Post-Pandemic Evolution of Pedagogical Methods for Young Learners in Mathematics (7 to 10 Years Old)

Bervyn Si Jin YEO BSc, PGDE
Centre Director and Mathematics Tutor
AlphaOmegaMath Learning Centre (Tampines), Singapore

Beth Sze Hui LIM BA, PDGE
History and Social Studies Tutor
AlphaOmegaMath Learning Centre (Tampines), Singapore

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Abstract
The first author is a former mainstream school mathematics teacher and the second author is his wife, also a former mainstream school teacher. The two authors have taught in their schools during and after the pandemic period and have explored various ways to engage their students through various forms of pedagogy. They acknowledge that the pandemic brought a set of challenges to teaching, but together with it, long-lasting opportunities that may transform the education scene permanently. As such, the authors have employed a repertoire of teaching strategies to cater to their student's learning needs, learning from fellow educators and seeking feedback from different stakeholders. One of the key challenges the authors have encountered is to inculcate a sense of self-directedness in their students when it comes to blended learning. In this paper, they have chosen to share, from the perspective of experienced educators who have taught students during the pandemic period, how to leverage and capitalize on the new pedagogical approaches that arose out of the pandemic and integrate them into existing pedagogical strategies, particularly in the area of Mathematics.
Keywords: Mathematics Learning, Self-Directed Learning, Blended Learning

Introduction

The sudden onset of the global Covid-19 pandemic has affected countries all over the world, causing major disruption to teaching and learning for educators and students alike. The transition towards online learning as a main mode of instruction have become a panacea for this unprecedented pandemic. This expository seeks to highlight the underlying challenges of transiting from face-to-face lessons in school towards online synchronous and asynchronous learning, in the context ofteaching and learning of Mathematics. For those who have courageously taken this leap to transit, they have also been able to embrace the many new opportunities posed by the pandemic. Lastly, the study also seeks to expand its discussion beyond the pandemic period, to expound on possible post-pandemic pedagogies that have evolved in recent times and how these new pedagogical approaches have been seamlessly integrated into the teaching and learning of Mathematics in the post-pandemic period.

Challenges Posed By The Pandemic

Transitioning from traditional face-to-face learning to online learning is a whole new experience for both educators and student. The speed at which both parties are compelled by circumstances to adapt and embrace this transition, gives rise to much anxiety and stress. Out of the many challenges faced, the key challenges are namely; short attention span of students, inconducive home environment for learning, limited access to the appropriate online tools and the internet, systemic issues as well as the lack of a personal touch.

The short attention span of students is often a challenge especially when delivering content-heavy materials and lectures. Studies show that attention cannot remain at the same level of intensity for prolonged periods of time for the same piece of work. The duration of the focus and the focus itself are also correlated to the age of the individual as well as the task given and timing given within a course (Bunce, Flens, & Neiles, 2010; Cummings Hlas, Neyers, & Molitor, 2017)[16]. Attention problems are common challenges faced at everyeducational level (Bunce et al., 2010; Cummings Hlas et al., 2017; Wang, 2015; Weimer, 2014)[17]. Therefore, intentional efforts of educators to sustain student's attention and maintain high energy in delivering the lesson, while challenging,

[16] Bunce, D. M., Flens, E. A., & Neiles, K. Y. (2010). How Long Can Students Pay Attention in Class? A Study of Student Attention Decline Using Clickers. Journal of Chemical Education, 87(12), 1438–1443. https://doi.org/10.1021/ed100409p

[17] Ibid.

is albeit imperative for the effective retention of skills and knowledge taught.[18]

Moreover, many students confined to their home quarters have undergone great psychological and emotional distress, affecting their learning productivity. Some students expressed that they had to attend to their family members who have taken ill, preoccupying their learning time. Others have younger siblings at home that may contribute to the noise in the house, making online lessons difficult to attend. For others, low internetbandwidth also poses problems. Online face-to-face classes are encouraged by most; however, somestudents (who are economically disadvantaged) have expressed that the face-to-face online class consumes more data packages, which strains the family's finances[19]. For others, the lack of access tothe required software for the learning of Mathematics can also impede online learning. These new-found anxiety and stress often extend tothe parents and guardians of students. According to an interview conducted by The Straits Times (2020), parents who are not as well-versed in technology and online learning may struggle to assist their children in the administrative processes and trouble-shooting through any technical issues that might arise. This is even more so for parents with children belonging to the younger age group, who may be more dependent on parental guidance and supervision to complete their online lessonsand assignments. For others, the interview brought to light the common challenge of time management; parents often find themselves stretched on both ends handling work-from-home while also needing to supervise their children's home-based learning.[20]

Furthermore, effective learning may be further hampered by the limitations of online platforms. Although a variety of online learning platforms such as Zoom, Padlet, SLS (Student Learning Space) etc. are available, it proves limited in the teaching and learning of Mathematics. One key reason is the lack of an avenue to check for student understanding, especially for large groups of students for online lessons. Such platforms also make it hard to check the working of every single student and provide immediate and personalized feedback. Although Padlet does give the affordance of allowing the upload of photos showing solutions and screen sharing, such affordances are limited by the lack of Mathematical notations and functions embedded in the software. There is also little avenue for educators to check on the authenticity ofthe work submitted (as some students may end up plagiarizing their classmate's work or from online materials). This proves a challenge for subsequent assessment of the quality of actual learning taking place[21]. As such, all these contribute to an overall limitation in fully engaging students in their learning of Mathematics. In addition, the sheer highvolume of student login and usage may often cause systemic issues and server overload. Common learning platforms such as the Student LearningSpace (SLS) portal was reportedly facing periodic hiccups and glitches during the home-based learning period[22]. All these can thus impede learning from taking place and give rise to much frustration and inconvenience. While technical and systemic issues may be unavoidable, it underscores the importance and need for a robust online learning platform and regular systemic upgrades.

Lastly, the lack of personal touch can impede effective learning. According to researchers Drago and Wagner (2004), certain student learner profiles especially kinesthetic learners, often require a more hands-on approach to learning, which may prove challenging in an online learning context.[23] Kinesthetic learners often prefer experiential learning, while the nature of an online learning environment may be deemed more suitable for other learner profiles (visual and read-write learners). Moreover, the lack of an in-person, face- to-face collaborative learning experience may also

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[18] Cicekci, M. A., & Sadik, F. (2019). Teachers' and Students' Opinions About Students' Attention Problems During the Lesson. Journal of Education and Learning, 8(6), 15. https://doi.org/10.5539/jel.v8n6p15

[19] Pokhrel, S., & Chhetri, R. (2021). A Literature Review on Impact of COVID-19 Pandemic on Teaching and Learning. Higher Education for the Future, 8(1), 133–141. https://doi.org/10.1177/2347631120983481

[20] Ang, J. (2020, April 8). *Parents struggle to juggle working from home and supervising kids' home-based learning amid Covid-19 crisis*. The Straits Times. https://www.straitstimes.com/singapore/juggling-working-from-home-and-supervising-kids-home-based-learning-is-a-struggle-for-some

[21] Pokhrel, S., & Chhetri, R. (2021). A Literature Review on Impact of COVID-19 Pandemic on Teaching and Learning. Higher Education for the Future, 8(1), 133–141. https://doi.org/10.1177/2347631120983481

[22] Ong, J. (2021, May 19). *Covid-19: Some parents, students face login issues, delayed uploads on first day of home-based learning*. TODAY. https://www.todayonline.com/singapore/covid-19-some-parents-students-face-login-issues-delayed-uploads-first-day-home-based

[23] Drago, W. A., & Wagner, R. J. (2004). Vark preferred learning styles and online education. *Management Research News*, *27*(7), 1–13. https://doi.org/10.1108/01409170410784211

give rise to feelings of isolation, especially in the learning of Mathematics. A phenomenon known as "Math anxiety" is defined as a feeling - or set of feelings - with negative connotations resulting in a specific behaviour toward Mathematics tasks. Such feelings are generally centred on fear and nervousness, resulting in blockage when dealing with Mathematics tasks.[24] Such feelings havearisen over the course of the pandemic, where online learning becomes a norm. Feelings of isolation when attempting Mathematical problems and the lack of a physical educator readily available to provide immediate support and guidance, may be leading causes. Mathematics anxiety also occurs to a greater extent for students who are afraid of failure and punishment, for high performing students in mathematics, and those who have behavioural anxiety towards low performance in mathematics (García-Fernández et al., 2013)[25]. With online learning taking place, the lack of immediate feedback to close any learning gaps oran affirmative nod/ pat on the shoulder from educators, may thus escalate such anxiety.

Overcoming The Challenges

All is not doom and gloom. With the concerted efforts of the various stakeholders; school leaders, educators, parents/guardians and students themselves, the above-mentioned challenges can in fact be mitigated.

Firstly, the Ministry of Education (MOE) has, in recent years, made the necessary provisions to better support students who lack a conducive learning environment at home. Such is done by allocating several school personnel and classrooms to accommodate students who may prefer using the school facilities to conduct their Home-Based Learning classes[26]. Many schools have even generously loaned out laptops to students under the Financial Assistance Scheme (FAS) as they may not have the means to own a personal laptop for learning[27]. Class mentors and technicians have also been deployed on stand-by to assist parents and students in trouble-shooting technical glitches. All these were done to help mitigate the stress and anxiety of transiting to online platforms for learning.

Secondly, to safeguard and promote the mental and emotional well-being of students during the pandemic, class mentors have conducted more frequent check-ins with individual students in their class. Under the Ministry's guidelines, Character and Citizenship Education (CCE) lessons were also modified to focus on mental wellness[28]. Specific to Mathematics, educators are intentionally integrating more collaborative tasks to students while also activating the chat function of online lectures to allow for personal queries and clarifications. Class buddies were also tactfully assigned to pair up a higher progress learner with a lower progress learner to provide more peer support. As an additional measure, educators have even taken the initiative to record instructional videos to further support lower-progress learners. On a national level, the Ministry of Education removed the common last topics (CLTs) from End- of-Year examinations in recent years to further reduce the stress faced by students and parents[29].

Thirdly, to balance out the removal of CLTs, curriculum recovery lessons were also conducted after examinations to bridge learning gaps. This is especially paramount for Mathematics, a multi-layered subject. In order to engage students for higher-level topics, basic fundamentals must first be established. For instance, without a robust and concrete understanding of linear algebraic equations, students may face difficulties grasping the subsequent topic on quadratic equations. As such, many schools have taken to conducting bridging classes in the post-examination period to cover the CLT.

It is through the concerted efforts of various stakeholders that the challenges posed by the

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[24] Arnal-Palacián, M., Arnal-Bailera, A., & Blanco, C. (2022). Math Anxiety in Primary Education during Covid-19 Confinement: Influence on Age and Gender. *Acta Scientiae*, *24*(1), 145–170. https://doi.org/10.17648/acta.scientiae.6745

[25] García-Fernández, J. M., Inglés, C. J., Martínez-Monteagudo, M. C., Marzo, J. C., & Estévez, E. (2011). Inventario de Ansiedad Escolar: validación en una muestra de estudiantes de Educación Secundaria. *Psicothema*, 23(2), 301-307.

[26] Mahzam, R. (2020, May 4). *Support for students returning to their schools during full HBL*. Ministry of Education, Singapore. https://www.moe.gov.sg/news/parliamentary-replies/20200504-support-for-students-returning-to-their-schools-during-full-hbl

[27] ibid.

[28] 2020 Student Development Curriculum Division. (2020). *Character & Citizenship Education (CCE), Syllabus Secondary*. Ministry of Education, Singapore. https://www.moe.gov.sg/-/media/files/secondary/syllabuses/cce/2021-character-and-citizenship-education-syllabus-secondary.pdf?la=en&hash=D41C87D627D3AA6CF52C14538121EA5E1B9E0B44

[29] Ng, W. K. (2021, July 27). *Lighter load for national and year-end school exams to help ease stress: Chan Chun Sing*. The Straits Times. https://www.straitstimes.com/singapore/politics/lighter-load-for-national-and-year-end-school-exams-to-help-ease-stress-chan-chun?utm_campaign=stfb

pandemic can be better mitigated, to ensure the continued effective learning of Mathematics.

Emerging Opportunities

On a related note, through the process of mitigating challenges posed by the pandemic, many valuable new opportunities for the teaching and learning of Mathematics have emerged.

Firstly, educators have introduced a more dynamic and interactive approach to online learning. Such initiatives include the use of dialectic approaches that involve conversational journaling between learners and educators. Educators have encouraged the active use of live chat room features between students working together in groups, allowing for real-time communication and the exchange of ideas and strategies to solving Mathematical tasks. One such communication platform is found in zoom, where educators can utilize the screensharing function to share two selected students' work, demonstrating how two different approaches can be used on the same question. Educators can then facilitate active student discussion on which of the following methods / approaches is better. Moreover, through the creative use of social media platforms like Twitter, Instagram, facebook and telegram, students are better able to sound out any further queries to address individual learning gaps, while allowing their peers to contribute valuable inputs online. For government schools in Singapore, educators have also undergone professional development in the area of ICT to further boost their facilitation skills and mastery of online platforms for better online discussions and collaboration[30]. These have indeed helped encourage greater student participation and effectiveness in collaborative learning, to arousegreater curiosity and interest for the learning ofMathematics.

Secondly, Singapore schools have also sought the benefits of a more Blended learning approach towards education. This approach is essentially hybrid learning, which combines the use of online learning with that of the conventional face-to-face learning in a classroom (Lee et al., 2017; Thai et al., 2017). This integration has been proven to be able to enhance student engagement and learning (Garrison & Kanuka, 2004)[31] beyond the confines of a physical classroom. For effective Blended learning, educators need to first develop a deeper understanding and appreciation of the different learner's profile amongst their students. Many educators have consequentially adopted differentiated instructions (DI) and a plateau of various appropriate online platforms to cater to these differing learning needs. Such commonly used platforms during the pandemic include Microsoft Teams, Google Classroom, Google Meets, Canvas and Blackboard. These platformsserve as a one-stop unified communication tool to allow educators to communicate effectively with both fellow colleagues and students, easing the creation and sharing of useful resources online and offline for enhancing student engagement. (Petrie, 2020).[32]

Specific to the teaching and learning of Mathematics, new software like Ace-learning's Math Virtual Reality also addresses the afore-mentioned limitations of existing platforms like Padlet which lacks Mathematical expressions. Ace-learning's Math Virtual Reality application allows students to look at 3D shapes and objects from different angles, which enables better visualization of complex geometrical shapes (see Figures 1a and 1b)[33]. This is especially useful in solving and visualizing three-dimensional problems related to bearings, angles of elevation and angles of depression, a topic students tend to face difficulties in. Consequentially, students can thus more accurately calculate the respective volume, surface area and dimensions of these objects to solve the Mathematical problems.

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30 *Learn for Life – Ready for the Future: Refreshing Our Curriculum and Skillsfuture for Educators*. (2020, March 4). Ministry of Education, Singapore. https://www.moe.gov.sg/news/press-releases/20200304-learn-for-life-ready-for-the-future-refreshing-our-curriculum-and-skillsfuture-for-educators

31 Garrison, D., & Kanuka, H. (2004). Blended learning: Uncovering its transformative potential in higher education. *The Internet and Higher Education*, *7*(2), 95–105. https://doi.org/10.1016/j.iheduc.2004.02.001

32 Petrie, C., Aladin, K., Ranjan, R., Javangwe, R., Gilliland, D., Tuominen, S., & Lasse, L. (2020). spotlight on quality education for all during Covid-19 crisis. In *https://hundred.org/en/collections/quality-education-for-all-during-covid-19*. HundrED. https://cdn.hundred.org/uploads/report/file/15/hundred_spotlight_covid-19_digital.pdf

33 ACE-Learning System. (2018, April 18). *Math VR* [Video]. YouTube. https://www.youtube.com/watch?v=E-ZlqaTMlsU

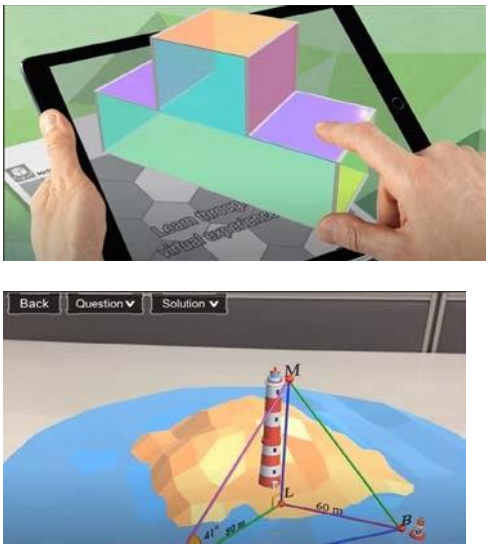


Figure 1. Visualization of Complex Geometrical Shape

Additionally, another useful Mathematical software that has recently been popularized in schools for Blended learning is GeoGebra.[34] GeoGebra is an interactive Mathematics application that allows for a more hands-on virtual learning experience. This application allows for an accurate drawing of straight lines, coordinates and two-dimensional shapes. The user-friendly application has clear instructions given and is popular amongst primary schools especially in teaching and learning the topic on angles. Inserted below is a sample of a hands-on activity done on Geogebra (see Figure2)[35] which allows primary school students to practice measuring an angle using a movable digital protractor. The angles can be randomized for repeated practice to further instill confidence.

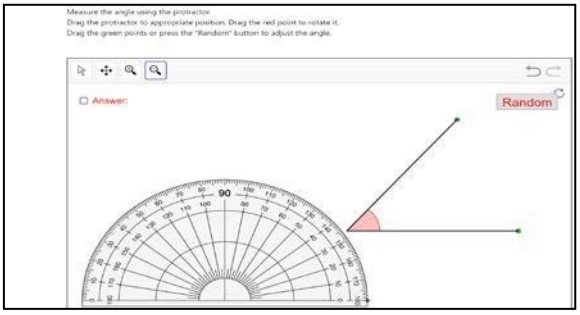


Figure 2. A Sample of a Hands-on Activity done on Geogebra

Such 'hands on' activities thus create an online learning environment that allows students to experience high interaction and experimentation with key Mathematical materials, a great tool for kinesthetic learners. Geogebra also ties in topics with real-life scenarios and applications, to encourage students to formulate, connect, and apply new ideas to existing knowledge to facilitate higher-order thinking (see Figure 3).[36] Through its interactive geometry, algebra, statistics and calculus application, the learning and teaching of Mathematics becomes more engaging.Furthermore, the application can be used on multiple platforms (desktops, website, phones etc.).For students from less privileged backgrounds, this ease of access allows them to continue their learning on their personal mobile devices, no longer being constraint by the limited access to a shared family desktop/laptop.[37] Learning can now take place anytime, anywhere.

Figure 3. New Ideas to existing Knowledge to facilitate Higher-Order Think A subset of Blended learning that emerged from the pandemic, is the flipped classroom pedagogical approach, which allows educators to further engage learners. This pedagogical approach allows educators to provide pre-learning resources such as articles, pre-recorded videos and YouTube links before the class. Students are thus able to engage with the content online prior to the lesson, thus allowing educators to use actual lesson time (online and offline) to facilitate discussions to deepen understanding, while also addressing any common misconceptions and learning gaps (Doucet et al., 2020).[38] This approach reduces lesson time used for content coverage or repetition of concepts previously covered. Educators can better focus on more interactive engagements with students during lesson, thus managing the challenge of student's short attention span. Flipped classroom can also be utilized to assess student's actual learning taking place, through the uploading of pop-quizzes and mini assignments online. Some platforms like SLS,

[34] *Probability and Statistics (Middle School)*. (n.d.-b). GeoGebra. https://www.geogebra.org/m/tn7wppdp

[35] *Measuring Angles Using Protractor*. (n.d.). GeoGebra. https://www.geogebra.org/m/fMnsdbzv

[36] Wood, N., & Sereni-Massinger, C. (2016). Engaging Online Kinesthetic Learners In Active Learning. *IMCIC*. https://www.iiis.org/CDs2016/CD2016Spring/papers/HB788PF.pdf

[37] *Classroom resources*. (n.d.). GeoGebra. https://www.geogebra.org/materials

[38] Doucet, A., Netolicky, Dr. D., Timmers, K., & Jim Tuscano, F. (2020). Thinking about pedagogy in an unfolding pandemic (An Independent Report on Approaches to Distance Learning during COVID-19 School Closure). *Education International*.

Nearpod and Ace-learning etc. also offer a self-checking function where students can receive immediate feedback on their performance and be given brief explanations on why certain methods/answers are incorrect. Intrinsically motivated and higher progress learners can further explore related topics and content uploaded online, while also attempting higher-order thinking questions. Such asynchronous learning is an effective way to promote greater self-directedness.

Post-Pandemic Learning

Hybrid learning holds great promise for the future of education as it exploits advancements made in the recent pandemic years to meet the needs oflearners today and in the near future, to attain desired learning outcomes in education. Since its incorporation into the education sector, technology has proven itself to be invaluable and indispensable in safeguarding our learning continuity.

Under the government's directives towards being a Smart Nation, the Ministry of Education has since revitalized its ICT in Education Masterplan (originated in 1997) to its newly minted Education Technology (EdTech) Plan.[39] The crux of the EdTech Plan consists of four aspects. Firstly, itseeks to encourage greater self-directedness through developing pedagogy, tools and structures to help students develop intrinsic motivation for greater ownership of their learning. Secondly, it seeks to personalize and customize learning experiences for students to better suit differing learning pace and pathways of each child. Thirdly,it seeks to promote more positive collaborative learning experiences by connecting students' learning to the community and the larger world(real-world context). Lastly, it seeks to promote a more human-centred learning experience (with each child at the centre) by leveraging on data to better understand students' interests, attitudes and motivations so as to optimize their learning[40]. This

new directive thus seeks to position Singapore as a leader in the use of ICT in education, effectively integrating ICT into everyday learning and teaching[41]. Furthermore, the steady roll-out of Personal Learning Devices (PLDs) to students in all secondary schools across Singapore by 2021[42], serves as a means to enhance digital literacy and promote blended and self-directed learning. Many schools have even taken the liberty to install useful softwares like Geogebra, MathType etc. to assist students in their learning of Mathematics.

In schools across Singapore, Home-Based Learning (HBL) has also become common place. For instance, at Queensway Secondary School, the HBL Day is conducted once a fortnight[43]. The school has also introduced an hour of Student- Initiated Learning into its HBL curriculum, where students are given the freedom to explore projects and skills of their interest, moving beyond syllabus content and assessment. Topics for exploration can range from cooking to sports to art to even coding. Students are then encouraged to journal down and document their learning progress under the supervision of their parents and guidance of class mentors, before sharing their reflections with peers in school. Such an initiative has not only helped deepen students' passions and interests for learning, it has also encouraged critical and inventive thinking of the society and world around them through experimental learning and reflective thinking, underpinning the holistic education approach and 21st century competencies directed by the ministry[44].

Attached below are some artefacts of Student-Initiated Learning that took place in Queensway Secondary School (see Figure 4 on the following page)[45].

[39] *EdTech Plan*. (2021, June). Ministry of Education, Singapore. https://www.moe.gov.sg/education-in-sg/educational-technology-journey/edtech-plan

[40] ibid.

[41] *EdTech* (n.d.). Ministry of Education, Singapore. https://www.sgdi.gov.sg/ministries/moe/departments/etd

[42] *Personal learning device*. (2020, November). Ministry of Education, Singapore. https://www.moe.gov.sg/news/parliamentary-replies/20201102-personal-learning-device

[43] *Blended Learning at Queensway*. (2022). Queensway Secondary School. https://www.queenswaysec.moe.edu.sg/the-Queensway-experience/blendedlearning/

[44] *21st Century Competencies*. (2021, October). Ministry of Education. https://www.moe.gov.sg/education-in-sg/21st-century-competencies

[45] *Blended Learning at Queensway*. (2022). Queensway Secondary School. https://www.queenswaysec.moe.edu.sg/the-Queensway-experience/blendedlearning/

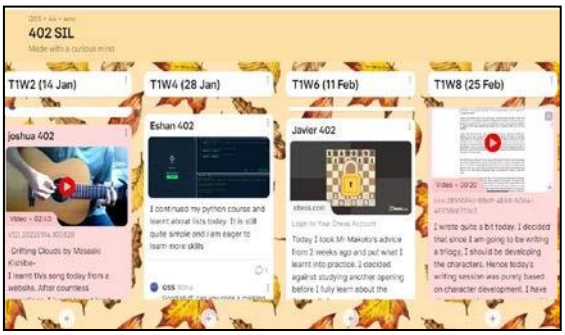


Figure 4. Some Artefacts of Student-Initiated Learning

Another school that successfully took on thestudent-initiated learning programme was Junyuan Secondary School. The school has crafted a comprehensive scaffold to better guide students on their self-directed learning journey, ensuring greater ease (see Figures 5a, 5b and 6).[46]

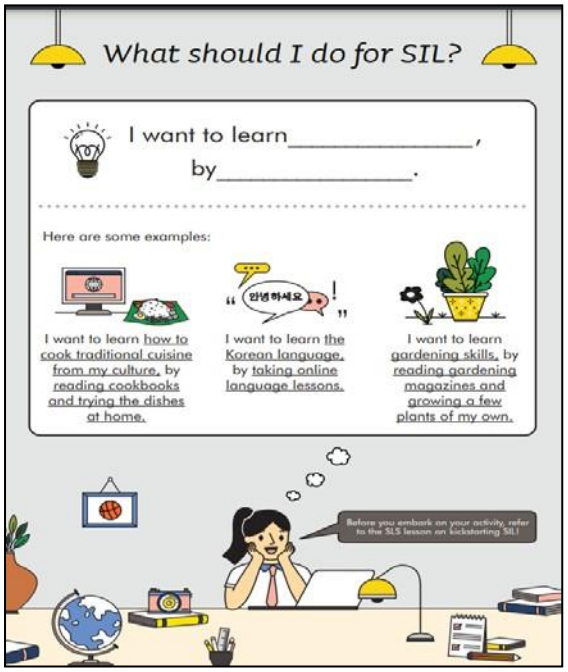


Figure 5a. A Comprehensive Scaffold on Self-Directed Learning

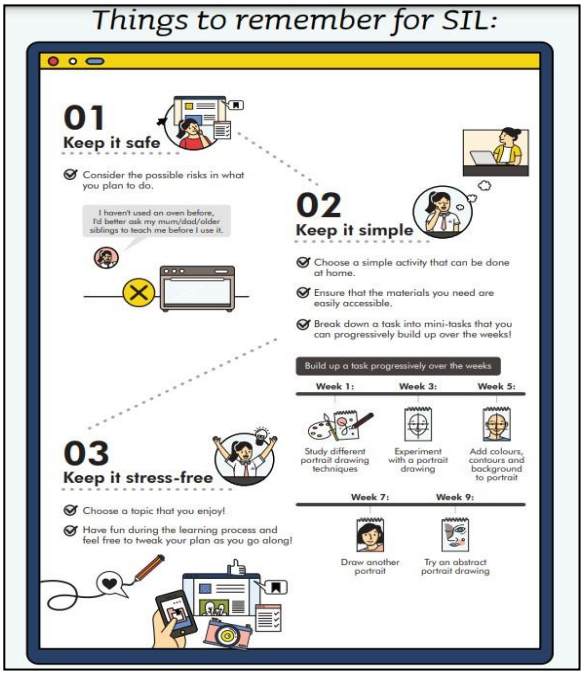


Figure 5b. A Comprehensive Scaffold on Self-Directed Learning

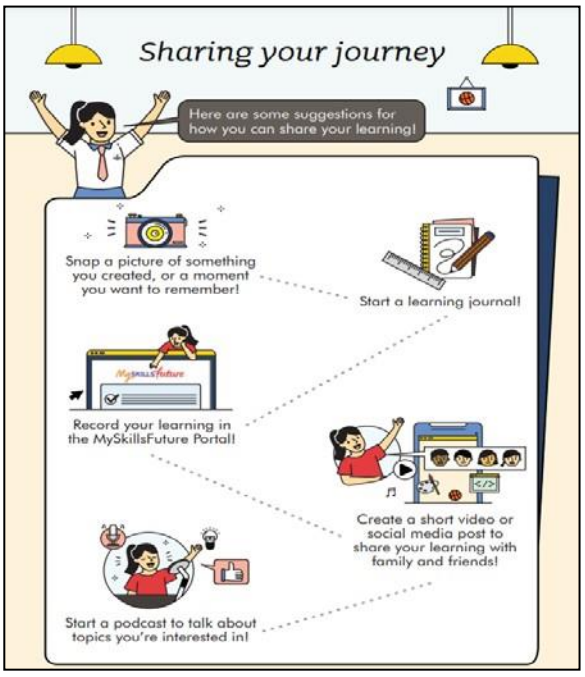


Figure 6. A Comprehensive Scaffold on Self-Directed Learning

Such initiatives are part of a larger ministry wide effort to inculcate a greater sense of ownership in learning and fostering self-directedness in learning. It reinforces the Ministry's direction to ease away from an overt emphasis on extrinsic motivation like grades, awards and examinations to more intrinsic

[46] *Home Based Learning*. (2022). Junyuan Secondary School. https://junyuansec.moe.edu.sg/our-programmes/home-based-learning

motivations fuelled by a deeper passion for learning and the joy of learning[47]. Accompanying this gradual shift is a noticeable change in the role of teachers. Teaching in classrooms is moving away from frontal teaching that emphasizes on singular methodical approaches, to embrace multiple approaches to problem solving. Educators also undergo professional development to enhance their pedagogical effectiveness for blended learning. Intentional efforts are made to integrate more discussions in classrooms. One such initiativeis Talk Moves (Michaels, O'Connor, 2013)[48] which uses effective questioning techniques to provide opportunities to probe and assess student's understanding of key Mathematical concepts and skills. Through the learners' articulation, a teacher can better assess their depth of understanding, while also correcting any misconception. Learner's overtime develop greater confidence in talking about Mathematics and using it. This initiative has been adopted into primary schools in the teaching and learning of Mathematics.[49]

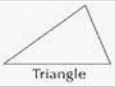
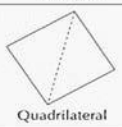
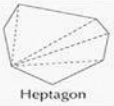
To boost and promote greater self-directed learning, lesson materials also require more customization to cater to differing progress learners, while including more open-ended questions to stimulate critical thinking. See Table 1 below for a comparative analysis of the difference between a conventional Mathematics worksheet for primary school, with one that encourages greater self-directedness.

The comparison is based on three question sets on the topic of angles and perimeters. The third question is a higher-order thinking (HOT) question that is included to stretch higher progress learners.

Table 1. A Comparative Analysis of the Difference between Conventional Math Worksheet for Primary School

Typical Worksheet Questions (Conventional)	Questions designed to induce Self-Directed Learning
1a. List down two properties of a square. 1b. List down two properties of a rectangle.	1. Are all rectangles, squares? Are all squares, rectangles? ❖ Discuss this with your partner.
2. What is the sum of angles in a triangle?	2. Can you draw a triangle with two right-angles? Why? ❖ Login to your Personalised Learning Device (PLD) and try drawing such a triangle using the Geogebra App.
3. What is the sum of angles in a 7-sided shape? Hint: You can divide the shape into triangles.	3. How can we find the sum of angles in any shape, regardless of the number of sides? a. Use Geogebra to draw the following shapes. b. Divide the shapes into triangles. c. Find the sum of angles in each shape (see Table 1a below).

Table 1a. Angles in Various Shapes

Polygon	Number of sides	Number of Triangle(s) formed	Sum of Interior Angles
 Triangle	3	1	$1 \times 180° = (3-2) \times 180°$
 Quadrilateral	4	2	$2 \times 180° = (4-2) \times 180°$
 Pentagon			
 Hexagon			
 Heptagon			

[47] (2019, July 30). Primary and secondary schools to cut down on exams and tests, as MOE announces sweeping changes to reduce emphasis on grades. *TODAY*. https://www.todayonline.com/singapore/primary-and-secondary-schools-cut-down-exams-and-tests-moe-announces-sweeping-changes

[48] Michaels, S., & O'Connor, C. (2015). Conceptualizing Talk Moves as Tools: Professional Development Approaches for Academically Productive Discussions. *Socializing Intelligence Through Academic Talk and Dialogue*, 347–361. https://doi.org/10.3102/978-0-935302-43-1_27

[49] Curriculum Planning and Development Division. (2020). *Mathematics syllabus (Primary one to six)*. Ministry of Education, Singapore.

As shown in Table 1, Mathematical questions can be more intentionally designed to promote self-directed learning in students, using the following guiding principles:

1. Arousing Curiosity
2. Facilitating Discourse
3. Progressive Thinking

Arousing Curiosity

To arouse curiosity, the question usually starts with a trigger. Educators trigger students to tap on prior knowledge by asking the following question, "Are all squares, rectangles?" or "Are all even numbers multiples of 2?" These statements spark curiosity in students as they are induced to ponder over thegiven question, tapping on their understanding of the mathematical concept/notion.

Facilitating Discourse

As a follow-up, educators can facilitate discourse amongst students on the trigger question to elicit a multitude of responses. It promotes self-directed learning as students are trained to justify their perspectives and hypotheses to their peers, using mathematical concepts and logical reasoning. This is an advancement from the more conventional approach to learning; through formulae application and recall. For younger learners, perhaps more teacher facilitation and simplification of the discourse can be given. Younger learners could simply be instructed to choose between a few options and share with their seat partner. Teacher can then gather a few pairs to share their conclusion while getting the class to raise their hands if they agree or disagree. Exposing to discourse at a young age is imperative in nurturinga culture of positive questioning and discussion.

Progressive Thinking

Questions given can also be better scaffolded in sequential order to promote progressive thinking. Through Socratic questioning techniques, students are progressively directed towards discovering and understanding a mathematical concept on their own. Educators facilitate the process by guiding and probing students towards the right direction, while avoiding hand-holding so as not to short-circuit the discovery process. This is imperative as research has shown that memory retention for self- acquired knowledge in an integrated and progressive manner is generally higher compared toinformation that has been dictated or passed down in isolation.[50]

[50] Varga, N. L., & Bauer, P. J. (2017). Young adults self-derive and retain new factual knowledge through memory integration. *Memory & Amp; Cognition*, *45*(6), 1014–1027. https://doi.org/10.3758/s13421-017-0711-6

Conclusion

Blended learning and online learning can indeed be powerful tools to supplement the teaching and learning of Mathematics. This can be so if the following criterion are met: Sufficient student support from various stakeholders (from schools, teachers and parents), students' ability to practice more self-directed learning skills and foster good online learning habits, educator's continued professional development to keep them up-to-date with the latest technological affordances and platforms to make well-informed choices and applications of suitable online learning tools. A progressive shift in parental mindset to embrace the prospects and benefits of online learning as well as sustained school support for learning from home are also imperative for the continued success of blended learning.

Finally, the combination of different techniques and software is also necessary as no one solo software is holistic in catering to the myriad oflearning styles and learner profiles.[51] Scholars have often worked on the assumption that students are reflective learners who are able to be self-directed in their learning. However, this may not be so for younger age groups who may need more scaffolding and facilitation in order to effectively use ICT for the learning of Mathematics.

It is only with the concerted effort and dedication of the various stakeholders in meeting the above criterion, can the learning of Mathematics evolve to encourage greater debate, reasoning, questioning, and self-discovery to ignite the joy of learning.

References

[1] Bunce, D. M., Flens, E. A., & Neiles, K. Y. (2010). How long can students pay attention in class? A study of student attention decline using clickers. *Journal of Chemical Education*, *87*(12), 1438–1443. https://doi.org/10.1021/ed100409p

[2] Ibid.

[3] Cicekci, M. A., & Sadik, F. (2019). Teachers' and students' opinions about students' attention problems during the lesson. *Journal of Education & Learning*, *8*(6), 15-19. https://doi.org/10.5539/jel.v8n6p15

[4] Pokhrel, S., & Chhetri, R. (2021). A literature review on impact of COVID-19 pandemic on teaching and learning. *Higher Education for the Future*, *8*(1), 133–141. https://doi.org/10.1177/2347631120983481

[51] Tay, L. Y., Lee, S. S., & Ramachandran, K. (2021). Implementation of Online Home-Based Learning and Students' Engagement During the COVID-19 Pandemic: A Case Study of Singapore Mathematics Teachers. *The Asia-Pacific Education Researcher*, *30*(3), 299–310. https://doi.org/10.1007/s40299-021-00572-y

[5] Ang, J. (2020, April 8). Parents struggle to juggle working from home and supervising kids' home-based learning amid Covid-19 crisis. *The Straits Times*. Singapore Press Holdings. Retrieved from: https://www.straitstimes.com/singapore/juggling-working-from-home-and-supervising-kids-home-based-learning-is-a-struggle-for-some.

[6] Pokhrel, S., & Chhetri, R. (2021). A literature review on impact of COVID-19 pandemic on teaching and learning. *Higher Education for the Future*, *8*(1), 133–141. https://doi.org/10.1177/2347631120983481.

[7] Ong, J. (2021, May 19). *Covid-19: Some parents, students face login issues, delayed uploads on first day of home-based learning*. TODAY. Mediacorp. Retrieved from: https://www.todayonline.com/singapore/covid-19-some-parents-students-face-login-issues-delayed-uploads-first-day-home-based-learning.

[8] Drago, W. A., & Wagner, R. J. (2004). VARK preferred learning styles and online education. *Management Research News*, *27*(7), 1–13. https://doi.org/10.1108/01409170410784211.

[9] Arnal-Palacián, M., Arnal-Bailera, A., & Blanco, C. (2022). Math anxiety in primary education during Covid-19 confinement: Influence on age and gender. *Acta Scientiae*, *24*(1), 145–170. https://doi.org/10.17648/acta.scientiae.6745.

[10] García-Fernández, J. M., Inglés, C. J., Martínez-Monteagudo, M. C., Marzo, J. C., & Estévez, E. (2011). Inventario de Ansiedad Escolar: Validación en una muestra de estudiantes de Educación Secundaria. *Psicothema*, 23(2), 301-307.

[11] Mahzam, R. (2020, May 4). *Support for students returning to their schools during full HBL*. Ministry of Education, Singapore. Retrieved from: https://www.moe.gov.sg/news/parliamentary-replies/20200504-support-for-students-returning-to-their-schools-during-full-hbl.

[12] ibid.

[13] 2020 Student Development Curriculum Division (2020). *Character & citizenship education (CCE), Syllabus secondary*. Ministry of Education, Singapore. Retrieved from: https://www.moe.gov.sg/-/media/files/secondary/syllabuses/cce/2021-character-and-citizenship-education-syllabus-secondary.pdf?la=en&hash=D41C87D627D3AA6CF52C14538121EA5E1B9E0B44.

[14] Ng, W. K. (2021, July 27). Lighter load for national and year-end school exams to help ease stress: Chan Chun Sing. *The Straits Times*. Singapore Press Holdings. Retrieved from: https://www.straitstimes.com/singapore/politics/lighter-load-for-national-and-year-end-school-exams-to-help-ease-stress-chan-chun?utm_campaign=stfb.

[15] Ministry of Education Singapore (2020, March 4). *Learn for life – Ready for the future: Refreshing our curriculum and skillsfuture for educators*. (2020, March 4). Retrieved from: https://www.moe.gov.sg/news/press-releases/20200304-learn-for-life-ready-for-the-future-refreshing-our-curriculum-and-skillsfuture-for-educators.

[16] Garrison, D., & Kanuka, H. (2004). Blended learning: Uncovering its transformative potential in higher education. *The Internet and Higher Education*, *7*(2), 95–105. https://doi.org/10.1016/j.iheduc.2004.02.001.

[17] Petrie, C., Aladin, K., Ranjan, R., Javangwe, R., Gilliland, D., Tuominen, S., & Lasse, L. (2020). *Spotlight on quality education for all during Covid-19 crisis*. Retrieved from: https://cdn.hundred.org/uploads/report/file/15/hundred_spotlight_covid-19_digital.pdf.

[18] ACE-Learning System (2018, April 18). *Math VR* [Video]. YouTube. Retrieved from: https://www.youtube.com/watch?v=E-ZlqaTMlsU

[19] GeoGebra (n.d.). *Probability and statistics (Middle school)*. Retrieved from: https://www.geogebra.org/m/tn7wppdp

[20] GeoGebra (n.d.). *Measuring angles using protractor*. Retrieved from: https://www.geogebra.org/m/fMnsdbzv.

[21] Wood, N., & Sereni-Massinger, C. (2016). Engaging online kinesthetic learners in active learning. *IMCIC*. Retrieved from: https://www.iiis.org/CDs2016/CD2016Spring/papers/HB788PF.pdf.

[22] GeoGebra (n.d.) *Classroom resources*. Retrieved from: https://www.geogebra.org/materials.

[23] Doucet, A., Netolicky, D., Timmers, K., & Tuscano, F. J. (2020). Thinking about pedagogy in an unfolding pandemic (an independent report on approaches to distance learning during COVID-19 school closure). Work of education international and UNESCO. Retrieved from: https://issuu.com/educationinternational/docs/2020-research-COVID-19-eng.

[24] *EdTech Plan*. (2021, June). Ministry of Education, Singapore. Retrieved from: https://www.moe.gov.sg/education-in-sg/educational-technology-journey/edtech-plan.

[25] ibid.

[26] Ministry of Education Singapore (n.d.) *EdTech*. Retrieved from: https://www.sgdi.gov.sg/ministries/moe/departments/etd.

[27] Ministry of Education Singapore (2020, November). *Personal learning device*.Retrieved from: https://www.moe.gov.sg/news/parliamentary-replies/20201102-personal-learning-device.

[28] Queensway Secondary School (2022). *Blendedlearning at Queensway*. Retrieved from: https://www.queenswaysec.moe.edu.sg/the- Queensway-experience/blendedlearning/.
[29] Ministry of Education Singapore (2021, October). *21st Century Competencies*. Retrievedfrom: https://www.moe.gov.sg/education-in- sg/21st-century-competencies.
[30] Queensway Secondary School (2022). *Blendedlearning at Queensway*. Retrieved from: https://www.queenswaysec.moe.edu.sg/the- Queensway-secondary-school/experience/blendedlearning/.
[31] Junyuan Secondary School (2022). *Home basedlearning*. Retrieved from: https://junyuansec.moe.edu.sg/our- programmes/home-based-learning.
[32] Ministry of Education Singapore (2019, July 30).Primary and secondary schools to cut down on exams and tests, as MOE announces sweeping changes to reduce emphasis on grades. *TODAY*. Mediacorp. Retrieved from: https://www.todayonline.com/singapore/primary-and-secondary-schools-cut-down-exams-and- tests-moe-announces-sweeping-changes.
[33] Michaels, S., & O'Connor, C. (2015). Conceptualizing talk moves as tools: Professional development approaches for academically productive discussion. *Socializing intelligence through talk and dialogue*, 333-347.https://doi.org/10.3102/978-0-935302-43-1_27.
[34] Curriculum Planning and Development Division.(2020). *Mathematics syllabus (Primary one to six)*. Ministry of Education, Singapore.
[35] Varga, N. L., & Bauer, P. J. (2017). Youngadults self-derive and retain new factual knowledge through memory integration. *Memory & Cognition*, *45*(6), 1014-1027. https://doi.org/10.3758/s13421-017-0711-6.
[36] Tay, L. Y., Lee, S. S., & Ramachandran, K. (2021). Implementation of Online Home-Based Learning and Students' Engagement During theCOVID-19 Pandemic: A Case Study of Singapore Mathematics Teachers. *The Asia- Pacific Education Researcher*, *30*(3), 299–310. https://doi.org/10.1007/s40299-021-00572-y.