STUDENT PESPECTIVES AND KEY TECHNOLOGIES FOR ENGAGEMENT IN ONLINE MATHEMATICS COURSES

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Introduction

One of the top challenges that hinder positive outcomes in any online course is the lack of student engagement in the course itself. Engagement can be thought of as evidence of student's actively participating in, connecting with interest, willingness to explore and practice concepts in order to reach quality learning. True student engagement is critical to any course, as it stimulates the learning process. In Meyer's (2014) opinion, effective engagement strategies may be the one key aspect in making online programs productive for an institution. Activities that involve collaboration and sharing of ideas among students promote a deeper level of thought and create meaning for the learner (Banna, et.al., 2015, p2), which is evidence of student engagement. With an appropriate choice of technology, and using it effectively, active learning and student engagement can be achieved in mathematics courses taught online.

Background

Due to the rapid spread of COVID-19 in early March 2020, city and state universities, along with most educational institutions, transitioned from in-person to fully remote learning. Teachers were challenged to rethink, reinvent, and recreate how they deliver instruction using solely digital media. Teachers had little or no time to prepare for this transition through getting adequate professional development. Students not only had to become responsible learners but also needed to quickly adapt to learning online without their teachers' or peers' presence. By 2022, an increasing number of institutions welcomed teachers, students, and staff back into classrooms. According to the Bay View Analytics, who has published trends on distance learning in higher education for over two decades, there was a 46% increase in students enrolled totally online or a combination of online and on-campus from 2019 to 2022 (Seaman et al., 2024). While the long-term future of online learning in higher education remains uncertain, it is essential to reflect on recent experiences to inform future practices. This paper will expose the reader to a case study that was conducted on a pre-calculus course in the Spring 2022 semester at an undergraduate college in Queens, New York. It evaluates student's perspectives learning math online during the pandemic, and in particular key technologies they used to engage with the content. The researcher will share how teaching math online due to the pandemic has influenced her current approach to teaching math in-person and virtually.

Literature Review

Before the COVID-19 pandemic, the use of technology in mathematics classrooms was common as technology was considered an essential tool that teachers and students should use to support mathematical reasoning, higher-order sense-making, problem-solving, and communication (National Council of Teachers of Mathematics, 2011; Pollatsek et al., n.d; Radovic et al., 2019). Mathematics instructors have generally used smartboards, calculators, graphing websites (i.e., Desmos & GeoGebra), computer algebra systems (i.e., Mathematica & Maple), online homework systems (MathXL, WebAssign, MyOpenMath, Lumen OHM), and other digital media in their courses (Alabulaziz, 2021; Perienen, 2020). However, the challenge for math instructors during the pandemic was creating an online environment that would mirror the traditional chalk and board approach (Cassibba et al., 2021; Wang, 2021). Teachers were used to writing math symbols on the board in a traditional classroom, and could check students' understanding by walking around the class, looking at the students written responses in their notebook or at the board. Teaching students from behind a screen, without the capacity to determine whether the students were actually engaging in the learning process, was difficult for some instructors (Almarashdi & Jarrah, 2021; Baloran et al., 2021). Institutions offered professional development on various online teaching methods, but this rushed approach was treated as emergency training rather than formal professional development aiming to give instructors adequate time to consider existing research and best practices (Ardic, 2021; Engelbrecht et al., 2020). Significant amounts of time were spent exploring and adjusting to various software/platforms, constructing online materials, and gathering existing materials online that would support teaching. Nevertheless, some instructors appreciated their newfound skills and planned to continue using technologies such as touch screens and pen tablets after the pandemic (Alabulaziz, 2021; Cassibba et al. 2021).

Before the pandemic, students viewed learning mathematics as challenging (Fritz et al., 2019, as cited in Almarashdi & Jarrah, 2021; Casinillo, 2019; Jaggars, 2014; Mohd & Rustam, 2016). Students in Jaggars's (2014) study admitted they would not risk taking a math course online due to the difficulty of the subject; they preferred the face-to-face classroom, classifying it as a richer experience. Challenges (e.g., lack of technology, poor internet connection, less interaction with the instructor, feelings of isolation) associated with the sudden switch to learning math online during the pandemic hindered student satisfaction with the math course itself and therefore negatively affected student engagement levels (Wester et al., 2021). According to Baloran et al. (2021), when students are satisfied with their course, they are more likely to actively engage, which promotes better academic outcomes.

To overcome the awkwardness of learning online due to the pandemic, there was increased use of video connections (Zoom, Blackboard Collaborate), pen tablets, touchscreens, and discussion boards to help replicate face-to-face teaching (Alabulaziz, 2021; Cassiba et al., 2021; Wang 2021). In Jones et al.'s (2022) case study, instructors as well as students were given an iPad and Apple pencil to support their technology needs. These technologies were integrated into the lessons as learning tools to support student engagement. Lecture notes were provided on a digital whiteboard with spaces for annotations. Students were encouraged to use iPads and digital pens to share answers to questions. They worked in teams on problem sets and discussed their solutions in the live class. Students responded positively to this setting and cited being able to collaborate and obtain more relevant detailed feedback from their instructor. However, not all students or instructors in online course always have the same access to technology and internet in order to fully participate which is referred to as digital inequality (Chan et al., 2021; Lanius et al., 2022; Meehan & Howard, 2020). For example, a student with a poor internet connection in Meehan and Howard's study (2020) had to ensure that his family remained offline during his exam times so that he could access the exam. He declared having lost exam time more than once due to poor Internet. Poor connectivity frustrates students, causing anxiety and worries of failing the course.

Radmehr and Goodchild (2021) recommended that mathematics teaching and learning communities share challenges and solutions for teaching online, arguing that "it can be a valuable exercise to establish a form of information exchange" (p 4). Other studies (Jones et al., 2022; Mang & Wardley, 2012) shared technological pedagogical skills on how to integrate technology into online lessons because the simple presence of technology does not automatically have positive outcomes. Boloran et al.'s (2021) study recommend institutions to assess the quality of technology integration in online learning by determining student course satisfactions levels. Their study results found that student's course satisfaction levels are significantly correlated with their level of engagement in the course itself.

Purpose of the study

The purpose of this study was to determine student perceptions (satisfactions, attitudes and opinions) learning mathematics in a pre-calculus course ran online during the pandemic, and report on how they engaged with the content in the online environment through the use of different technologies. The research questions (RQs) that guided this investigation are as follows:

RQ1. In which ways were students in the pre-calculus course engaged in learning mathematics online through using technology?
RQ2. What were students' overall satisfaction levels, attitudes, and opinions regarding their online pre-calculus course?

Methodology

Course Setting and Sample Selection

This study took place during the 2022 spring semester at an undergraduate college in Queens, New York (USA). In November 2021, prior to the start of the semester, a new variant (Omicron) of the coronavirus caused a surge of infections that lasted until approximately February 2022 (Baker et al., 2022). Although colleges had begun to return to in-person learning, this surge caused institutions to remain flexible in terms of course modality. The Mathematics and Computer Science Department in this study offered almost 100% of their math courses in a hybrid format, according to which at least 30% of the course meetings were held in-person and the remaining sessions online (synchronous mode). All exams were held in person on campus to safeguard authentic assessment implementations.

The researcher's pre-calculus class (N = 30) was invited to participate in this study, of which about 74% were freshmen, 13% juniors, and 13% sophomores. Freshmen pursuing STEM-related fields take this course early in their degree path as it is a pre-requisite to the calculus course required for their major. Most of the course was taught online (about 70%), with the remaining sessions (about 30%) used mainly for administering paper exams and some teaching.

Course Structure

The pre-calculus course was taught with a common syllabus organized into weekly topics. The free *Precalculus* textbook by OpenStax was used as a resource for teaching and learning. To engage with students in the online environment, remote communication was permitted through the web conferencing platform Zoom, and Lumen Online Homework Manager (OHM) was used to administer interactive assessments. A digital pen/pencil and Wacom tablet was used in the synchronous meetings. Perusall (a social annotation tool) and Whiteboard.fi (an instant formative assessment tool) were used to assess students' understanding and provide them with a different way to demonstrate their work. The results chapter of this paper elaborates on how students engaged in learning math via these technologies.

Instruments used for data collection

To answer RQ1, the researcher reported on ways pre-calculus students engaged in learning math online throughout the semester. To evaluate students' overall perceptions (i.e., satisfactions, attitudes and opinions) of learning math online, a survey was administered at end of the semester. The survey consisted of Likert-scale and open-ended questions aimed at helping to answer RQ2. The survey was self-administered via Blackboard. Students were given time during class to fill it out or could complete it on their own outside of class. However, according to the Institutional Review Board (IRB) which governs how research studies are conducted, only students 18 years or older were permitted to complete the survey, but not obligated to do so.

Results

RQ1. In which ways were students in the pre-calculus course engaged in learning mathematics online through using technology?

Student engagement in a course can be defined as the quality of effort they devote to actively participating in, and exploring the material presented to them to attain quality learning (Krause & Coates, 2008). Online programs such as Zoom, Lumen OHM, Perusall, Whiteboard.fi, and other technologies were integrated into the course in this study to help facilitate opportunities for students to engage in their coursework. This section elaborates on how these tools were used in the course.

Zoom Video/Audio Meetings. Zoom gained popularity in higher education since the COVID-19 pandemic (Sandu et al., 2021; Serhan, 2020) by providing video and audio in real time for synchronous meetings. To replicate the chalkboard used in in-person teaching, the instructor used a digital pen/pencil with a Wacom tablet to write and share the lesson via Zoom. Figure 1 presents an example of a lesson on finding the exact value of the six trigonometric functions of specific angles. Students were called on to answer questions and could speak their answer or write it in the chat.

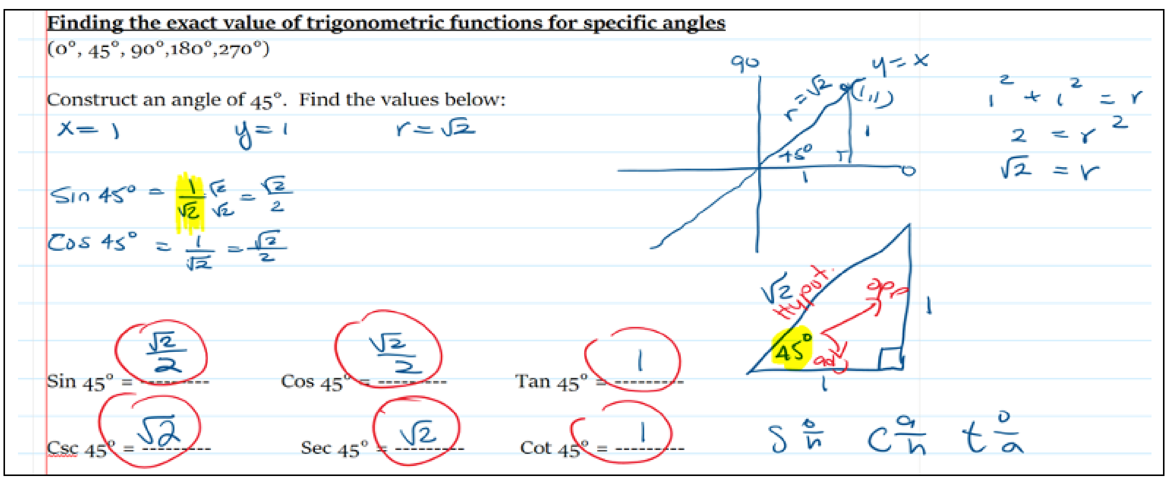

Figure 1. Lesson file shared with students

Zoom also has a built-in whiteboard that allows students to display their work to the class. To write on the whiteboard, students could use their mouse to click on the pen option.

Other students discovered that if they joined the session using their phone or tablet, they could use their touch screen to write easily on the whiteboard.

The instructor was able to provide students the opportunity to learn collaboratively on Zoom through the use of breakout rooms. In breakout rooms, students could discuss mathematical ideas without the teacher and then report their findings to the class as a whole. With Zoom, sessions could be recorded and saved online for students' reference. The instructor chose not to record their lessons but instead created brief videos (using the software Snagit) covering a specific content. Snagit software is discussed next.

Snagit. Snagit (developed by the company TechSmith) is a versatile tool that enables users to capture screenshots, edit images, and record lightweight screen recordings. The instructor used Snagit to create concise videos covering certain course content. The Snagit videos were uploaded to YouTube and shared with the class via Lumen. The instructor would also often use Snagit to deliver personal feedback to students on their work. For example, students often received video responses in which the instructor explained problems by hand while offering verbal commentary. This approach often made feedback clearer and more accessible than traditional email communication.

Lumen Online Homework Manager (OHM). The company Lumen Learning created Lumen OHM, an online homework platform that provides thousands of interactive assessment questions to help students master mathematics and other quantitative skills (Lumen Learning, 2022). Students in this study were assigned homework to practice what they learned in class. Most of the questions provided immediate feedback, while others were open-ended and required grading by the instructor. Students could email the instructor within Lumen if they encountered problems; if this occurred, the professor would receive a copy of the question inside the email and could access the answers the students submitted with a few clicks. Seeing the question and students' answers in the email facilitated the professors' ability to offer help.

Lumen was not only used for assigning homework, but it was also used in class while teaching. For example, when the instructor needed to assess if students understood a topic and wanted to allow students to practice a concept, students were asked to log into Lumen and complete a particular set of questions. Most of the questions in the Lumen testbank have multiple versions, making it hard for students to copy from each other. The instructor could access each student's record to see how they were performing on the assessment. Instructors could additionally require students to upload their scrap work (written solutions) for the assessment in addition to entering their final answer in the answer box. This gives the instructors an idea of how students worked out the problems in the assessment.

Lastly, the instructor was free to upload lesson files, post links to video lessons (YouTube, etc.), create discussion forums, post announcements, and so on through Lumen. Lumen also has a built-in gradebook so that students could track their overall course performance.

Perusall Software. Perusall is a social reading platform that allows students and teachers to annotate readings for free. The free *Precalculus* textbook by Openstax as well as other Open Education Resource (OER) textbooks were uploaded into Perusall for the pre-calculus courses, and students were able to annotate the textbook with answers to problem sets or comment on theorems and graphs. The entire class (including the instructor) could see the annotations in real time and could respond to what was posted.

The instructor used Perusall for students to review topics before taking exams. She uploaded review sheets with problem-solving questions for students to work on collaboratively as an assignment. Students were additionally asked to responding to their classmate's post regarding how they answered the review topic question, giving them feedback on their answer. Students were encouraged to not simply respond saying "good job" to their classmate, but to provide their own worked out solution. The instructor rated students according to their effort in answering the question rather than on whether they answered the question correctly. At the end of the assignment, the instructor checked that all questions were answered correctly. For examples, see Figures 2 and 3; the review sheet questions are in the middle white area, while student responses are to the right of the screenshot. Students could type their answers using text style or Latex and could also upload their scrap work from an image file. This type of assignment gave students the opportunity to problem-solve together. The instructor guided students in the right direction, trying to expand their thinking within the content area. Students generally completed this type of assignment outside of class, but it was sometimes used during lessons or office hours.

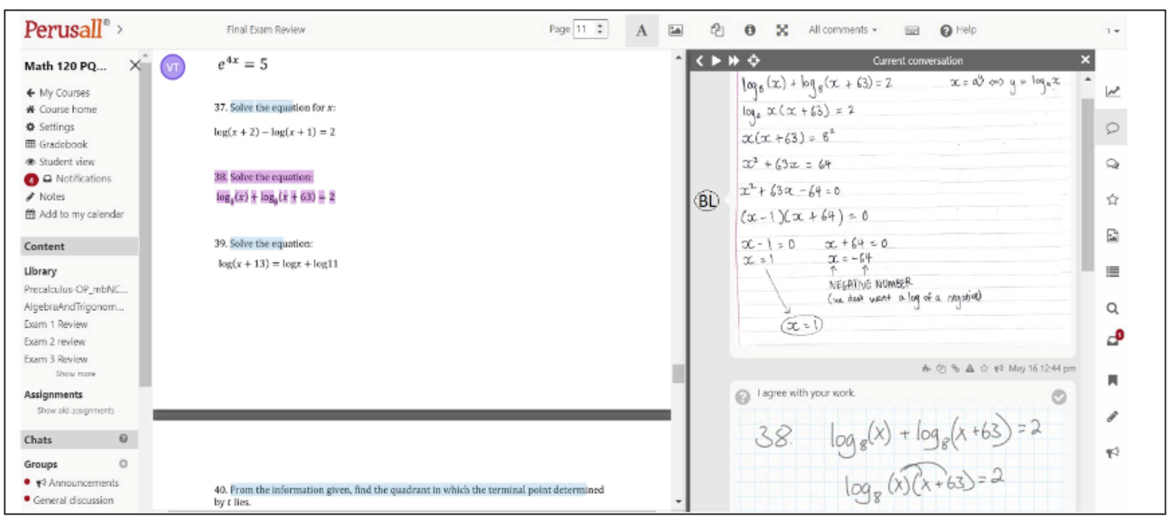

Figure 2. Student BL responses to Question 38 in Perusall Assignment to Solve a Logarithmic equation

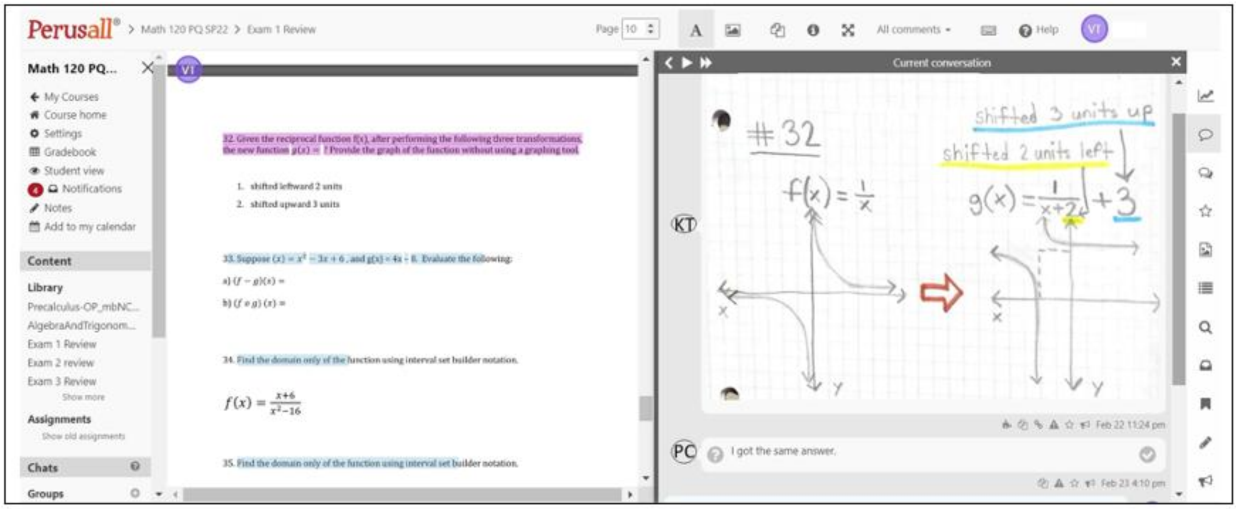

Figure 3. Student KT responses to Question 32 in a Perusall Assignment on Transformation of Functions

Whiteboard.fi. There were times in the online classes when students were overly quiet, making it challenging for the instructor to assess which students understood the material and which were struggling. In these cases, Whiteboard.fi was a useful tool. Whiteboard.fi provides an online whiteboard instructors can use to assess students. The application has a toolbar loaded with icons to help the user write easily on the board. They can write plain text, draw a picture, or quickly enter math expressions using the "insert math" icon. They can also add graphs, shapes, angles, image files, .pdf documents, and more to the board. The board can have one or many pages. Once it is ready to be shared, the instructor copies the unique URL link (room code or QR code) associated with the board and shares it with students; this gives every student their own individual whiteboard with work on it shared by their teacher. The instructor can see all of the students' individual edits to the board in real time.

Figure 4 represents the teacher's board only while Figure 5 depicts the teacher's board at the top of the screenshot and students' boards (shared by the instructor) at the bottom.

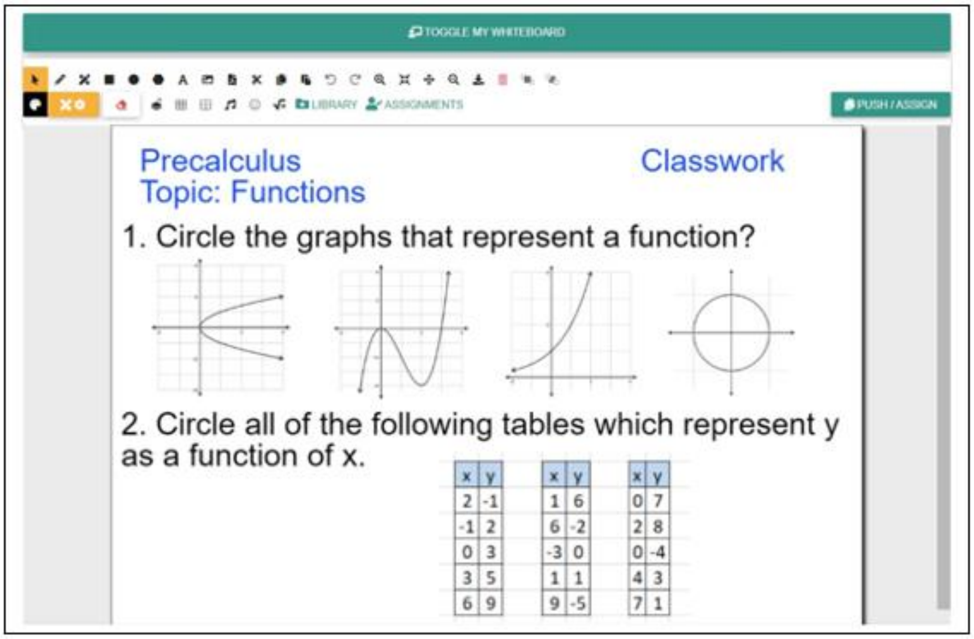

Figure 4. Whiteboard.fi – Instructor's board

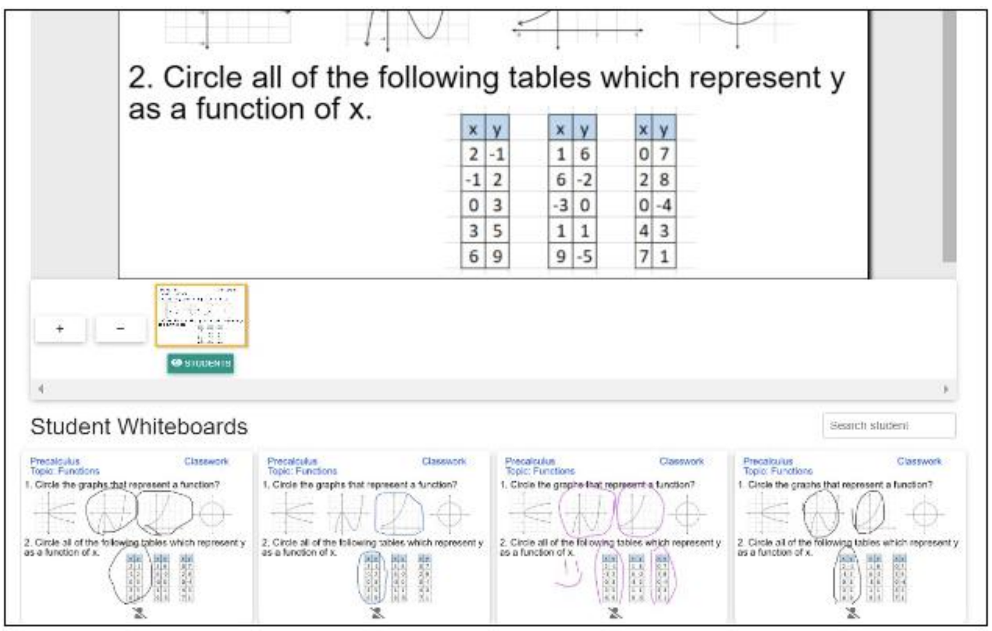

Figure 5. Whiteboard.fi – Instructor's board shared with students

Notably, as shown in Figure 5, students' boards do not include their names. The instructor can hide or reveal students' names based on preference. Moreover, Whiteboard.fi allows the instructor to join a student's board to write on it—such as to make corrections or simply to add a smiley emoji or check mark to indicate that the student did well on the assessment—by clicking the icon "enter student live session" (see Figure 6) and asking the student to accept their request to join their board. This replicates traditional in-person learning by allowing the professor to make corrections to students' paper in real time.

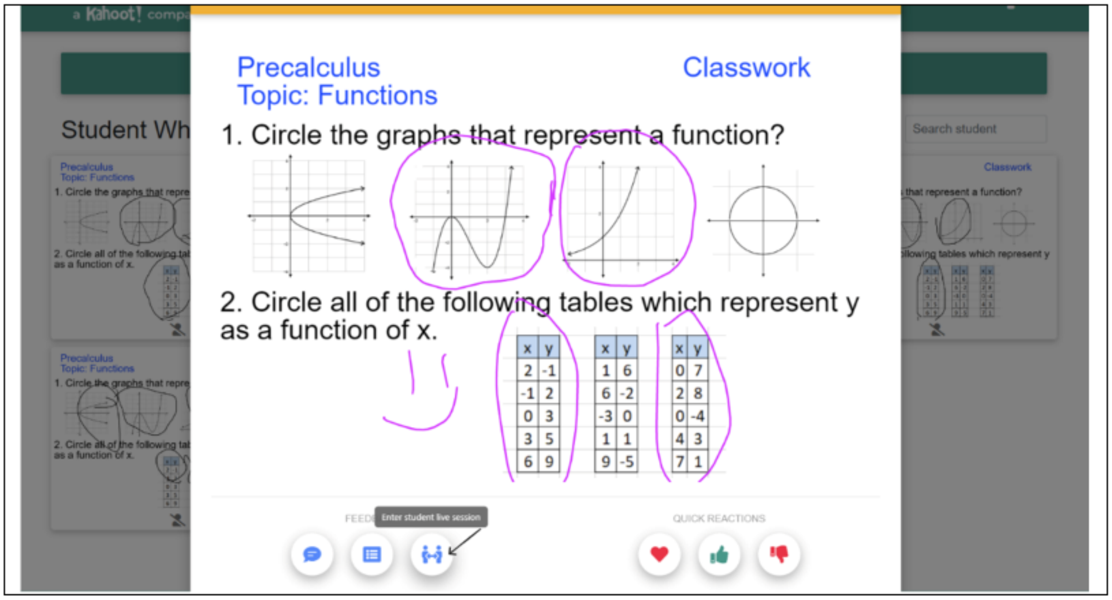

Figure 6. Whiteboard.fi – Instructor joins a student's board to write on it

Overall, Whiteboard.fi helped the instructor to engage every student in the class by providing opportunities for them to show their work. It provided an immediate overview of how students were performing. Because every student had their own individual board, the instructor could observe which areas students performed well in as well as where they struggled. Whiteboard.fi can be used during office hours and can be used to administer quizzes.

RQ2. What were students' overall satisfaction levels, attitudes, and opinions regarding their online pre-calculus course?

Near the end of the semester, students were encouraged to complete a survey to determine their overall satisfaction, attitudes, and opinions regarding learning mathematics online. Only 11 of the 30 students registered into the course completed the survey and were willing to share their responses in this study. Some students officially withdrew or stopped attending the course by the time the survey was administered, and maybe other didn't complete it due to the age restraint.

Table 1 displays interval measurements of means with verbal descriptions for the five-point Likert scale used in survey statements 1 to 19 in Table 2. The means of the descriptive statistics can be described using the verbal description (in Table 1) correlated with the interval.

Table 1

Interval Measurement for Likert Scale Statements Q1-19

Scale	Verbal Description	Interval
1	Strongly Disagree	1.00 – 1.80
2	Disagree	1.81 – 2.60
3	Neither Agree nor Disagree	2.61 – 3.40
4	Agree	3.41 – 4.20
5	Strongly Agree	4.21 – 5.00

For example, in the rows of Table 2, if the mean value falls from 4.21 to 5.00, we concluded that students generally strongly agreed with the survey statement.

According to the data on statements 1–19 in Table 2, students' overall satisfaction levels regarding learning math online were generally positive because the majority of students either agreed or strongly agreed with all of the statements except Q2 (mean = 2.82) and Q7 (mean = 2.91). For these two items, students tended to feel neutral about whether learning math online was challenging and whether the textbook helped them understand the material. With the abundance of digital resources available today, students are increasingly relying less on traditional textbooks for learning and more on video format.

Table 2

Descriptive Statistics on Student Satisfaction with Learning Mathematics Online

Statements	N	Mean	Percent				
			SD	D	Neutral	A	SA
Q1. My overall experience learning math online this semester was positive.	11	4.55	0.00	0.00	0.00	45.50	54.50
Q2. Leaning math online was challenging.	11	2.82	9.10	27.30	36.40	27.30	0.00
Q3. I felt at ease learning math online this semester.	10	3.80	0.00	10.00	20.00	50.00	20.00
Q4. I was able to access my learning materials easily online.	11	4.73	0.00	0.00	0.00	27.30	72.70
Q5. I was able to access my online assignments easily online.	11	4.55	0.00	0.00	9.10	27.30	63.60
Q6. The course assignments were not too difficult.	11	3.91	0.00	0.00	27.30	54.50	18.20
Q7. I used the textbook throughout the course to help me learn the material.	11	2.91	9.10	27.30	36.40	18.20	9.10

Q8. I found it easy to communicate online with other students in my class.	11	4.18	0.00	0.00	18.20	45.50	36.40
Q9. I found it easy to communicate with my instructor throughout the semester.	11	4.45	0.00	0.00	18.20	18.20	63.60
Q10. My instructor was responsive to my questions/concerns.	11	4.64	0.00	0.00	0.00	36.40	63.60
Q11. I learned a lot from the online (real-time) Zoom lectures.	11	4.27	0.00	0.00	9.10	54.50	36.40
Q12. I felt at ease participating in the lessons online.	11	4.27	0.00	0.00	27.30	18.20	54.50
Q13. It was easy for me to learn how to navigate in Lumen.	11	4.09	0.00	9.10	9.10	45.50	36.40
Q14. The videos in Lumen were helpful.	11	4.18	0.00	0.00	18.20	45.50	36.40
Q15. The Perusall assignments helped me study for the exams.	11	4.45	0.00	0.00	18.20	18.20	63.60
Q16. I felt like I could get help with the math from other students using Perusall.	11	4.09	0.00	9.10	18.20	27.30	45.50
Q17. Using Whiteboard fi increased my awareness of what I needed help with in the course.	11	4.18	0.00	0.00	9.10	63.60	27.30
Q18. Using Whiteboard fi allowed me to show the professor how well I understood the lesson.	11	4.27	0.00	0.00	18.20	36.40	45.50
Q19. Using Whiteboard fi during the online lesson made the lesson more engaging.	10	4.45	0.00	0.00	9.10	36.40	54.40

Notes: N = number of responses; SD = Strongly Disagree, D = Disagree, Neutral = Neither Agree nor Disagree, A = Agree, SA = Strongly Agree

Similar to Table 1, Table 3 shows interval measurements of means with verbal descriptions for the four-point Likert scale ratings used in statements 20 to 23 (Table 4). The means from the descriptive statistic be described in Table 4 using the verbal description (Table 3) correlated with the intervals.

Table 3

Interval Measurement for Likert Scale: Statements 20–23

Scale	Verbal Description	Interval
4	Always	3.28 – 4.00
3	Often	2.52 – 3.27
2	Sometimes	1.76 – 2.51
1	Never	1.00 – 1.75

Table 4 indicates that the majority of students participated often in the online lectures (mean = 2.80), often watched the videos provided in Lumen (mean = 2.91), and often reflected on the teacher's lecture files (mean = 2.55) because all three means fall within the interval [2.52, 3.27]. In addition, students overall searched for videos on websites like YouTube or Khan Academy for additional help with course materials sometimes (mean = 2.36.)

Table 4

Descriptive Statistics on Attitudes Towards Learning Mathematics Online

Statements	N	Mean	Percent			
			Never	Sometimes	Often	Always
Q20. How often did you participate in the online lectures?	10	2.80	0.00	40.00	40.00	20.00
Q21. How often did you watch the videos provided in Lumen?	11	2.91	0.00	45.50	18.20	36.40
Q22. How often did you reflect on the teacher's lecture files?	11	2.55	18.20	36.40	27.30	18.20
Q23. How often did you search for videos on websites like YouTube or Khan Academy for additional help with the course materials?	11	2.36	36.40	9.10	36.40	18.20

Note: N = Number of Responses

Lastly, students were given the opportunity to describe their opinions about learning mathematics online through three open-ended questions (Q24-26). Students were asked what they think makes online math classes challenging (Q24). The most common response from students was staying focused during synchronous learning. They also want clearer instructions from the instructor and need for better internet connection. Some stated that a lack of self-discipline made online learning challenging.

See specific comments made by students below:

> The challenging part was trying to focus online. In person, you are more focused on the lecture and more inclined to participate if there is an in-class assignment, but being online made that difficult.

> I personally got distracted often.

> [The challenge was] Staying focused.

> Online math classes can be difficult if the student is not disciplined. If I were to not pay attention one class, I would be lost and [must] study a lot to get back [on track]. But if the student is disciplined and does the work, it is not too challenging.

> The wifi mostly but stuff happens we can’t be in control of the wifi at the college

> I think an online math class gets challenging when there is a lack of communication between the professor and the students, not receiving feedback or clear instructions regarding the work and going over the course work back-to-back (fast).

When asked how they compared learning mathematics online to in-person learning (Q25), the majority of students reported preferring in-person learning because it keeps the class engaged and focused. Specific comments included the following:

> For me, at least, I like when math in-person is more about doing handouts—like learning the lesson and keeping the class engaged and seeing how well they understood and being able to participate with other students, too. Math online is different ‘cause it's just yourself and you can easily get distracted. Personally, class in person would be much more [engaging] and fun if the students would be able to communicate with each other instead of being solo.

> Learning math in person is definitely more engaging as you have direct feedback from your professor and other students that can support you.

> It's easier learning online since I don't have to leave my house but it is easier to stay engaged in-person.

Students were lastly asked to add any additional comments, including recommendations for future online math courses (Q26). While they viewed Whiteboard.fi, Lumen, Perusall, and online videos as useful resources, they wanted more practice problems and worksheets to apply various problem-solving techniques. For example, students remarked:

> Doing a review session before the quiz helps a lot.

> I would recommend having worksheets in math class. That way, students can go back to [the worksheets] whenever they want to rather than taking notes, which some might not even take or write down.

> I liked the videos on Lumen, but there were many times when the video only applied to one scenario of a kind of problem. For example, if the question has 4 different ways [that] it could be [solved], the video may only cover [one] way . . .
>
> While I liked the Perusall review, I think that the homework should have more questions that will be on the review/test. For example, the review may have all 4 different ways a problem can be written, but the homework will only have [one].
>
> Having the answers explained in class when we get them wrong is better than watching a video.
>
> Overall, I enjoyed this class. Whiteboard fi, perusall, lumen, and all the resources were really good and should always be used.

Discussion

The findings from this study reveal that students were generally pleased with learning mathematics online during their pre-calculus class as they agreed or strongly agreed with most of the Likert style satisfaction statements in the survey. Students felt at ease learning math online and reported participating often in lessons. Whiteboard.fi, Perusall, and Lumen enabled students to engage in lessons and permitted professors to evaluate students' comprehension and ability to solve problems. Students felt these applications were helpful resources for exam preparation, collaborating with other students, and increased their awareness of material they needed to work on. However, students wanted the teacher to provide more practice problems and worksheets that would require them applying different problem-solving techniques which would them prepare better for the exams. In Boloran's (2021) view, student opinions and satisfaction levels in online courses should not be overlooked because students tend to engage more when they are satisfied with their learning experience, thereby leading to better academic outcomes.

Students admitted that although learning online is convenient, staying focused is challenging due to background distractions. They also realized that if they did not pay close attention in class, they would fall behind and have to work hard to catch up. These findings support Kearsley's view that online learning is not suitable for every student and that "students without the necessary self-discipline and study skills find [this type of] teaching medium frustrating" (Engelbrecht & Harding, 2005, p. 271).

In this study, students preferred in-person teaching over online teaching, citing more access to the teacher and better engagement. This preference was also favored by students in studies that took place before the pandemic (Jaggars, 2014; Johnson et al., 2009; Mills & Raju, 2011). However, it should be noted that although higher education included online learning before the pandemic, most studies did not focus on how to implement online learning effectively in terms of replicating the in-person experience. Indeed, in 2005, Engelbrecht and Harding (2005) observed that "although much has been done to develop a pedagogy for distance learning and also for computer-based learning, a pedagogy for driving online courses in mathematics is still only in its development phase" (p. 1). Trenholm, Alcock, and Robinson's 2016 research on fully online mathematics courses determined that "the mathematics education research community knows little about this shift to [math taught fully online]" (p 147).

Engelbrech et al. (2020) questioned what the consequences of the pandemic will be on mathematics education and if 2020 (the start of the pandemic) will be the year in which education changed. While there is no concrete answer to these questions, it is vital for researchers to continue to assess the quality of online course delivery to measure satisfaction and student engagement. Since the beginning of the pandemic, a vast amount of research has addressed overall experiences of learning math online (see the Literature Review). This case study expands upon this branch of the literature by considering both student opinions and attitudes as well as specific ways students have engaged in the learning process. Radmehr and Goodchild (2021) recommended that institutions share experiences, challenges, and solutions in teaching online, which would aid in the development of best practices for this teaching modality. However, the researcher agree that institutions should not only continue to assess online mathematics courses but should also make changes that will facilitate maintaining and increasing student satisfaction levels in order to promote learning outcomes.

Limitations

The survey responses were low in this study; this may have been because the survey was administered at the end of the term, and students may have been tired of completing online work. Nevertheless, the results were meaningful and providing an understanding of how students felt about learning mathematics in the online environment. These results can be used to improve student experiences of learning math online in the future.

Conclusion

The sudden transition to online teaching caused by the COVID-19 pandemic brought numerous challenges, but it also opened the door for institutions to explore innovative uses of educational technology. The researcher / instruction featured in this study continues to use many of these tools (and more) in her mathematics courses—excluding Lumen—recognizing their value in enhancing instruction during the pandemic. She now uses MyOpenMath, a free alternative to Lumen, to support her teaching. While the future of online mathematics education remains uncertain, reflecting on current practices offers valuable insights for improving the delivery of this modality moving forward.

Resources

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