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## Students' Satisfaction and Performance in the Open Educational Resources (OER): Integrated Online Calculus Course

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## Students' Satisfaction and Performance in the Open Educational Resources (OER): Integrated Online Calculus Course

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### Abstract

Delivering an effective online mathematics course at the university level is more challenging than the offline mode because of the method course content's nature. One of the strategies to answer the challenges faced in an online learning environment is the utilization of Open Educational Resources (OER). This descriptive case study research investigates students' satisfaction and performance in the Open Educational Resources (OER)- integrated online calculus course. This study involved eight students who took a calculus course entirely online. The lecturer used various OER, both integrated into Canvas and during the online meetings. Students were satisfied with the online calculus course since it has met their expectations. The online course content and use of OER, classroom environment, and lecturer facilitation were three components that students find valuable. Likewise, students' performance in the online calculus course is excellent, where all students got grades A. Although students' performances in Unit Test 1 and Unit Test 2 are not as excellent as other assessments, they demonstrate active participation during the online meetings, frequently use OER, and consistently fulfill all assignments. They succeed in developing digital learning activities as their pair works and learning videos about the application of integral as their group projects.

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### Introduction

The COVID-19 pandemic has had significant impacts on human life globally. One of them is in the education field, where educational institutions must hold online learning effectively at all school levels. Teaching an online mathematics course effectively at the university level is more challenging than teaching in offline mode because of the method course content's nature. Lecturers who teach mathematics courses online may find it challenging to implement teaching strategies and learning activities that can be used effectively in face-to-face and online classes. The fact is that lecturer teaching strategies usually effective in face-to-face lectures are not necessarily effective when applied to online lectures (Coppola, Hiltz, & Rotter, 2001). Besides, there may be various other challenges, including, but not limited to, how to translate instructional strategies and activities designed for traditional face-to-face courses into online courses (Baran, Correia, & Tompson, 2011).

Despite the challenges faced by lecturers and students with online teaching-learning, some studies show that the

online course may provide a meaningful learning experience like the offline mode is carried out effectively. The results of Giovannella's research (2020) show that students can positively adapt to online learning during the coronavirus pandemic even though they were previously used to learning face-to-face. An extensive review of online learning fully concludes that students can be satisfied and perform well (Castro & Tumibay, 2019). The online course supports multiple modes of communication that fit with various students' learning styles and provides self-directed and collaborative learning opportunities. Thus, lecturers can facilitate powerful and effective online courses to achieve learning goals using the vast resources and capacities (The Illinois Online Network, 2005).

Effective online teaching depends on how lecturers design learning experiences appropriately and provide various instructional strategies that meet students' needs and promote students' engagement in the learning process (The Illinois Online Network (2005). Educators and experts have attempted to implement various strategies and resources in an online learning environment to answer the multiple challenges and problems faced in an online learning environment. One of these strategies is the utilization of Open Educational Resources (OER). Refer to the United Nations Educational, Scientific and Cultural Organization, OER is any educational material in the public domain or introduced with an open license (UNESCO, 2011). The nature of this open material is that anyone can legally and freely copy, use, adapt, and redistribute it. OER ranges from textbooks to curricula, syllabuses, lecture notes, assignments, tests, projects, audio, video, animation, technology tools, and software packages. Different OER types can be integrated into mathematics courses to make online courses more effective and interactive. In addition, OER will save time for lecturers as it is easily integrated into online courses.

In line with that, the Sampoerna University (SU) applies Canvas as its primary Learning Management System and encourages its lecturers to utilize various Open Educational Resources (OER) and technological platforms to optimize students learning in all courses. SU is one of the private Indonesian universities that aligns with American standards and focuses on students' success in their learning pathway. Thus, all SU students need to perform well and be satisfied with their learning experiences in all SU courses. Integral Calculus is one of the SU courses delivered entirely online and utilized the OER both in the Canvas shell and online meetings. The students have been doing various learning activities through Open Educational Resources (OER) such as Desmos Activity Builder, Padlet, and Microsoft whiteboard during meeting online with the lecturer for the Calculus course. Moreover, the Canvas modules are also embedded with alternative free reading materials, videos, or Geogebra Applets. All those attempts are made to promote students' learning to perform well and be satisfied with their learning experiences in an online calculus course. This research investigates students' satisfaction and performance in online learning that integrated OER into an Integral Calculus course. Thus, the following research questions are answered through this study: (1) How satisfied are students with the online calculus course?; (2) How do students perform in the online calculus course?

### **Incorporating Features of an Effective Online Mathematics Classroom**

Researchers have recently highlighted the importance of developing students' mathematical thinking and making

it visible by asking exciting and appropriate questions (Suurtamm, Quigley, & Lazarus, 2015). Students must be encouraged to work collaboratively and interact in ways that support and challenge their mathematical thinking (Artzt, Armor-Tomas, & Curcio, 2008). Protheroe (2007) describes an ideal mathematics classroom where students are actively involved in mathematics, making interdisciplinary connections, sharing mathematical ideas, and using manipulative strategies to solve mathematics problems. Lecturers also demonstrate accepting students' different strategies and ideas, influencing learning by asking challenging and exciting questions, and projecting positive attitudes towards mathematics. Liljedahl's (2016) research on "thinking classrooms" provides another example of an ideal mathematics classroom where students engage in collaborative problem-solving. One could easily imagine this happening in a face-to-face math class, but maintaining this approach in an online environment would be not easy.

Learning Management System (LMS) has several necessary components that allow collaborative engagement in an online platform for mathematics teaching and learning. For example, in an LMS, there is a forum for sharing ideas and discussions. Research shows that online discussion forums are an essential part of the online learning process (Cross & Palese, 2015; DeCosta, Bergquist, & Holbeck, 2015). In an online classroom (or any classroom), effective teacher-student, student-student, and student-student interactions build learning communities and promote active communication. Thus, lecturers need to build online learning environments for engaging students in mathematical thinking and communication.

Mathematical communication requires human senses and cognitive skills such as understanding, interpretation, visualization, mathematical ideas, and non-linguistic communication methods. In other words, communication and conceptualization of mathematics have a vital embodiment component (Sedaghatjou, 2018). Mathematical communication is multimodal and manifested and based on gestures, pointing, staring, and body language. Also, the process of understanding, interpreting, and visualizing mathematical graphs and pictures all play an essential role in learning mathematics in general.

One of the main tasks of learning mathematics is understanding, drawing, and interpreting graphs and mathematical objects (Healy & Fernandes, 2011). The vital role of diagrams is explored by Menz (2015), who goes one step further and suggests diagrams are the placeholder of mathematics. Understanding static diagrams or graphs provided in online classrooms becomes challenging without face-to-face interaction with the lecturer; however, being in the classroom does not necessarily mean understanding the instructor's graph or drawing. In such situations, Desmos Classroom Activity (DCA), with its dynamic features, is an excellent environment for students and teachers to experience mathematics. DCA promotes students to perform mathematical communication in an online learning environment.

Current technology makes it possible to use various interactive diagrams and representations in any desired LMS. GeoGebra, Desmos Classroom Activity (DCA), and other open-source tools can be embedded in all of the above LMS components where students can create, modify, and manipulate dynamic diagram mathematics to explore and discuss various mathematical concepts. By utilizing interactive diagrams, the online mathematics course has promoted students' mathematical communication through diagrammatic argumentation and

diagrammatic thinking.

## **Open Educational Resources (OER)**

Referring to the United Nations for Educational, Scientific and Cultural Organization, OER is any educational material in the public domain or introduced with an open license (UNESCO, 2011). The nature of this open material is that anyone can legally and freely copy, use, adapt, and redistribute it. Thus, a definition of OER should highlight a license that is as open as possible, encourages the right of access for everyone, and mentions users' ability to repurpose or adapt the resource. According to the William and Flora Hewlett Foundation, *Open Educational Resources are resources available in the public domain or issued under an intellectual property license that permits their free use and reuse. OER includes complete courses, course materials, modules, textbooks, streaming videos, tests, software, and other tools, materials, or techniques to support access to knowledge.* (Hewlett Foundation, [N.D.]). It can be concluded that OER is a wide range of teaching and learning resources that are available either in the public domain or under an open license.

The OER movement's primary goal is to make education more affordable and help learners achieve better learning outcomes. Hilton, Gaudet, Clark, Robinson, and Wiley (2013) claimed that utilizing OER into coordinated academic programs at the educational institution level will save students money and make education more affordable. Moreover, OER can play a vital role in online courses for many reasons. Some of the benefits include, but are not limited to, time-saving, easy integration, interactive nature, and free resources available. Apart from that, OER also saves costs for students because they can get free books, for example (Ko & Rossen, 2017), and help save lecturers' time because they can directly incorporate finished resources and activities into lessons. More importantly, OER replaces similar learning materials, enabling the same functionality (Orr, Rimini, & Damme, 2015) as face-to-face learning.

The integration of OER for teaching and learning purposes, particularly in mathematics education, is a high priority for many different countries and education systems. Mathematics teachers, educators, and researchers need to revise mathematics curricula and learning strategies to take advantage of various OERs, including electronic information technology (Fey, 1989). The National Council of Mathematics Teachers (2000) also emphasized the importance of using technology (OER) in mathematics education by stating that technology is essential in mathematics; it affects mathematics and enhances student learning. Various OERs contribute to student learning and facilitate instructional strategies for teachers in online and on-campus learning environments. However, lecturers must be willing to integrate and adopt new and relevant technologies that best suit learners' needs (Ludlow, 2001). OER helps equate online courses with the various on-campus aspects of similar courses if chosen and used appropriately.

Different OER types can be integrated into mathematics courses to make online courses more effective and interactive. Montgomery College (2015) categorized OER by content type into four groups: text-led, video-led, animation-led, and multiple media. Types of OER include complete courses, course materials, modules, learning objects, open textbooks, openly licensed (often streamed) videos, tests, software, and other tools, materials, or

techniques used to support access to knowledge. Thus, OER also includes various virtual manipulatives and mathematics applets that can be used in mathematics learning activities. Likewise, OER also includes various mathematics teaching videos showing students' problem-solving strategies when completing mathematics assignments.

Despite many types of OER for the online class environment, lecturers need to select and use it in mathematics learning. Sapire and Reed (2011) suggest that careful selection, adoption, modification, and implementation of OER by content experts have the potential to help students achieve quality learning experiences. Referring to Achieve.org (2011), some criteria of a good OER are:

- (1) be aligned to the curriculum or standards;
- (2) describe the subject matter;
- (3) support the teaching-learning process;
- (4) provide assessment opportunities;
- (5) provide technology interaction;
- (6) facilitate exercises and other practice activities;
- (7) give extension opportunities;
- (8) be accessible to all students.

One of the crucial aspects of utilizing OER in an online course is being aware of its authenticity, quality, and suitability, and it is necessary to choose them carefully based on the learning outcomes and objectives of the online course. Sometimes OER suitability also depends on the mathematics subject being taught (Miller, 2016). Lecturers are people who can understand and choose the most appropriate OER in mathematics learning. Thus, an effort should be made to provide insights and ideas on utilizing OER in online mathematics courses to make them more effective and interactive, similar to courses on campus.

## **Method**

According to Yin's classification accords with Merriam (1998), this research is classified as a descriptive case study since its purpose is to provide narrative accounts about students' satisfaction and performance in the online calculus course that integrates OER. Creswell (2013) argues that a researcher can deliberately choose participants and research sites that will support an in-depth exploration of the phenomenon under study in qualitative research. Thus, the participants of this study are eight students who took an online Integral Calculus course in the Odd semester academic year 2020-2021 at Sampoerna University. Furthermore, the role of the researcher in this study was as a participant-observer since the researcher taught the course and at the same time became a researcher to investigate emerging phenomena.

One of the characteristics of case study research is the existence of various data collection techniques that allow for in-depth analysis. Several data collection methods are recommended to strengthen the substance and understanding of the phenomenon being studied (Punch, 2009). Campbell and Fiske (1959) define triangulation as a powerful demonstration of concurrent validity, mainly qualitative research. The purpose of triangulation is

unrestricted to combine different kinds of data and relate them to enhance the findings' validity. Triangulation is applied in the data collection. Hence, the researcher uses various techniques of data collection: documents and records on Canvas and OER, questionnaires, and focus group discussions (FGD). In addition, the researcher uses several data collection techniques to gain a more holistic and better understanding of the phenomena under the research.

The question items used in questionnaires and focus group discussions (FGD) are developed according to the standards set by the university for students' satisfaction with SU course, which consists of course content, course assignments, and assessment, course environment, and lecturer's facilitation and professionalism. Furthermore, data of students' performance in the OER integrated-online Calculus course are collected from documents and records on Canvas and OER, which consist of students' works and responses. Students' performance assesses both from formative and summative assessments. Students were required to show their active participation during the online meetings, frequently access learning materials and OER given in the Canvas, complete all assignments, perform collaborative works, and pass Unit tests.

Creswell (2013) explained that the analysis and interpretation of data in qualitative research includes six stages. Researchers begin by collecting, organizing, and translating data for analysis. The second stage involves data exploration and coding according to the identified text segments. Third, coded segments are then used to formulate themes that provide a broader description of the phenomenon under investigation and contribute to the study's main findings. Such findings are then represented in a narrative discussion such as a chronology in the fourth stage. The fifth stage is to interpret research findings obtained from comparing the researcher's personal view of his findings and related literature. The sixth stage involves validating the accuracy of the findings primarily through triangulation and auditing.

## **Results**

This research was conducted in the Integral Calculus course for mathematics education students cohort 2019 in the Fall semester 2020- 2021. Lectures were held for 16 weeks using full online mode, where all lecture materials were managed using Canvas, an official Learning Management System used by the university. Lecturer always holds online meetings once a week through Google Meeting and utilizes several Open Educational Resources, both integrated on Canvas and direct online meetings.

During online meetings, the students were asked to access the Desmos Classroom Activity and Padlet. All learning activities during online meetings were carried out through these two tools. Students were asked to respond to the instructions and activities that the lecturer had designed through the tools. The students were also encouraged to learn independently after the online meetings ended. They completed the Individual Assignments and submitted their works on Canvas. The lecturer has shared various learning videos and utilizes OER as additional learning materials or a means for further exploration. In each module, they were given access to read learning materials available in Paul's Online notes, [math.libretexts.org](http://math.libretexts.org), Active Calculus, and additional explorations using Geogebra applet, Desmos graphing calculator, or Wolfram Alpha. Figure 1, 2 and 3 show

some screenshots of various OER used in the online calculus course, and the accesses were available on the Canvas.

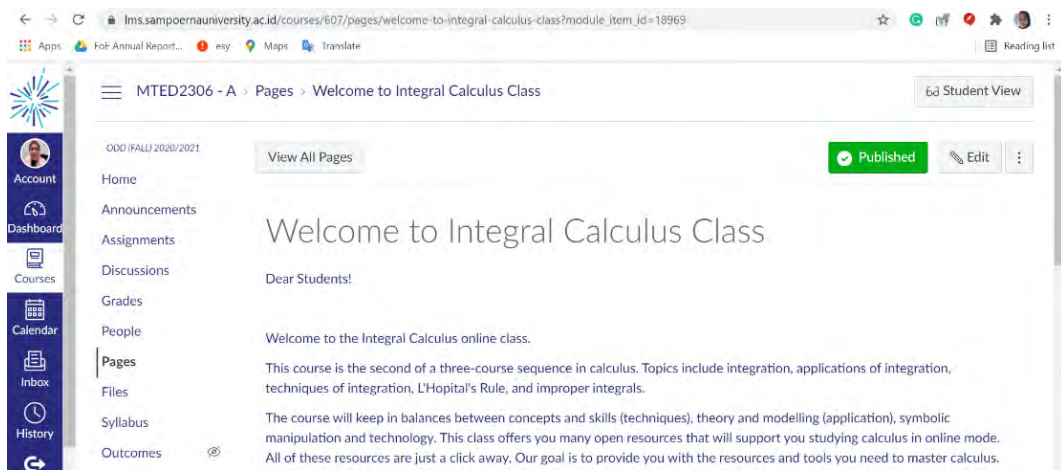


Figure 1. Welcome Page in the Canvas

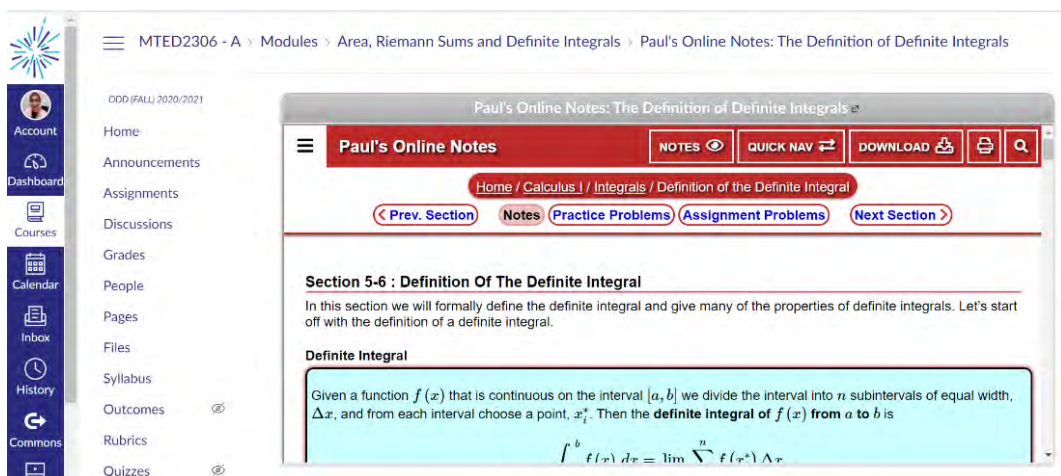


Figure 2. Paul's Online Notes Embedded in the Canvas

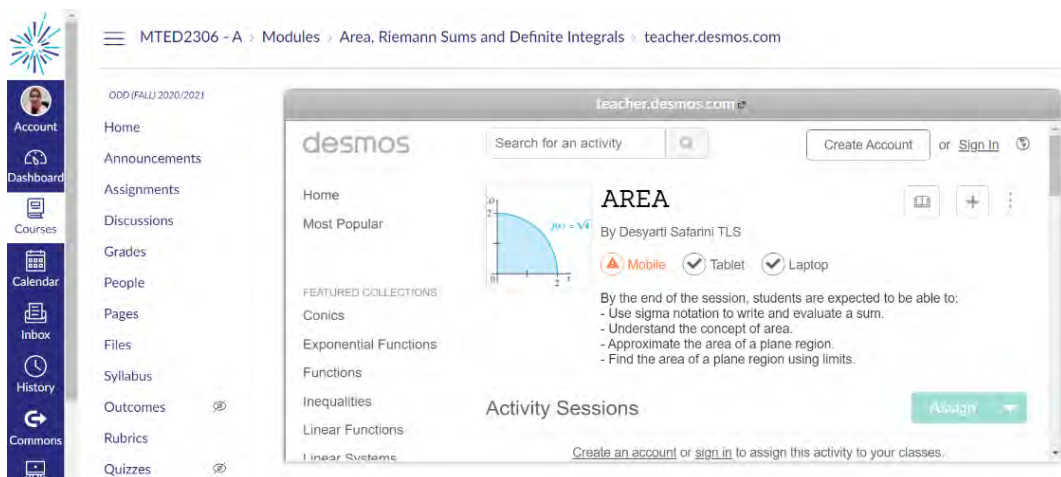


Figure 3. Desmos Classroom Activity Embedded in the Canvas



Furthermore, the students' performances were assessed through several assessments with different weights as shown in Table 1:

Table 1. Assessments of Online Integral Calculus Course

No.	Assessment	Weight	Remark*
1.	Unit Test 1	20%	Written test (Summative assessment)
2.	Unit Test 2	25%	Written test (Summative assessment)
3.	Class participations	10%	Scored based on online meeting participations and data from canvas
4.	Individual Assignments (1-14)	25%	Given every meeting
5.	Pair Project	15%	Students were work in pairs to create digital learning activities using desmos.teacher.com, which can be used to teach "Integration" for senior high-school students.
6.	Group Project	15%	Students were formed into two groups to create a video related to application of integration.
Total		100%	

In order to answer the research questions, the results of this study are presented in two sections.

### **Students' Satisfaction in the Online Calculus Course**

Based on the standards set by the university, there are several components of students' satisfaction with a course, which consist of course content, course assignments and assessment, course environment, and lecturer's facilitation and professionalism. Thus, students' satisfaction in the online calculus course will be explained as follows:

All students were satisfied with the online course content. They agreed that the course materials are valuable, the access to course materials is flexible and convenient, the course followed the syllabus well, and the online course is well organized. The details of students' satisfaction regarding the online course content can be seen in Figure 4. The results of this survey were confirmed through the Focus Group Discussion results, where all students agreed that the course materials were essential for them as prospective mathematics teachers. They also agreed that the lectures went according to the plan on the syllabus. The course materials are well organized on Canvas, and the lecturer provides many alternative reading materials, videos, and various free applications integrated on Canvas to master the course material better.

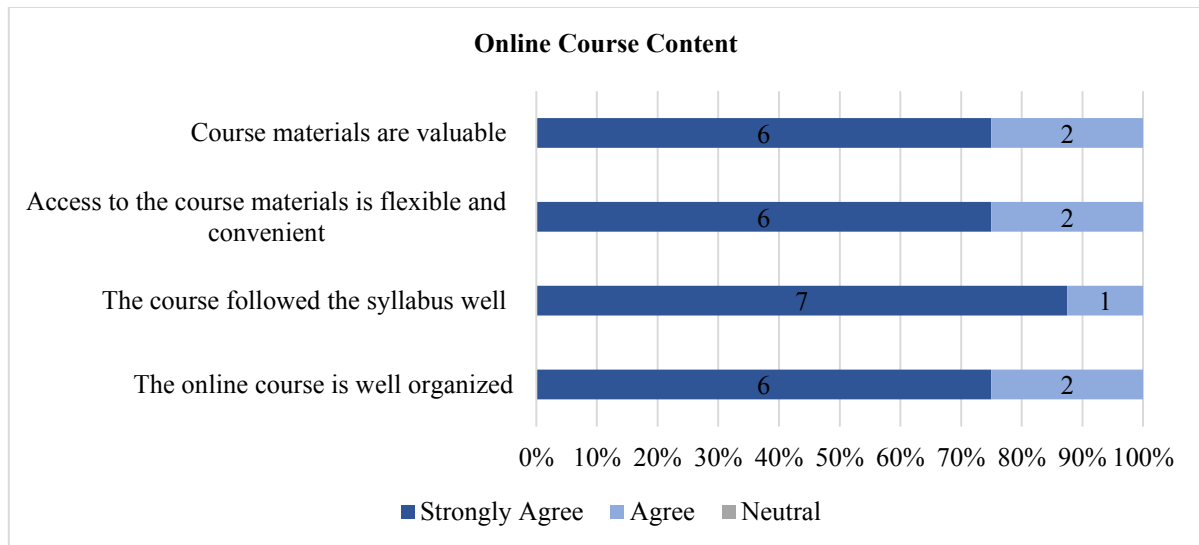


Figure 4. Students' Satisfaction on Online Course Content

The second component of students' satisfaction in the online calculus course is course assignments and assessments. All students agree that the graded assignments are useful. Also, the exams and the assignments are reflective of the course content. Meanwhile, not all students agreed that the workload for the calculus course was appropriate. According to students' responses in Focus Group Discussion, it was found that students felt exhausted to solve problems in the individual assignments which are given every week. However, they agreed that solving problems in the individual assignments helped them to understand the concepts better. Figure 5 represents the results of students' satisfaction with online course assignments and assessments.

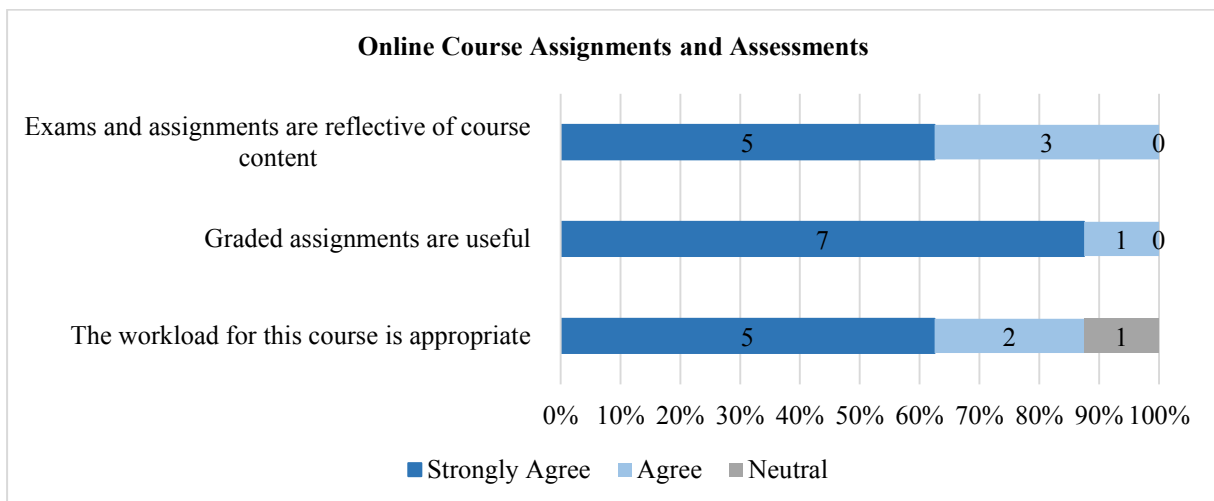


Figure 5. Students' Satisfaction on Online Course Assignments and Assessments

Regarding students' satisfaction with the online learning environment, all students agreed that they were encouraged to express themselves, to communicate with other students and the lecturer, to think carefully about the topics, and to form new ideas and understandings, they develop a deep understanding of the course topics and develop intellectual skills. However, a student gave a neutral response to the statement: this course helped

me develop professional skills. Based on the FGD results, it was known that all students agreed that the course helps them develop professional skills, specifically oral communication, technology literacy, and teamwork. This course forced them to actively communicate in English during the online meeting because the lecturers frequently asked students to respond to her instructions in Desmos Classroom Activity.

The students were also forced to use various OER within one semester and develop Desmos Classroom Activity as part of their pairwork. They also collaborated in their group project to create a learning video related to the application of integral. The details of students' satisfaction regarding the online course learning environment are captured in Figure 6.

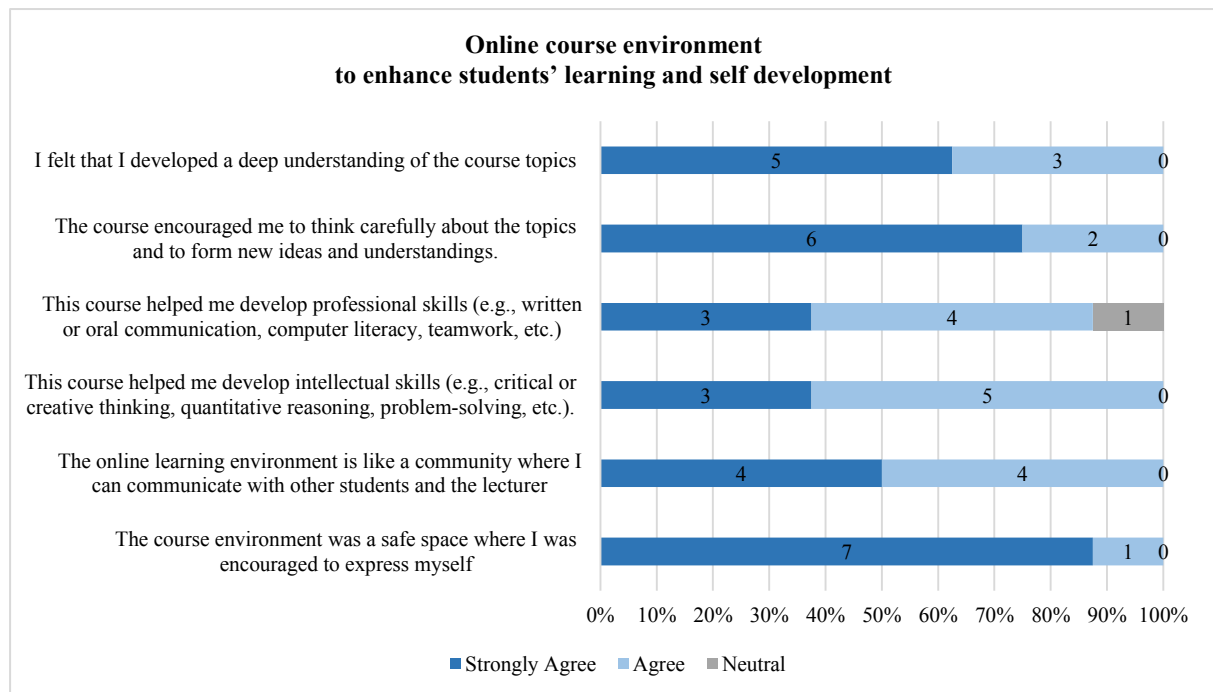


Figure 6. Students' Satisfaction on Online Course Environment

The fourth component of students' satisfaction in the online calculus course is the lecturer's facilitation and professionalism. All students were satisfied with the lecturer's facilitation and professionalism. They even strongly agreed that the lecturer is a technology-savvy facilitator who met their expectations for the quality of online facilitation.

All students agreed the lecturer was well prepared for class, used class time effectively, presented the course material in a clear manner that facilitated understanding and provided helpful feedback, encouraged students' participation in class, stimulated students' interest in the subject matter, and the online teaching methods are effective. The students were also satisfied with their online learning experience because they still get the same explanation from the lecturer as in face-to-face lecture sessions. Similar responses were confirmed from the FGD session. Figure 7 shows students' satisfaction with the lecturer's facilitation and professionalism.

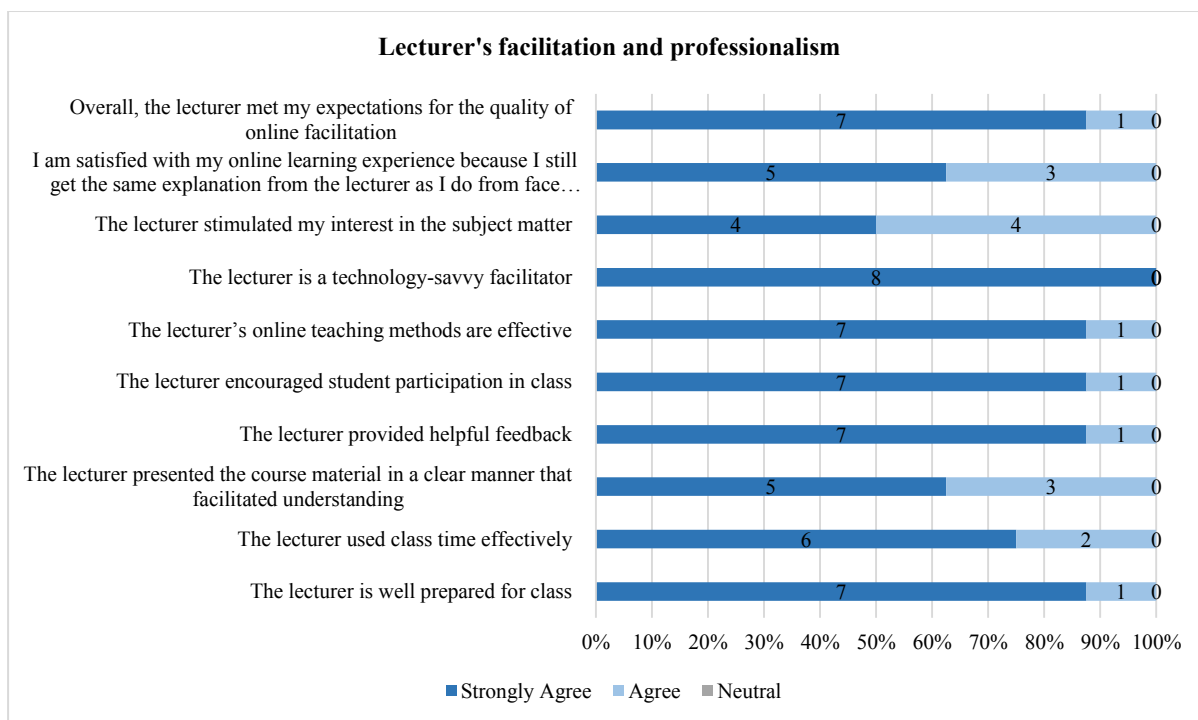


Figure 7. Students' Satisfaction on Lecturer's Facilitation and Professionalism

The researcher also gathers information about students' satisfaction with Open Educational Research in the online calculus course. All students agreed that the lecture becomes more interactive rather than in the traditional classroom. Most of the students also agreed that they enjoy using various applications and perform well during online activities. There was a student who picked a neutral for that statement. According to the FGD results, some students informed that their internet connection becomes slow when they simultaneously run several applications. Thus, they suggest using only Google Meeting and Desmos Classroom Activity during the online meeting. Although, they believed that several applications were also considered necessary for their learning (see Figure 8).

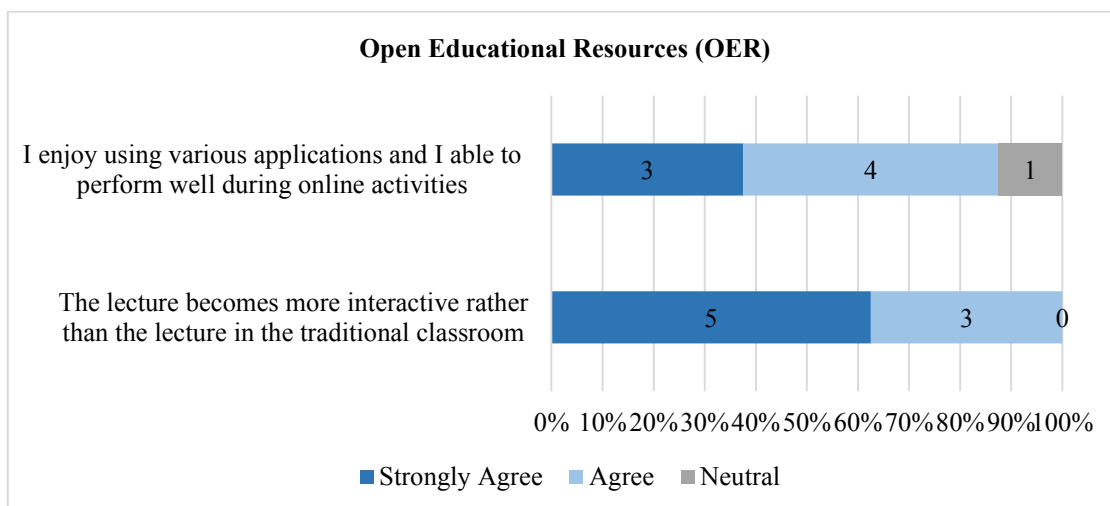


Figure 8. Students' Satisfaction on the Use of Open Educational Resources

All students agreed that Desmos Classroom Activity, Microsoft Board, and Desmos graphing calculators were valuable applications for the online learning activity. All students agreed that Desmos Classroom Activity is essential to support their learning during the online meeting. In comparison, the Geogebra applet is the least essential application and may not be available to support their online learning. Those responses may arise because the GeoGebra applet is rarely used during online meetings and is only shared via canvas with the aim of students being able to explore independently. Some applications always used in online meetings were Desmos Classroom Activity, Padlet, and Microsoft Whiteboards. Unfortunately, students seem to see that the use of Padlet is not essential for their learning since they can still give their responses through Desmos Classroom Activity although Padlet offers convenience for students to submit responses in photos of students' handwriting in an attractive wall display. Students prefer to use fewer applications during online meetings since the internet connections were getting slow when using several applications simultaneously. Figure 9 shows students' responses regarding the use of OER.

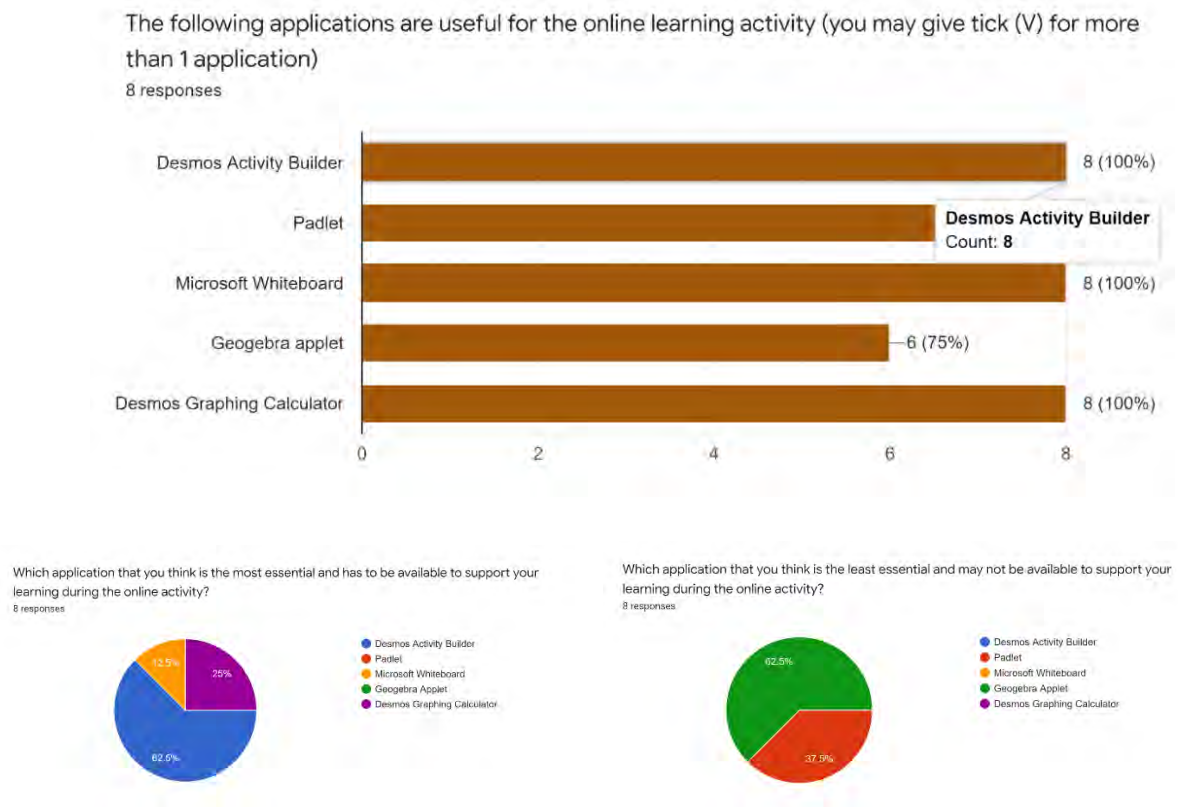


Figure 9. Students' Responses Regarding OER Use

Overall, all students felt satisfied with the online calculus course. They strongly agreed that the course met their expectations, and the online learning environment promotes sharing and caring among all participants (lecturers and students). Most of them agreed that the online learning activities made studying the course interesting and engaging. Students also mentioned that the valuable aspects of the online Calculus course were the class environment, especially during the online meetings, the lecturer's facilitation, and the online course contents and OER use. The following statements were excerpts of responses from S1 and S2:

R: *“What aspects of this course were most useful or valuable?”*

S1: *“The lecturer explanations, its teaching platforms and learning environment.”*

S2: *“The learning process that use various of application and the activities also encourage us to learn more about the topic besides all materials are available in Canvas plus many learning videos. I feel so energetic and happy to hear your voice during the learning.”*

### Students’ Performance in the Online Calculus Course

Students’ performance in the online Calculus course was excellent since they got an A grade and the average course grade was 91.67%. All students successfully fulfilled weekly Individual Assignments, actively participated in online meetings, worked in pairs to develop Desmos Classroom Activities, worked in groups to create learning videos, and passed the Unit Test 1 and Unit Test 2. The average score of all assessments is shown in Table 2.

Table 2. The Average Score of All Assessments

<b>Assessment</b>	<b>Average Score</b>
Online Meeting Participations	100.0
Roll Call Attendance	100.0
Individual Assignment 1	100.0
Individual Assignment 2	100.0
Individual Assignment 3	99.4
Individual Assignment 4	100.0
Individual Assignment 5	98.8
Individual Assignment 6	100.0
Individual Assignment 7	99.4
Unit Test 1	83.2
Individual Assignment 8	99.4
Individual Assignment 9	100.0
Individual Assignment 10	100.0
Individual Assignment 11	100.0
Individual Assignment 12	100.0
Group Project	100.0
Individual Assignment 13	100.0
Individual Assignment 14	98.8
Unit Test 2	76.1
Pair Project	91.3

Students' performances in Unit Test 1 and Unit Test 2 were not as excellent as other types of assessments. The average scores on Unit Test 1 and Unit Test 2 were 83.2% and 76.1%, respectively. The lowest and highest scores in Unit Test 1 were 61.3% and 97.5%, respectively. Meanwhile, the lowest and highest scores in Unit Test 2 were 50% and 97.5%, respectively. Based on this data, it appears that students' performances tend to be more diverse; there were students with sufficient, satisfactory, very good, and excellent performance. Students' performance on Unit Test 1 was also better than the ones on Unit Test 2 (see Figure 10).

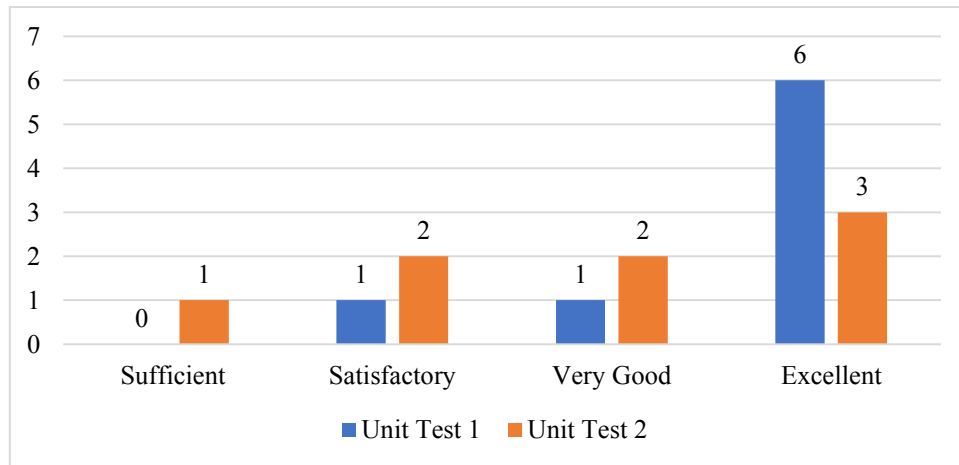


Figure 10. Students' Performance on Unit Test 1 and Unit Test 2

Students' performance was not only assessed using the summative assessment given in Unit Test 1 and Unit Test 2; students' active participation was also an important component and became part of the assessments. All students show that they frequently access OER on Canvas, where based on the data, the total page views made by students were in the range of 219-1.028. In other words, on average, students accessed Canvas 13-64 times per week. The majority of students have also submitted the assignments on time, with a range of 84%-100%, with an average of 94.125%. Table 3 shows the data regarding each student' performance in the online Calculus course.

Table 3. Students' Performance in the Online Calculus Course

<b>Student's Code</b>	<b>Final Grade</b>	<b>Final Score</b>	<b>On time submission</b>	<b>Total Page Views</b>
AAB	A	94	84%	1.028
HAC	A	91	100%	319
AJF	A	91	95%	587
NKA	A	93	95%	219
SRM	A	94	95%	1.023
BP	A	95	100%	622
AAR	A	88	89%	853
FOV	A	87	95%	608
<b>Average</b>		<b>91.67</b>	<b>94.125%</b>	

To assess students' performance during the ongoing online meetings, the lecturer refers to students' written responses collected through Desmos Classroom Activity (DCA) and Padlet. The lecturer might also use students' verbal responses during the meeting to assess their understanding and participation. Students were encouraged to engage in online meetings since they had to actively respond to the lecturer's instructions on every screen of DCA. Those who wish to write down their response in more detail were allowed to write the response on a piece of paper and then take a picture of it, and finally, they must upload their response in Padlet. Besides, students were also asked to write their learning reflection at the end screen of DCA. All students showed enthusiasm during the online meetings. They actively responded to the lecturer's questions or instructions and wrote their answers and reflections in DCA and Padlet. Figure 11, 12, and 13 show samples of students' responses in DCA and Padlet.

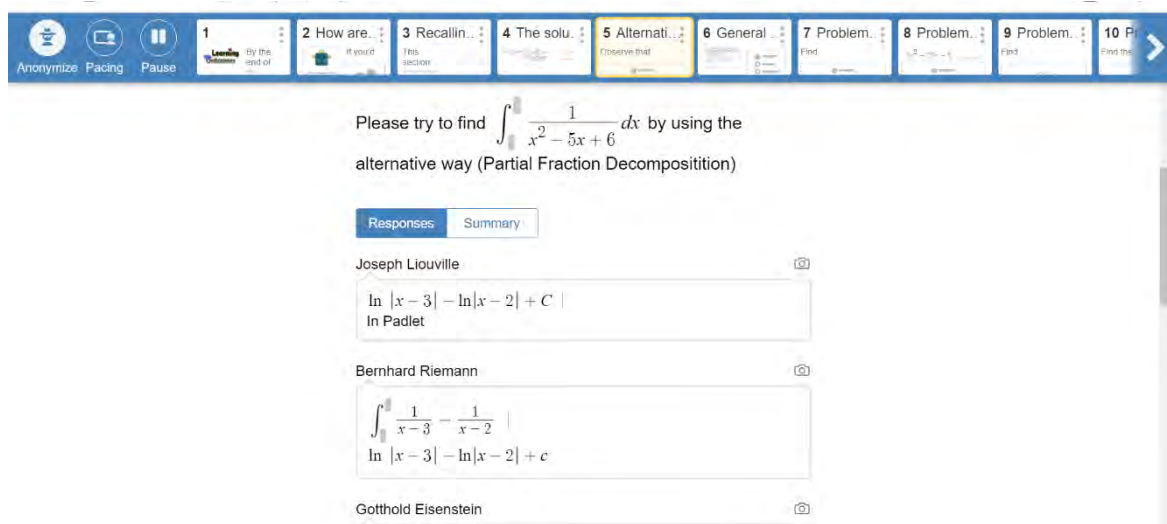


Figure 11. Student's Response in the Desmos Classroom Activity

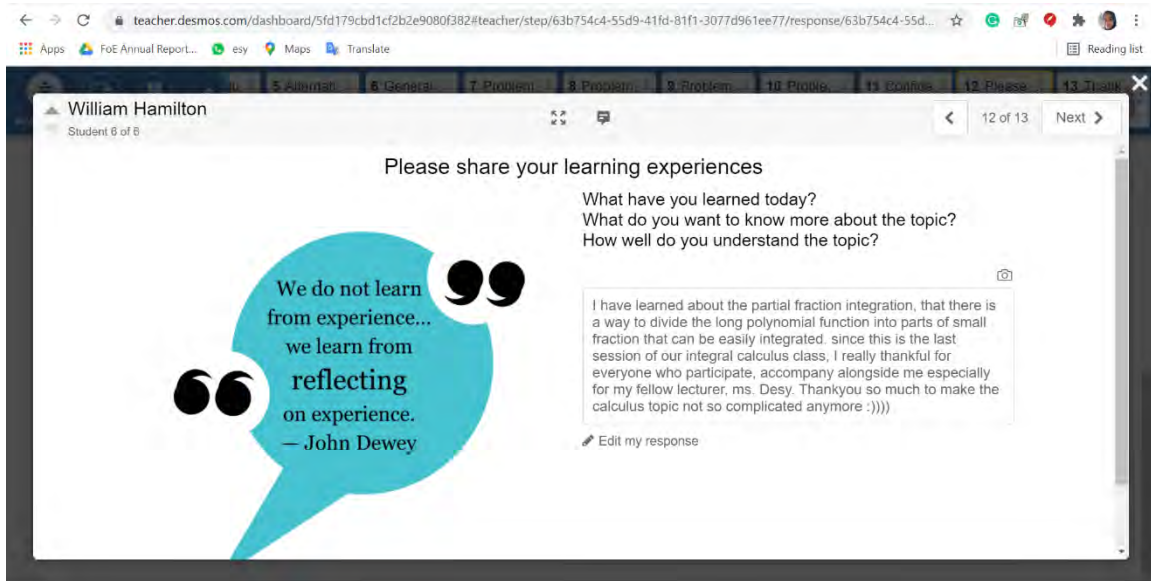


Figure 12. Sample of Student's Reflection in the Desmos Classroom Activity



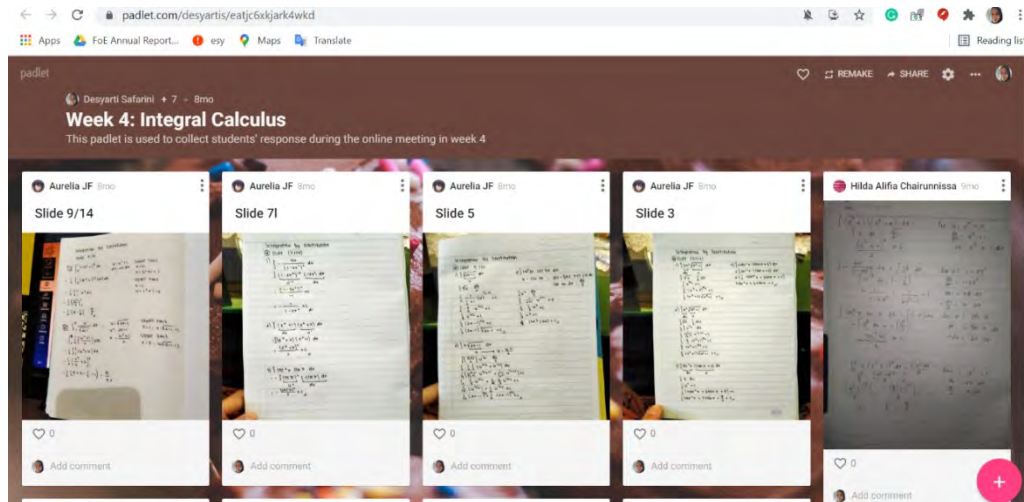


Figure 13. Students' Responses in the Padlet

The students were also required to perform pair work and group projects as part of their assessment in the Online Calculus course. The pair work assignment was to create digital learning activities using Desmos Classroom Activities ([desmos.teacher.com](https://desmos.teacher.com)), which can be used to teach “Integration” for senior high-school students. The digital learning activities should cover the use of all DCA features. The quality of digital learning activities was assessed using the Triple E Framework (<https://www.tripleeframework.com/triple-e-printable-rubric-for-lesson-evaluation.html>). The average score for pair work was 91.3%. This result can be considered excellent since the digital activities have used all DCA features and met the Triple E Framework rubric requirement. Moreover, the group project assignment was to create a learning video explaining how to find the volume of a solid revolution. The video duration was about 10 minutes, and students were required to be creative on the project. Students must refer to the given rubric and other supporting materials to conduct the project appropriately. The average score for the group project assignment was 100%. The pair work and group project assignments results can be accessed online by the public and the data can be seen in Table 4.

Table 4. Students' Pairwork and Group Project Results

Assignment	Results
Pair works	Pair work 1: Antiderivatives and Indefinite Integration <a href="https://teacher.desmos.com/activitybuilder/custom/5fdc97e13d57950cfd4326b5">https://teacher.desmos.com/activitybuilder/custom/5fdc97e13d57950cfd4326b5</a>
	Pair work 2: Area, Riemann Sums, and Definite Integral <a href="https://teacher.desmos.com/activitybuilder/custom/5fdc546561448d0d40f153e2">https://teacher.desmos.com/activitybuilder/custom/5fdc546561448d0d40f153e2</a>
	Pair work 3: The Fundamental Theorem of Calculus <a href="https://teacher.desmos.com/activitybuilder/custom/5fddeb63d29c2e3ca88b933f">https://teacher.desmos.com/activitybuilder/custom/5fddeb63d29c2e3ca88b933f</a>
	Pair work 4: Integration by Substitution <a href="https://student.desmos.com/activitybuilder/student-greeting/5fdc8b33e4c44a0d0481a7fa">https://student.desmos.com/activitybuilder/student-greeting/5fdc8b33e4c44a0d0481a7fa</a>
Group Projects	Group Project 1: Disk Method <a href="https://www.youtube.com/watch?v=UlfopD07cv8">https://www.youtube.com/watch?v=UlfopD07cv8</a>
	Group Project 2: Solid of Revolution: Shell Method EXPLAINED! <a href="https://www.youtube.com/watch?v=28pijIIIVec">https://www.youtube.com/watch?v=28pijIIIVec</a>

## **Discussion**

### **Research Question 1: How satisfied were students with the online calculus course?**

Students were satisfied with the online calculus course because it has met their expectations. The survey results and FGD showed that students were satisfied with all components set by the university, i.e., course content, course assignments and assessment, course environment, and lecturer's facilitation and professionalism. The online course contents and OER use, the class environment, and the lecturer's facilitation were several components considered valuable.

Regarding the course contents, all students agreed that they were valuable and well-organized. The lecturer provides many alternative videos and OER integrated on Canvas to help students better master the course material. OER offers similar learning materials and experiences, enabling the same functionality as face-to-face learning (Orr, Rimini, & Damme, 2015). Furthermore, all students agreed that Desmos Classroom Activity was the most important application for supporting their online learning. Unfortunately, Padlet was deemed unnecessary for their learning because they could still respond via Desmos Classroom Activity. Despite this, Padlet allows students to submit photos of their handwriting on an attractive wall display.

Regarding the online learning environment, all students agreed that they were encouraged to express their responses, communicate with other students and the lecturer, form new ideas and understandings. They also agreed that the course helps them develop professional skills, particularly oral communication, technology literacy, and teamwork. They had to respond to the lecture's written and verbal instructions during the online meeting. They were required to use various OER over one semester and create a Desmos Classroom Activity as part of their pair works. They also worked together to create a learning video about the applications of integrals. The lecturer's facilitation was also a valuable component of students' satisfaction in the online calculus course. The lecturer met all of the students' expectations for the quality of online facilitation. Lecturers need to build learning environments for active and student-centered online settings (Ragan, 2009, p. 6). In line with that, all students agreed that the lecturer provided a clear explanation and helpful feedback, encouraged student participation in class, stimulated students' interest in the subject matter, and used effective online teaching methods.

Regardless of positive responses from the students about their satisfaction with the online calculus course, there is still room for improvement. Not all students agreed that the calculus course workload was appropriate in terms of course assignments. Students felt hard while attempting to solve many problems in weekly individual assignments. However, they did agree that solving problems in individual assignments helped them understand the concepts better. Therefore, the lecturer may reduce the number of questions in individual assignments for future calculus courses. It is in line with Sapphire and Reed's (2011) study, which suggests that careful selection of OER by educators can support students in achieving quality learning experiences. Thus, another aspect that can be improved is to use only Google Meet and Desmos Classroom Activity during the online meeting. Some students reported that when they run multiple applications simultaneously, their internet connection becomes slow. Nonetheless, they believed that several applications were also required for their learning.

## **Research Question 2: How did students perform in the online calculus course?**

Students' performance in the online calculus course was excellent, as all students got grade A, and the average course score was 91.67. Furthermore, all students completed weekly Individual Assignments, actively participated in online meetings, collaborated in pairs to create Desmos Classroom Activities, worked on group projects to create learning videos, and passed Unit Tests 1 and 2. Students' performances on Unit Test 1 and Unit Test 2 were not as excellent as other types of assessments. The average scores on Unit Test 1 and Unit Test 2 were 83.2% and 76.1%, and it appears that students' performances tend to be more diverse; there were students with sufficient, satisfactory, very good, and excellent performance.

Another vital component in students' performance in the online calculus course was students' active participation in online meetings, accessing the OER, and completing Individual Assignments on the Canvas. All students showed great enthusiasm during the online meeting; they actively responded to lecturers' questions or instructions and wrote their answers and reflections on DCA and Padlets. Previous research found that discussion during online meetings is an essential part of the learning process and becomes part of formative assessments (Cross & Palese, 2015; DeCosta, Bergquist, & Holbeck, 2015). In addition, students actively access OER on Canvas about 13-64 times per week. All students consistently fulfill the assignments given by the lecturer, and the majority submit them on time, with an average assignment score of 94.125%.

Researchers suggest educators encourage students to work collaboratively and build interactions in ways that support and challenge each other's strategic thinking (Artzt, Armor-Tomas, & Curcio, 2008; Davidson, 1990). In this study, students were also required to complete pair work and group projects. They show excellent performances in those two assignments. The average score of the two assignments were 91.3 and 100. Students successfully created digital activities using the DCA platform and met the Triple- E framework rubric for effective educational technology tools. In addition, the group project assignment was successfully produced two learning videos that explained the application of integral.

## **Conclusion**

The students were satisfied with the online calculus course because it has met their expectations. Some of the valuable components were the online course content, OER use, the classroom environment, and lecturer facilitation. All students agreed that the course content was valuable and well organized as many alternative videos and OER are integrated on the canvas to help them master the concepts. Mathematics educators should utilize various OER in their mathematics teaching-learning strategies to gain many advantages (Fey, 1989). Moreover, Desmos Classroom Activity was also rated as the most critical application to support their learning. They also agreed that the learning environment encouraged them to express their responses, communicate with other students and lecturers, form new ideas and understandings, and help them develop professional skills. Lecturer's facilitation also met students' expectations of the quality of online facilitation.

The students' performances in the online calculus course were excellent where all students got grades A. Although the students' performances on Unit Test 1 and Unit Test 2 were not as excellent as other assessments, students showed active participation and great enthusiasm during the online meetings and frequently used OER. All students consistently fulfill the assignments given by the lecturer. They also showed excellent performances in Pair work and group project assignments by successfully developing digital learning activities in the DCA platform and creating learning videos related to the application of integral.

## Recommendations

Despite many positive responses from students, they find it hard to solve many questions in weekly individual assignments. Therefore, lecturers may reduce the number of questions in individual assignments in the future. It was also recommended that lecturers only use necessary applications during online meetings to avoid slow internet connection problems.

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