

# Overcoming challenges in teaching calculus remotely during COVID-19 pandemic

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## Method Article

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# Abstract

**Purpose:** This tutorial provides two specific examples to demonstrate how we tackled challenges in teaching Calculus remotely to first year undergraduate biomedical engineering students of XYZ University during a pandemic.

**Methods:** Lessons and education materials were delivered remotely using XYZ University's version of open-source Moodle learning management system and Tencent's WeChat social media platform. We implemented transformative learning theory and active learning principles in our initiatives.

**Results:** Students motivation and engagement improved through appropriate challenges and application of timely real-life examples in Calculus based-on positive feedback received anonymously from students via end-of-course surveys.

**Conclusion:** Remote learning is an evolving paradigm which challenges instructors to use novel and creative ways to engage with students.

## Challenge Statement

As institutions the world over scramble to maintain normality in the face of a global pandemic caused by COVID-19, we can only imagine how the population of London survived a similar emergency caused by the bubonic plague in 1665, more than three and a half centuries ago. It was also during this period, which young scholar and polymath Isaac Newton made several important discoveries including the foundation for Calculus in which he relentlessly pursued eventually elevating his status as the foremost philosopher of his time. In his own words, "I was in the prime of my age for invention & minded Mathematicks & Philosophy more than at any time since." [1] Although most of us pale in comparison with the intellectual giant, we should all look up to Newton's experience with optimism during this challenging period.

It is interesting to draw parallels between what happened in London in 1665 to what is happening today. Even then, social distancing measures were practised as academics and students left university campuses en masse. In attempts to continue organised studies many students followed their tutors wherever they went. Today, with the prevalence of real-time communication tools at our disposal, we are more fortunate than those before our time. The challenge we face currently is to finesse the best approach to deliver lessons on short notice. Remote delivery of planned lessons already comes with its own set of challenges [2]. With limited preparation time and resources available in a crisis situation, how can we approach remote lesson delivery differently [3]? In this tutorial, we examine the approach that we have taken to teach Calculus course remotely from Australia to 55 freshmen students from the department of Biomedical Engineering at XYZ University in China during this pandemic. All the students learned remotely from their homes. We illustrate our approach with two novel initiatives, paying special attention to the needs of students in isolation and maximising effectiveness of on-line engagement.

# Novel Initiatives

Students lament of being extremely isolated during this pandemic. Separated from their peers, many may lack self-motivation and languish in isolation. We believe that in this bleak period lies the opportunity by which educators can capitalise on to transform and enhance the learning experience. *Transformational learning* is both a social and solitary process [4]. The most solitary part involves critical reflection which is likely to occur sans contact with peers or instructors. In the first initiative, we encouraged critical reflection by challenging students with an open-ended exploratory question of global-scale importance. We reminded the students that there is no one correct answer and that different approaches can lead to different answers. This is akin to different approaches governments around the world are adopting to combat COVID-19. Good open-ended questions that test student understanding and ability in Calculus are few and far in between. One such question is on finding continuous functions  $f(x)$  which satisfy the following three conditions [5].

- i.  $f(x) \geq 0$ , where  $0 \leq x \leq 1$ ;
- ii.  $f(0) = f(1) = 0$ ;
- iii. The area bounded by the graph of  $f(x)$  and the  $x$ -axis between  $x = 0$  and  $x = 1$  is equal to 1.

The students were asked to compute the arc length of the function. By highlighting that this is a problem in which a global community of like-minded people are actively engaged in, we added context and extended it to a problem beyond the classroom [6]. And to make it even more interesting, we turned this into a competition where students were told to find functions which minimise the arc length. The student who came up with the shortest arch length wins. Not only does this problem require an iterative problem-solving approach, its importance and urgency made this problem exciting and rewarding to the students. To help speed up the process of finding possible solutions, students were directed to use online computer algebra systems such as GeoGebra ([www.geogebra.org](http://www.geogebra.org)) or Desmos ([www.desmos.com](http://www.desmos.com)). It was encouraging to find that students approached this problem independently and came up with their own unique solutions. Figure 1 shows a selection of two example solutions which students submitted.

Contact time with students is precious, both in the classroom and especially remotely. Students who spend long hours at home attend online lessons with high expectations to be engaged and learn. How do we maximise student engagement and use this time effectively? Research-backed principles of teaching suggested that students learn best through *active learning* using real-life examples which concern them [7], [8]. Based on these guiding principles, we engaged the class remotely using relevant and timely information in this second initiative. Every student was required to participate in this exercise. We first covered the theory of consumer surplus as an application of Integration in economics. Subsequently, we made use of current news about supermarket shelves being emptied by panic shoppers in Australia. This peculiar and bizarre situation about toilet paper shortage were reported worldwide recently [9]. The question was posed to the class about how much they are willing to pay for a roll of toilet paper. Each student was asked to input their answer into a shared spreadsheet (Excel, Microsoft Office 365) which was updated in real-time for everyone. Throughout the process, students were reminded to consider

themselves as if they were shopping for toilet paper. Once the spreadsheet was fully populated, the instructor then announced his secret price and started building a graph showing consumer surplus based on the data gathered. Through this exercise, we actively engaged with the students using data which they provided. The relatively low-bandwidth requirement of shared spreadsheet allowed real-time interaction and the whole class benefited from seeing how their data was transformed into a graph to explain the concept of consumer surplus. Figure 2 shows a slide taken from the example and the interactive activity using the shared spreadsheet.

## Reflection

We are aware that during this pandemic, learning may be severely impacted for students as they face great uncertainties to their health, social lives, and family. It is important that in the face of massive disruption to learning, being adaptive and flexible in such a situation requires the instructor to be open-minded and creative with lesson delivery. We have illustrated this with two initiatives which were well-received by students based on anonymous feedback from an end-of-course survey.

In the first initiative, we focused on the needs of students who are forced into isolation during this pandemic and learned primarily remotely at home. Being isolated allowed these students ample opportunity to focus and reflect on lessons learned in solitude. We leveraged on this situation by directing the students' effort towards an open-ended question which required an iterative problem-solving approach. This required the students to immerse themselves in the problem, often trying a few guesses before coming up with possible solutions. Our expectation is that students who are adequately challenged and given the necessary tools to solve open-ended problems on their own are able to learn independently. This mode of learning is suggested by Vygotsky as the zone of proximal development [10]. Many students approached this problem by writing down their thought process before coming up with unique solutions on their own. When students were asked at the end of the semester what they liked most about the course, anonymous responses such as, "..., I have exercised my thinking ability and logical ability", "the projects. They are fun and can activate the mind", and "project, which has an interesting meaning, connects knowledge with life," corroborate with our expectation. Based on the evidence we have seen so far, we believe that students who enjoyed this challenge experienced transformative learning through critical reflection. For this reason, we plan to adopt similar open-ended challenge questions to future modes of teaching.

In the absence of peer group dynamic in a classroom setting, lessons can get mundane very quickly especially when students are left to learn in a *laissez-faire* manner [11]. In the second initiative, we examined the role of the instructor in trying to maximise engagement with the class remotely. During this pandemic, availability of masks, sanitisers, food and toilet paper is a major concern for everyone. By using toilet paper as a tongue-in-cheek example application of Calculus in real-life situation, we drew in and held the students' attention. A student mentioned, "some interesting activities, for example, buying toilet paper. I think these activity can let us be more interesting in learning calculus, and let us know calculus is useful in our daily life." This was corroborated by another student who felt that connecting

learned knowledge with current events improves interest in the subject. This finding agrees with the learning principles suggested by Ambrose *et al.* who stated that when students find positive value in their learning activity, they are likely to be fully engaged and use their time effectively to achieve the desired learning outcome [8]. In our experience, tailoring lesson topics to relevant events combined with sensible use of online collaborative tool sufficed to maximise engagement with student remotely. Although far from perfect, this is a prudent strategy for interacting with students.

This pandemic has presented us with unique challenges as well as opportunities. It seems, however, that not many stakeholders are ready to fully embrace remote learning. This is indeed the case for our students based on their feedback. Out of 20 students who responded, 17 students prefer face-to-face classroom lesson compared to remote learning. Only one student felt more at ease having online lessons, while two students did not have a preference. The reasons given for the majority's preference are better focus, less interruption by family members, less trouble caused by internet connectivity and ease of communication (nothing related to course delivery or content, thankfully). One silver lining comes from an anonymous student who mentioned, "the quiz time made me felt happy and excited, since I can play game as well as enhance my memory." This suggests that technology can indeed be a used to improve online lesson delivery and assessment. The use of online tools such as Quizziz ([www.quizizz.com](http://www.quizizz.com)) and Kahoot ([www.kahoot.com](http://www.kahoot.com)) will be fully explored in the future as pilot trials suggest they have a positive impact on student experience. Notwithstanding any improvement to the current pandemic situation, we may have no choice but to evolve as we proceed towards uncharted territory. From this experience we realise that there is much to be done before we can replace classroom lesson delivery with totally online learning, not the very least the impromptu ones. Remote learning is indeed an evolving paradigm which challenges instructors to use novel and creative ways to engage students.

## Declarations

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## Conflict of interest

Q.F. is on the editorial board. All other authors declare no conflict of interest.

## Authors' contribution

D.N conceived and designed the teaching tips and drafted and critically revised the manuscript. S.M. was an instructor for Calculus and provided critical feedback for the manuscript. E.H. provided feedback for course content and curriculum for Calculus. E.H. and Q.F. provided critical feedback for the manuscript. All authors read and approved the final manuscript.

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## Figures

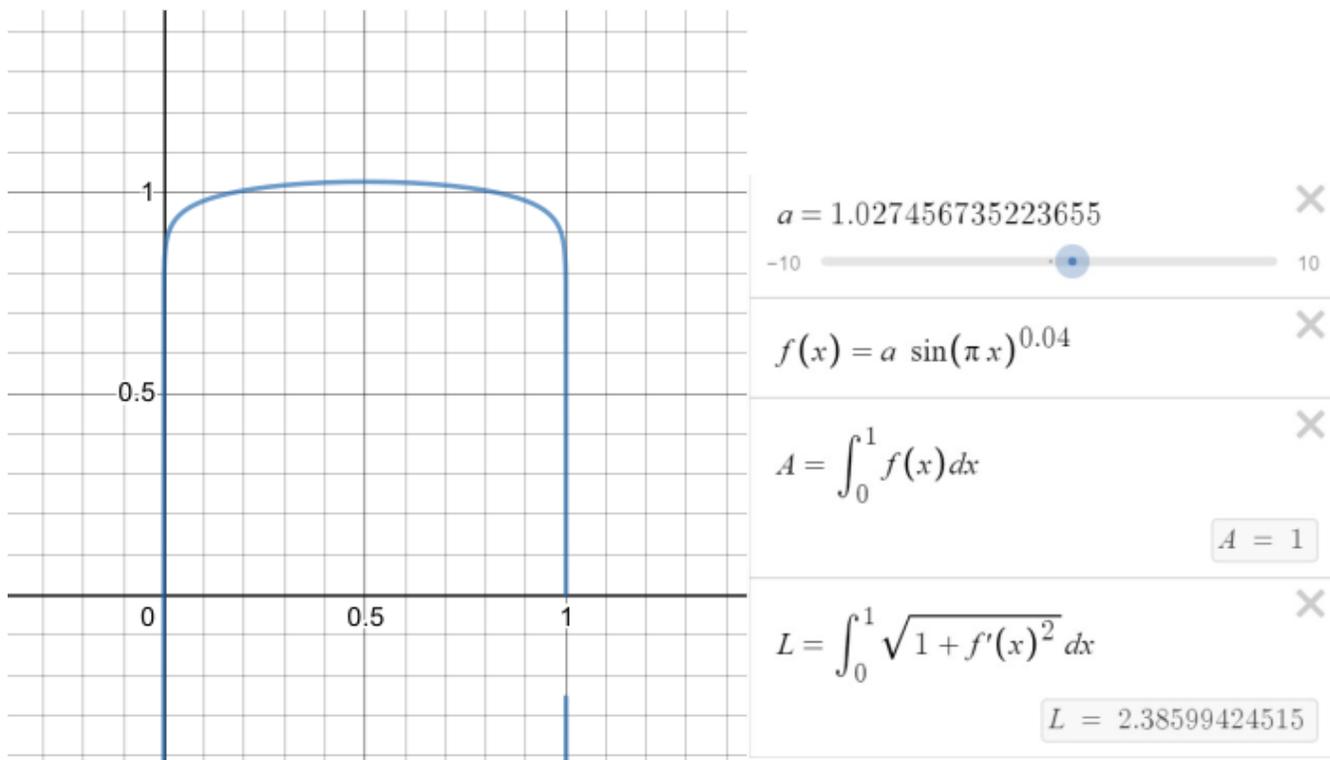
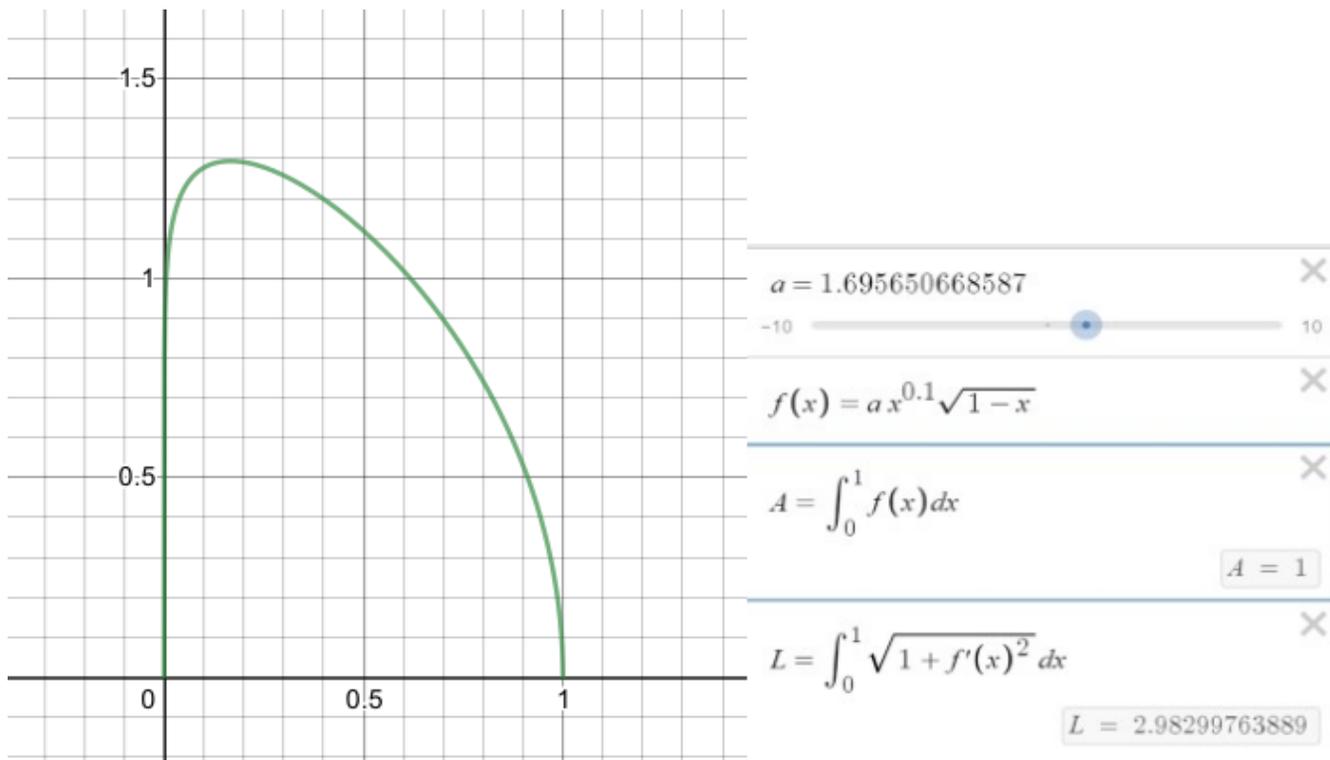


Figure 1

Two examples of solutions by students using Desmos.

# (A) Workshop

Australians are going crazy over *this* daily necessity. How much are you willing to pay for one roll of toilet paper?



(B)

English Name	My secret price, P [¥]	Is p > P
Alice	¥ 2.00	1
Bob	¥ 3.00	1
Benny	¥ 3.00	1
Beth	¥ 2.00	1
Bell	¥ 2.50	1
Brad	¥ 5.00	1
Candy	¥ 2.00	1
Cath	¥ 2.50	1
Cate	¥ 2.00	1
Cindy	¥ 2.00	1
Cherry	¥ 2.00	1
Christ	¥ 3.00	1
Denny	¥ -	0
Dao	¥ 3.00	1
Ella	¥ 3.00	1
Eliz	¥ 2.00	1
Elon	¥ 2.00	1
Ethan	¥ 3.00	1
Greg	¥ 4.00	1
George	¥ 2.00	1
Gao	¥ 3.00	1
Goth	¥ 2.00	1
Han	¥ 2.50	1
Hun	¥ 2.00	1
Handsome	¥ 3.00	1
Jack	¥ 2.00	1
John	¥ 5.00	1
Jin	¥ 2.00	1
Jorge	¥ 6.00	1
Kan	¥ 3.00	1
Klaus	¥ 3.00	1
Klay	¥ 2.00	1
Larry	¥ 2.00	1
Lee	¥ 3.00	1
Leong	¥ 2.00	1
Leng	¥ 2.00	1
May	¥ 1.00	0
Meg	¥ 2.00	1

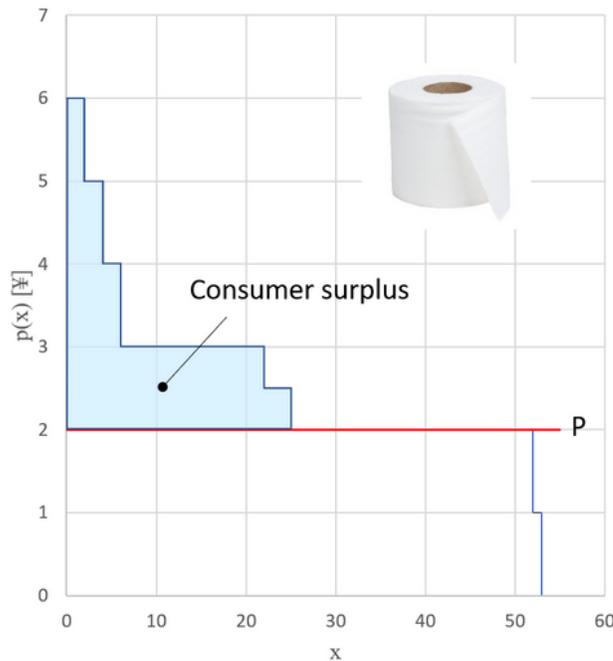


Figure 2

(A) Example exercise incorporating real-life situation, (B) collaborative spreadsheet illustrating real-time participation from students guided by instructor. Students' names have been changed. Not all students are shown.

## Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [Fig.2Surplusworkshop.xlsx](#)