. She suggested for online instructors to incorporate multiple and meaningful ways of interacting with students and to design online lessons that encourage and require students to interact among themselves. It seemed that interaction was an important element in online courses (Gray & DiLoreto, 2016; Martin & Bolliger, 2018; Martin et al., 2012). Given the short time that teachers had to switch to teaching in the online environment during the pandemic situation, teachers could be presented with different challenges that shape how teachers design for interactions that support student engagement. Thus, there is a research opportunity to study how teachers come together as a community to prepare and implement online learning to support student engagement and the kinds of professional learning that they had to go through.

Learning Environment and Technology

One of the most fundamental considerations for student engagement and learning with technology is the availability and accessibility to the technology itself (Hew & Brush, 2007; Tay et al., 2017; Turgut & Aslan, 2021). Students need to be equipped with the necessary technological hardware (e.g., computers and Internet access) and the technological know-how of operating the technological hardware and navigating the software applications for learning to occur. Given the array of software applications for learning, it would be interesting to understand how teachers choose appropriate applications and its affordances for learning. What would take precedence in teachers' considerations, the technological affordances for learning, students' readiness or using the latest technological tools? The demands on technological hardware would also be high in students' homes as learning and working have shifted to the online environment. Consequently, there could be sharing of devices for learning. For students who do not have access to technology, how would they cope with learning in an online engagement? These questions present opportunities for research to find out how teachers design the online learning experience and student engagement during this period.

Learning Activities

Several authors highlighted the importance of learner-content interaction (Martin & Bolliger, 2018; Moore, 1989). The choice of content (e.g., whether challenging and relevant) and how it is being taught or delivered (e.g., whether active and collaborative forms of learning) impacts students' learning engagement, be it online or in

face-to-face settings. Patrick and Powell (2009) reported that learning activities and instruction combining online and face-to-face elements had a larger advantage relative to purely face-to-face or purely online instruction. In addition, online learning can be enhanced by giving learners control of their interactions with technological media and prompting of learner reflection. Teachers interacting with students, parents, and colleagues are identified as one of the primary differences between online and face-to-face instruction and as one of the most important aspects of online learning (Weiner, 2003). Teachers are designers of students' learning experiences. It is useful to understand the rationalisations that teachers have in their choice of tools, instructional strategies and learning activities in the online context. How do teachers implement learning activities, as synchronous or asynchronous formats or a combination of formats?

Peers

Peers are important as they create learning communities where students can interact collaboratively to build peer-to-peer relationship, which is very important for learning engagement of students (Everett, 2015; Gray & DiLoreto, 2016; Moore, 1989; Northey et al., 2015). Peer engagement does not share parents' and teachers' responsibilities for facilitating other students' engagement but they can impact student engagement through collaboration and motivation. Moore (1989) suggested that interaction between learners may be more motivating for adolescent learners than for adults. The opportunity for research is, therefore, to investigate with the various demands and complexities of designing online learning experiences for students in this pandemic situation, how could opportunities for peer-to-peer interactions be incorporated? Would content delivery and the monitoring of student learning take precedence over including peer-to-peer interactions in teachers' considerations?

Family

A number of questions still exist about the effectiveness of online education for K-12 students although it has grown in popularity over the last two decades. Online education started for older students and those in the university. For students in K-12, they must be self-motivated, engaged and participating, and accountable for their own learning. In addition, parents should be available to monitor, mentor, and motivate these students (Archambault & Larson, 2015; Curtis & Werth, 2015; Farmer & West, 2019; Smith et al., 2016). "Parents are one group of stakeholders virtually absent from literature related to K-12 online learning environments. Full-time, online schools often partner with parents to oversee and support students who are completing their education in an online environment. Parents play a significant role in educating students who attend school online, and research has been conducted on their roles" (Curtis & Werth, 2015, p. 165). Parent engagement can positively influence student engagement by facilitating interaction, organising students' learning environments, and instructing students. Although the roles and responsibilities of parents and teachers are not the same, their influence overlaps. The pandemic presents a unique situation where parents are working and students are learning from homes at the same time. It would be timely to investigate how teachers leverage parents to support students' online learning experiences.

Purpose of Study

This study contributes by understanding teachers' perspectives and teases out their design, gaps, and possible improvements for teaching and learning mathematics in such an online HBL environment. This paper attempts to document teachers' design and implementations of teaching and learning experiences, their reflections of student engagement, and gaps so that teachers continue to improve on the use of technology for meaningful learning and student engagement after the passing of this looming dark cloud.

Background

Learning with Technology in Singapore

Singapore schools are not unfamiliar with online learning as the Singapore Education Ministry has put in place National ICT Masterplans since 1997 as a key strategy to prepare students for the future. Schools have carried out e-learning days in preparation for a national emergency situation and also to enculturate teachers and students for online learning.

To date, schools are well-equipped with the necessary technological infrastructure. Teachers are also trained in how to effectively use technology for their teaching and students' learning. In recent years, the Ministry of Education (MOE) has developed an online platform called the Singapore Student Learning Space (SLS). It contains resources for students so that they can always revisit the lessons to reinforce their learning. It provides curriculum-aligned resources and teachers could make use of these resources to design lessons. In addition, the local ministry has led an online network community on ideas to design technology- and online-based lessons on Facebook, known

as the Singapore Learning Designers' Circle (https://www.facebook.com/groups/sglearningdesigners/). This community grew exponentially to more than 15,000 members during the COVID-19 circuit breaker period.

Home-Based Learning in Singapore During Its Circuit Breaker Period

Full home-based learning in Singapore was declared from 8 April to 4 May 2020 during its Circuit Breaker Period (Kurohi, April 14, 2020). Despite the short notice, there was mass acceptance of online learning by students, teachers, and parents although there were also challenges faced by some of the students and their families (Davie, June 28, 2020). This pandemic had fast-forwarded the use of technology and online learning in many education systems, including that of Singapore. The government of Singapore also announced on 17 June 2020 that all secondary school students will receive a personal laptop or tablet for learning in the coming year—7 years ahead of the original target. "This is one of the ways the government, schools, and the community are working together to keep social mobility alive, and ensure every individual is afforded the opportunity to do well, regardless of his starting point" (Sin, Jun 18, 2020).

Research Design and Method

Eight mathematics teachers from two elementary and two secondary schools participated in this exploratory, qualitative study. The teachers' profiles are described in Table 1.

Due to the precautionary measures during the period of study (i.e., from late July to August 2020), all teachers were interviewed via Zoom by the three authors. Each teacher interview was approximately 60 min. The semi-structured interview involved teachers describing their experiences in designing online HBL, mathematic lessons, how they designed lessons to engage teachers and their

Table 1 Details of mathematics teachers interviewed

No.	School	Level teaching
1	Elementary	Grades 4 & 6
2	Elementary	Grades 3 & 5
3	Elementary	Grades 5 & 6
4	Elementary	Grade 5
5	Secondary	Grades 8 & 9
6	Secondary	Grade 7 & Grade 10
7	Secondary	Grade 9
8	Secondary	Grade 10

perceptions of students' engagement. The semi-structured interview was guided by the questions shown in Appendix with additional questions constructed as the interview evolved based on teachers' responses. All interviews were transcribed for analyses. Ground-up thematic analyses were conducted in phases. Member checking was done throughout the analyses to ensure the validity and reliability of findings.

- Phase 1—initial coding and familiarisation of data. The researchers read the interview transcripts. Annotations were done together with initial codes to highlight notable considerations that teachers made in designing online HBL experiences and their observations of student engagement.
- Phase 2—analysing codes and identifying themes. The authors discussed their initial codes to understand different interpretations and align any differences. As there were three researchers, any differences were mediated by the third researcher. Initial codes were combined to form an initial set of themes
- Phase 3—reviewing and defining themes. Initial themes were reviewed by regrouping smaller themes to form broader themes or broader themes were divided into subthemes. This process was done iteratively until the researchers came up with a thematic map that adequately described findings.

Findings

The final thematic map describes findings as two main themes and 4 sub-themes (see Fig. 1). Theme 1 unpacks teachers' considerations for HBL relating to their: (a) design preparations and implementations and (b) professional learning as a community. Theme 2 illustrates students' factors for HBL in the form of teachers' descriptions of: (a) students' HBL engagement and (b) readiness.

Theme One: Teachers' Considerations for HBL

Theme one describes how teachers prepared and implemented HBL lessons by consolidating technological tools and ideas for implementing lessons in synchronous and asynchronous formats.
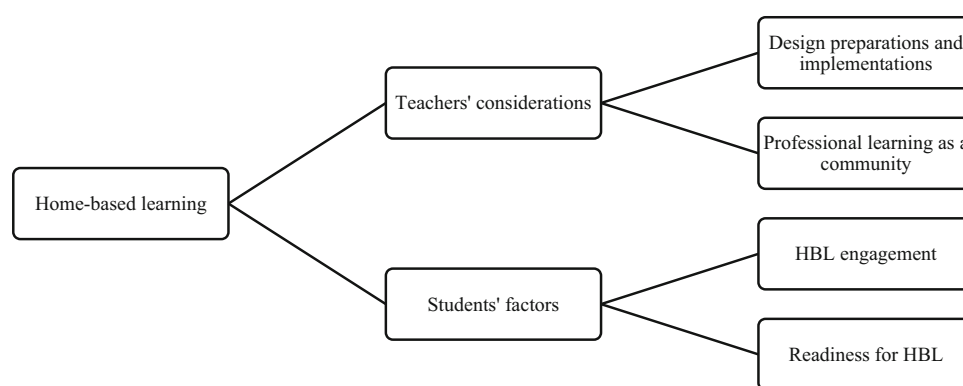
Teachers' HBL Preparation and Implementations

Teachers Consolidating Technology and Lesson Ideas Teachers prepared for the possibility of school closure and online HBL by working as a community to consolidate and share useful software applications so teaching and learning could continue. *"We have our level*

Fig. 1 Thematic map

431 *meetings…. we discuss about the things that we want to do*
432 *with our students and then that is how we share and cross*
433 *pollinate the ideas…".* The school timetable was re-or-
434 ganised to manage students' screen time. Teachers used the
435 ministry's SLS platform and supplemented it with other
436 tools (e.g., Google applications) to implement online HBL.
437 Technology familiarisation sessions were conducted for
438 teachers who needed instructions on how to use online
439 applications for HBL. Teachers also shared lesson ideas
440 and resources across schools through an existing commu-
441 nity, Learning Designers Circle Facebook page, which was
442 set up by Educational Technology Division (ETD) of the
443 Ministry of Education (Singapore). *"There is SGLDC*
444 *[Singapore Learning Designers Circle], it is a Facebook*
445 *group … teachers will share their lesson ideas, their*
446 *considerations on that Facebook page. So, I will use the*
447 *materials that I found there and share with my teachers."*
448 In addition, teachers also reviewed their scheme of work
449 and decided to teach topics that required students to acquire
450 less conceptual understanding during HBL. *"I think it*
451 *depends on topics… because certain topics, say construc-*
452 *tion, I don't think I can actually put that into a home-based*
453 *learning. I really need to tell them physically how to do*
454 *certain things."*

455 *Teachers Implementing Lessons in Synchronous and*
456 *Asynchronous Formats*   Online HBL was implemented in
457 synchronous and asynchronous formats to emphasise sub-
458 ject content delivery and monitor students' learning. *"It is*
459 *a mix of synchronous and asynchronous teaching. So,*
460 *depending on the level, depending on the type of student*
461 *profile of the class…".* Teachers could implement more
462 variations of HBL for higher grade students by toggling
463 between formats in contrast with elementary students who
464 needed more teachers' support. Typically, lessons included
465 three segments (1) reviewing students' mistakes in the
466 assigned homework; (2) teaching lesson content; and (3)
467 clarifying understandings through question and answer.
468 Teachers acknowledged that they needed more time to
469 design teaching resources, so they leverage existing

470 materials from SLS and adapted it accordingly. Teachers
471 also shared their teaching resources with communities
472 within and beyond schools to support each other.

473 Lessons in synchronous formats used video conferenc-
474 ing software application (e.g., Zoom) to mimic classroom
475 practices and implemented all three segments as "live"
476 sessions. *"There was a lot of promotion on use of video*
477 *conferencing in Google Meet and zoom … a lot of what*
478 *was being delivered was the same thing, frontal teaching,*
479 *classroom teaching".* Synchronous lessons lasted between
480 35 and 40 min. Each segment was no longer than 15 min
481 because teachers were mindful of students' attention span.
482 *"For the HBL to be effective, maybe the lesson cannot be*
483 *one hour… because one hour is actually quite strenuous on*
484 *the eyes…it is only like about 35–40 min."* Synchronous
485 lessons were also digitally recorded and uploaded to SLS
486 or Google Classroom so students, particularly absentees,
487 could revisit lessons. Teachers found it challenging to
488 monitor students' engagement and learning online as stu-
489 dents could be multitasking. Furthermore, the 'cut and
490 paste' technological affordance meant students could pla-
491 giarise answers from online sources. *"not every lesson that*
492 *I do, will be live [synchronous]. So, I will mix it up a little*
493 *bit. Sometimes it's [asynchronous] just assessing SLS,*
494 *sometimes it's just doing the timed practice on their*
495 *own…".* Asynchronous lessons implemented the first and
496 third segments described earlier as "live" sessions. The
497 second segment was implemented as an "off-line" expe-
498 rience where students accessed teacher prepared lesson
499 resources in SLS, PowerPoint slides or screencast with the
500 teacher's voice, and teacher curated learning activities
501 from the Internet (e.g., educational websites or digital
502 videos). Teachers monitored students' progress and
503 understanding by using self-marking functions when it was
504 available in software applications, by getting students to
505 take pictures of the written mathematics solutions and
506 submitting it through the relevant software applications or
507 by using the inking function on laptops and tablets to grade
508 students' work and provide feedback. Teachers also taught
509 students to file their online homework for future revisions.

510 Constant feedback was exchanged between students and
511 teachers to refine the HBL lessons.

512 *Professional Learning as a Community—Just-in-Time*
513 *Professional Learning*

514 Before school closure for HBL, just-in-time professional
515 learning sessions were conducted to update teachers about
516 the latest technological tools. Teachers also attended online
517 tutorials to learn about different software applications to
518 support HBL. *"a lot of like online learning platform that*
519 *were available. So, the ICT head will tell us, oh if you want*
520 *to learn about how to use Google Classroom, there is this*
521 *online lesson, tutorial like that…"* Occasional trouble
522 shooting was done amongst teachers and technical per-
523 sonnel using emails and mobile phone applications (e.g.,
524 WhatsApp) to ensure the HBL run smoothly. *"we had*
525 *some form of professional development…. Then during the*
526 *HBL period, we were very actively using the WhatsApp*
527 *level chat, like oh, I have difficulty with this and all, what*
528 *do I do. So, we are helping each other… Yeah, so that*
529 *helps a lot."* The teaching community supported each other
530 by sharing different ideas and diverse perspectives for
531 teaching and learning with technology.

532 Teachers acknowledged that HBL required more time
533 and resources. However, it was not necessary for them to
534 have or learn about the latest technology for HBL. *"it's not*
535 *so much of the number of apps to learn to use at this point*
536 *in time. It's more of like, okay, like how do you enhance the*
537 *use of zoom. ……, I want to learn how to further leverage*
538 *on those apps. … you know, learn more about what other*
539 *features of these apps, like for example, zoom, you can*
540 *organise them into different chat groups and then they can*
541 *discuss about certain problems, then after that they can*
542 *come back to the main class."* It was more important for
543 teachers to have professional learning experiences that
544 focused on understanding and using the affordances of
545 technological tools to design meaningful learning experi-
546 ences. Teachers welcomed the sharing of resources and
547 teaching ideas within and across schools.

548 **Theme Two: Student' Factors for HBL**

549 Theme two describes students' engagement and readiness
550 for HBL. The two sub-themes describe teachers' consid-
551 erations to support students' emotional, behavioural, cog-
552 nitive and social engagement during HBL as well as
553 teachers' understandings of how students' readiness for
554 HBL is shaped by accessibility of technology, maturity and
555 age.

556 *Students' HBL Engagement*

557 *Teachers Leverage Novelty Effects and Parents to Support*
558 *Emotional Engagement* Students' emotional engagement
559 were important considerations as teachers designed and
560 enacted HBL experiences. The novelty effects of technol-
561 ogy got students excited to start the online HBL experi-
562 ence. Even before the HBL period, when students were
563 brought to the computer laboratory to familiarise with the
564 Zoom software application, they were very excited about it.
565 *"It was like shiny new platform; it was like a novelty for*
566 *them"*. As the weeks progressed, fatigue set in. *"So, I think*
567 *after a while, it wears off, you see."*

568 Students from graduating classes became insecure over
569 missing schools and their pending examinations. *"I think*
570 *the kids who are sitting for national exams, I think they are*
571 *also feeling quite worried and insecure, that we didn't have*
572 *a mid-year exam or some assessments."* Teachers tried to
573 allay students' fears by using synchronous online video
574 conferencing to check-in and chit-chat with them and
575 support their emotional well-being. Teachers also worked
576 with parents and guardians to ensure students had emo-
577 tional support during this period of learning.

578 *Teachers Manage Classroom Discussions and Issues to*
579 *Support Behaviour Engagement* The HBL environment
580 was conducive for learning because students could pay
581 attention without disruptions from classmates. Compared
582 to the classroom environment, "quietness" could be
583 maintained because teachers could mute all or some stu-
584 dents in the online environment. Talkative or disruptive
585 students could be managed by technology. One interesting
586 observation was that students who were usually quiet and
587 less participative in face-to-face contexts became proactive
588 in asking questions and participated actively. *"I finally*
589 *hear those quieter ones, when they have questions, they*
590 *finally start to ask. Because usually in a physical class-*
591 *room, I think it will be dominated by the vocal ones."*

592 The online environment also brought about behavioural
593 engagement issues, such as students being late, absent,
594 multitasking, and late homework submission. For some
595 students, teachers had to call up students or their par-
596 ents/guardians to find out reasons for being late or absent.
597 Teachers managed students' behavioural engagement by
598 requesting students to activate their webcam to mark
599 attendance and check their identity. Teachers wanted to
600 ensure students were at their computers all the time and
601 paying attention. Teachers also reflected that students
602 needed more "chasing" to submit their homework in an
603 online environment.

Teachers Recognise the Importance of Assessment, Feedback, and Guidance for Cognitive Engagement Teachers-associated cognitive engagement with the learning of content knowledge. Teachers were more confident of students' cognitive engagement in the face-to-face setting than the online environment. Teachers observed that students who were usually engaged or self-directed students in the classroom remained equally engaged in the online setting. *"students who show up for my live lessons will tend to be the more engaged and the more serious ones…. they are listening and as I'm explaining a certain question, usually from the workbook or textbook, they are there writing down or taking notes".*

Teachers recognised that online formative assessments were key in online HBL to gather students' feedback on their understanding and progress. Unlike the physical classroom, where such feedback could be done seamlessly and adapted "on the fly", the online environment required prior planning. Thus, teachers had to adjust their practices. *"One of the things, I thought was an issue for home-based learning, was that there's less face time, so harder for us to give feedback. Immediate feedback. So, like doing [face-to-face] lessons we can, I can move around, you know… and I can point them their mistakes straight away."*

Teachers also reflected that younger or special needs students needed more guidance because online HBL posted different learning challenges and additional demands of handling technology. Even when lesson packages were well-designed, these students needed home support to facilitate cognitive engagement.

Teachers Acknowledge Constraints for Social Engagement Teachers shared that peer-to-peer discussions were less prevalent in online HBL contexts. However, teachers had the inclinations that students engaged in discussions outside of lesson time. *"They will, like chat with each other, either by calling each other or by texting each other, outside of the lesson, like in their own time. We learnt that through chatting with them in the morning…"* Interactions during online asynchronous lessons were mainly between teacher and students. Teachers felt that the limited student-to-student interactions could be attributed to how teachers kept lessons within 30–40 min.

Students' Readiness for HBL

Students' Readiness is Shaped by Accessibility of Technology Accessibility of technology plays a role in students' readiness for HBL. Some students did not have technological devices or had to share technological devices with siblings to access online HBL. Schools mitigated these issues by loaning computing devices to these students.

Learning with technology is not new to teachers and students, thanks to the consistent efforts by schools and the ministry of education since the first ICT Masterplan in 1997. Prior experiences with virus like SARS, H1N1, and MERS, which threatened to close schools, had also prompted the ministry of education to have periodic learning experiences with schools to prepare teachers and students with the possibility of online HBL. Consequently, teachers and students, are ready for HBL. However, the lengthy 4 weeks of HBL was unprecedented. Teachers reflected that students rose to the challenge because they understood the seriousness of the situation and persevered in learning. This experience forced students to become self-directed learners, especially for those in the upper elementary (Grades 4–6) and secondary (Grades 7–10) levels. *"I think the benefits is that the home-based learning, basically, I think it forces the kids to be independent in their learning. … I realised, that the success of home-based learning, it's really self-directed and being independent in their learning and being able to do that."*

Students' Readiness for HBL is Shaped by Their Maturity and Age Teachers mentioned that students' maturity, in terms of self-directedness, motivation and ICT-savviness, and age, played a role in their engagement of the online HBL experience. *"I see a general trend with the younger ones. I think they are not so used to this. This whole home-based learning. I think the older ones actually adapt a lot faster."* Younger students, especially those from Grades 1–3, needed more synchronous learning experiences and support from adults at home. Secondary students (Grades 7–10) seemed more self-directed and could manage asynchronous lessons. *"Then, for your really, really low progress, your specialised groups, …video conferencing really helped them."* Lower progress and special needs students needed face-to-face experiences with teacher scaffolding and guidance at home for HBL to be productive. *"we need to monitor. So, usually, this type of students, we monitor and realise they have an issue, they cannot study at home. They have to call back to school, this is called special need."* Special arrangements were made for students with special needs to return to school so teachers could conduct either one-to-one or small group lessons for them.

Discussion and Implications

The two themes in findings gleaned five recommendations for online HBL experiences (see Table 2). These recommendations are discussed below.

Table 2 Summary of practical implications

Theme one: teacher considerations	Theme two: student factors
• Teachers need to make deliberate and consistent efforts to monitor students' engagement and progress	• Expand online learning spaces to include social network platforms for students to continue discussions beyond lesson time
• Teachers use a variety of software applications for their lesson delivery	• Inculcate students with skills and habits for learning in online and face-to-face contexts
• Teachers need continuous PD to understand how to more effectively use instructional strategies and technological affordances for meaningful learning with technology	

Implications—Teacher Considerations

Teachers Need to Make Deliberate and Consistent Efforts to Monitor Students' Engagement and Progress

Dynamics of online HBL makes monitoring students' progress more complex than face-to-face lessons. The shift in medium of instruction, from face-to-face to online contexts, changes the dynamics of teaching and learning. Another layer of complexity involving mediation by technology is introduced. As suggested by (Chai et al., 2010, 2019; Koehler & Mishra, 2009) in the TPACK framework, teachers now need to consider the interplay of technology, pedagogy and content in designing online learning experiences. Other factors of consideration include students' skills, emotions, ways of participation, their performance in assessments, and interactions (Dixson, 2015; Martin & Bolliger, 2018). Thus, the teaching and learning process becomes more complex which aligns with our findings.

The maintenance of students' engagement is key for productive learning. Teachers interviewed were concerned about students' engagement during the HBL experience. Our teachers reflected that they could observe students' cognitive, behavioural, emotional, and social engagement more easily in a face-to-face setting. Fredricks et al. (2004) describe these three aspects of student engagement but did not draw connections. Our findings seem to illuminate some connections between the three aspects of student engagement. While teachers are concerned about students' content understanding, the practical implication drawn from this HBL experiences is that students' behavioural and emotion engagement were important to support cognitive engagement. Teachers need to purposefully design communication opportunities during online HBL experiences to find out students' concerns and needs, and to maintain a two-way communication channel.

Teachers Use a Variety of Software Applications for Their Lesson Delivery

The practical implications gleaned about the combination of tools teachers used to implement online HBL show that teachers used video conferencing software (e.g., Zoom or WebEx) to create their virtual classrooms, a central repository to house relevant digital resources (e.g., SLS), a communication platform for dissemination and exchange of information (e.g., email systems), assessment applications for the monitoring of students' progress and learning, and discussion forums to support students' exchange of ideas and discussions (e.g., Padlet or Google Classroom). Teachers are not looking for the latest software applications. Teachers are concerned about leveraging the technological affordances for meaningful teaching and learning. Our findings align with literature—such as Martin and Bolliger (2018) and Moore (1989)—to stress that teachers need to focus on learner-content interactions and the technological affordances that tools have to support these interactions. Teachers' choice of content, how it is going to be taught to support students' learning engagement shapes the selection of tools rather than using the latest tools. Thus, it important for schools to equip students with the skills on how to use technology for learning, especially for younger students. Students need to know-how to use technology before they can use technology for learning. While it is useful for schools to think about a standardised suite of tools to support online HBL, the curation of tools needs to consider teachers' readiness, student profiles, and learning goals.

Teachers Need Continuous PD to Keep Up-to-Date with Educational Technology

Research shows that the most important determinant of students' learning experiences relates to the quality of teaching and professional learning (Mourshed et al., 2010). Teachers' understandings of instructional strategies and affordances of ICT for learning are enriched when

772 professional learning involves continued practice through
773 first hand experiences of online learning in different
774 classroom contexts (Borko, 2004). Continuous teacher
775 professional development is necessary to keep our teachers
776 up-to-date with the technological know-how. Professional
777 learning communities provide possible platforms for
778 teachers to engage in effective, continuous professional
779 learning because it embodies substantive features of
780 effective professional learning which focus on continuity
781 and sustenance (Hairon, 2020).

Implications—Student Factors

783 *Expand Online Learning Spaces to Include Social Network*
784 *Platforms for Students to Continue Discussion Beyond*
785 *Lesson Time*

786 Social engagement seems lacking in online HBL because
787 of the limited lesson duration and functions on video
788 conferencing applications that our teachers used. Teachers
789 acknowledged that there were limited student group work
790 and collaboration sessions. However, they did not rule out
791 that students connect through other social networking
792 platforms for school or social purposes. The practice
793 implications, therefore, is for teachers to expand the online
794 spaces for HBL to include social network platforms for
795 students to continue discussions beyond lesson time. In
796 other words, social engagement as defined by Fredricks
797 et al. (2004) may not be confined to official lesson time
798 during HBL. Teachers could intentionally design for stu-
799 dents' social engagement before and after lesson time
800 during the HBL experience. This is important because
801 peer-to-peer relationship is critical to support students'
802 learning engagement (Everett, 2015; Gray & DiLoreto,
803 2016; Moore, 1989; Northey et al., 2015).

804 *Inculcate Students with Skills and Habits for Learning*
805 *in Online and Face-to-Face Contexts*

806 Our findings show that age and maturity play a role in
807 student engagement and in students having a productive
808 HBL experience. Similarly, students with the right learning
809 dispositions benefited from online HBL. This finding reit-
810 erates the importance of continuous inculcating of the
811 necessary skills and habits of being a motivated and self-
812 directed learner so that students can toggle between
813 learning in the online and face-to-face contexts. As high-
814 lighted by researchers (Hew & Brush, 2007; Tay et al.,
815 2017; Turgut & Aslan, 2021), student engagement and
816 learning is shaped by technological availability and
817 accessibility. Having access to technological hardware is
818 important but what is more fundamental is for students to

819 have the technological know-how to use the hardware and
820 software so that learning can occur.

Limitations

822 This study is limited by the small sample size of eight
823 mathematics teachers. This is an exploratory, qualitative
824 study. The intent is not to make generalisations but to
825 provide initial understandings of how online HBL was
826 conducted during the pandemic to inform future, more in-
827 depth studies involving more teachers and subjects.
828 Another limitation is that findings only included teachers'
829 perspectives. It would be meaningful to include students'
830 and parents' voices to have a holistic understanding of
831 student engagement and challenges during the online HBL
832 experience.

Conclusion

834 The COVID-19 pandemic and lockdowns have caused
835 schools to shift their teaching and learning online. In such a
836 situation, technology plays a core supportive role in
837 teaching students and their learning. The considerations to
838 design online learning experiences to engage students
839 meaningfully are more complex than face-to-face class-
840 room contexts. This paper attempts to gather Singapore
841 teachers' considerations in designing mathematics, online
842 HBL lessons and teachers' perspectives of students'
843 engagement during the COVID-19 pandemic lockdown in
844 2020.

845 Findings share nuanced considerations describing
846 teachers' implementations of HBL and the importance of
847 engaging students in an online learning context. Findings
848 also highlight how engaged students are in an online
849 learning context and how teachers could design online
850 lessons to capture the attention of their students better.
851 Although this study only looks into the perspectives of a
852 group of mathematics teachers, findings may also apply to
853 other subject areas.

854 While this study is an exploratory, qualitative study that
855 elicits insights from a small number of mathematics
856 teachers, findings provide evidence-informed understand-
857 ings by unpacking the considerations teachers take to
858 design lessons and engage students meaningfully in an
859 online HBL environment. Future studies can continue to
860 inform this area of work by involving more teachers from
861 different subjects, grade levels, schools, and geographical
862 contexts. The inclusion of students and parents would
863 likely provide further insights in this field of study as well.

Data Availability The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Conflict of interest The authors declare that we have no conflict of interest.

Ethical Approval All procedures performed in this study involving human participants were in accordance with the ethical standards of the institutional research committee. Nanyang Technological University, Institutional Review Board—IRB-2020-06-090.

Appendix

Interview Questions

1. How did you conduct your online, home-based learning during the recent school closure? Can you describe in detail how these lessons (e.g., a series of lessons) were conducted?
2. How engaged do you think were your students? How did you gauge your students' engagement levels?
3. Where or how did you get your ideas on how to conduct your lessons?
4. Were all your lessons online?
5. Were your students motivated to learn?
6. Were students engaged behaviourally, cognitively and emotionally, in your opinion?
7. Reflecting on how you were conducting your lessons during the circuit breaker period, how would you rate your lessons? Were they good, successful? If yes, why do you say so? If not, can you also reflect on them.
8. Did you experience any technical issues or complaints? You think the current technological infrastructure is adequate? What improvements can be made?
9. How do think students learning was affected by shifting it into the online environment? If so, how? If not, why?
10. Are there any other digital platforms like google classroom or zoom used other than SLS?
11. What were the difficulties you faced during this home-based learning and how you overcame them?
12. What do you think are the advantages and disadvantages of home-based learning for the teachers and students?

a. What do you think are factors that hindered your teaching and student's learning?
b. How effective do you think is your teaching and students' learning in HBL?
13. How do you think home-based learning can be improved?
14. What kind of support do you think is needed to enhance home-based learning and increase the students' engagement in HBL?

References

Archambault, L., & Larson, J. (2015). Pioneering the digital age of instruction: Learning from and about K-12 online teachers. *Journal of Online Learning Research, 1*(1), 49–83.

Baker, C. (2010). The impact of instructor immediacy and presence for online student affective learning, cognition, and motivation. *Journal of Educators Online, 7*(1), 1–30.

Bangert-Drowns, R. L., & Pyke, C. (2002). Teacher ratings of student engagement with educational software: An exploratory study. *Educational Technology Research and Development, 50*(2), 23–37.

Barbour, M. K. (2013). The landscape of K-12 online learning: Examining what is known. *Handbook of Distance Education, 3*, 574–593.

Bond, M., & Bedenlier, S. (2019). Facilitating student engagement through educational technology: Towards a conceptual framework. *Journal of Interactive Media in Education*. https://doi.org/10.5334/jime.528.

Borko, H. (2004). Professional development and teacher learning: Mapping the terrain. *Educational Researcher, 33*(8), 3–15.

Borup, J., West, R. E., Graham, C. R., & Davies, R. S. (2014). The adolescent community of engagement framework: A lens for research on K-12 online learning. *Journal of Technology and Teacher Education, 22*(1), 107–129.

Burnham, B. R., & Walden, B. (1997). *Interactions in distance education: A report from the other side*. Paper presented at the Annual Adult Education Research Conference Proceedings.

Chai, C. S., Koh, J. H. L., & Tsai, C.-C. (2010). Facilitating preservice teachers' development of technological, pedagogical, and content knowledge (TPACK). *Journal of Educational Technology & Society, 13*(4), 63–73.

Chai, C. S., Hwee Ling Koh, J., & Teo, Y. H. (2019). Enhancing and modeling teachers' design beliefs and efficacy of technological pedagogical content knowledge for 21st century quality learning. *Journal of Educational Computing Research, 57*(2), 360–384.

Curtis, H., & Werth, L. (2015). Fostering student success and engagement in a K-12 online school. *Journal of Online Learning Research, 1*(2), 163–190.

Davie, S. (June 28, 2020). Home-based learning set to be regular part of schooling post Covid-19, says Education Minister Ong Ye Kung. *The Straits Times*. Retrieved from https://www.straitstimes.com/singapore/education/home-based-learning-set-to-be-regular-part-of-schooling-post-covid-19-says

Dixson, M. D. (2010). Creating effective student engagement in online courses: What do students find engaging? *Journal of the Scholarship of Teaching and Learning, 10*, 1–13.

Dixson, M. D. (2015). Measuring student engagement in the online course: The Online Student Engagement scale (OSE). *Online Learning, 19*(4), n4.

Everett, D. R. (2015). Adding value: Online student engagement. *Information Systems Education Journal, 13*(6), 68.

Farmer, T., & West, R. (2019). Exploring the concerns of online K-12 teachers. *Journal of Online Learning Research, 5*(1), 97–118.

Fredricks, J. A., Blumenfeld, P. C., & Paris, A. H. (2004). School engagement: Potential of the concept, state of the evidence. *Review of Educational Research, 74*(1), 59–109.

Fredricks, J. A., McColskey, W., Meli, J., Mordica, J., Montrosse, B., & Mooney, K. (2011). Measuring student engagement in upper elementary through high school: A description of 21 instruments. Issues & Answers. REL 2011-No. 098. *Regional Educational Laboratory Southeast.*

Gray, J. A., & DiLoreto, M. (2016). The effects of student engagement, student satisfaction, and perceived learning in online learning environments. *International Journal of Educational Leadership Preparation, 11*(1), n1.

Hairon, S. (2020). Back to the future: Professional learning communities in Singapore. *Asia Pacific Journal of Education, 40*(4), 501–515.

Hawkins, A., & Barbour, M. K. (2010). US virtual school trial period and course completion policy study. *The American Journal of Distance Education, 24*(1), 5–20.

Henrie, C. R., Halverson, L. R., & Graham, C. R. (2015). Measuring student engagement in technology-mediated learning: A review. *Computers & Education, 90*, 36–53.

Hew, K. F., & Brush, T. (2007). Integrating technology into K-12 teaching and learning: Current knowledge gaps and recommendations for future research. *Educational Technology Research and Development, 55*(3), 223–252.

Koehler, M., & Mishra, P. (2009). What is technological pedagogical content knowledge (TPACK)? *Contemporary Issues in Technology and Teacher Education, 9*(1), 60–70.

Koh, T. S., & Lee, S. C. (2008). Digital skills and education: Singapore's ICT master planning for the school sector. In S. K. Lee, C. B. Goh, B. Fredriksen, & J. P. Tan (Eds.), *Toward a better future—Education and training for economic development in Singapore since 1965* (pp. 167–190). The World Bank.

Kuh, G. D. (2003). What we're learning about student engagement from NSSE: Benchmarks for effective educational practices. *Change: The Magazine of Higher Learning, 35*(2), 24–32.

Kuh, G. D. (2009). The national survey of student engagement: Conceptual and empirical foundations. *New Directions for Institutional Research, 2009*(141), 5–20.

Kurohi, R. (April 14, 2020). Singapore schools to shift to full home-based learning from April 8 to May 4 amid Covid-19 pandemic. *The Straits Times*. Retrieved from https://www.straitstimes.com/singapore/education/schools-to-shift-to-full-home-based-learning-from-april-8

Martin, F., & Bolliger, D. U. (2018). Engagement matters: Student perceptions on the importance of engagement strategies in the online learning environment. *Online Learning, 22*(1), 205–222.

Martin, F., Parker, M. A., & Deale, D. F. (2012). Examining interactivity in synchronous virtual classrooms. *International Review of Research in Open and Distributed Learning, 13*(3), 227–261.

Moore, M. G. (1989). Editorial: Three types of interaction. *American Journal of Distance Education, 3*(2), 1–7. https://doi.org/10.1080/08923648909526659.

Mourshed, M., Chijioke, C., & Barber, M. (2010). *How the world's most improved school systems keep getting better*. McKinsey.

Northey, G., Bucic, T., Chylinski, M., & Govind, R. (2015). Increasing student engagement using asynchronous learning. *Journal of Marketing Education, 37*(3), 171–180.

Patrick, S., & Powell, A. (2009). A summary of research on the effectiveness of K-12 online learning. *International Association for K-12 Online Learning.*

Rice, K. L. (2006). A comprehensive look at distance education in the K–12 context. *Journal of Research on Technology in Education, 38*(4), 425–448.

Robinson, C. C., & Hullinger, H. (2008). New benchmarks in higher education: Student engagement in online learning. *Journal of Education for Business, 84*(2), 101–109.

Sin, Y. (Jun 18, 2020). Each secondary student to get learning device by next year. *The Straits Times*. Retrieved from https://www.straitstimes.com/politics/each-secondary-student-to-get-learning-device-by-next-year

Smith, S. J., Burdette, P. J., Cheatham, G. A., & Harvey, S. P. (2016). Parental role and support for online learning of students with disabilities: A paradigm shift. *Journal of Special Education Leadership, 29*(2), 101–112.

Tay, L. Y., Nair, S. S., & Lim, C. P. (2017). A regression analysis of elementary students' ICT usage vis-à-vis access to technology in Singapore. *Educational Media International, 54*(1), 34–47.

Turgut, Y. E., & Aslan, A. (2021). Factors affecting ICT integration in TURKISH education: A systematic review. *Education and Information Technologies.* https://doi.org/10.1007/s10639-021-10441-2.

Weiner, C. (2003). Key ingredients to online learning: Adolescent students study in cyberspace—The nature of the study. *International Journal on E-learning, 2*(3), 44–50.

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