Open Educational Resources (OER) & Calculus: Pre- and Post-Pandemic

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Abstract

Before the creation of Massive Open Online Courses and Creative Commons, Calculus has always been taught face to face, i.e., in person which has been quite effective given all the competent STEM graduates and labor force of the 20th century. When the COVID-19 pandemic set in, every university mathematics department started teaching Calculus virtually using Open Educational Resources. Utilizing free e-books and lecture video recordings became normal. How has this OER transition and implementation impacted the learning of STEM students? Most published articles delved with generalized learning outcomes in their study methodologies and results. What about assessing OER's impact on students' learning at the level of course specific and measurable learning objectives? This research reports on the impact of Calculus OER on specific students' learning outcomes; presents trend analyses of the students' performance and success rates at each specific learning objectives in the course.

Introduction

Calculus curriculum reform effort was started in 1989. Hahn (2022) discussed in his book the application of the two-decade reform and its future technological and pedagogical implications as started by Callahan et.al. (1988). Ferrini-Mundy, J., & Graham, K. G. (1991) reported that the development of topics to be taught in Calculus have issues for learning and teaching. Over the last two decades, Calculus has been taught as a sequence of three 4-credit hour courses: Calculus 1 (Single Variable) to Calculus 3 (Multivariable). The curricular development and improvement over the years have effectively led to stronger foundations of STEM majors and graduates. Bullock, Callahan, and Cullers (2017) reported via the American Society for Engineering Education in 2017 that "strong effects on women and underrepresented minorities (URM) retention. The new Calculus course improved retention for both groups by more than 9 percentage points." Hagman (2019) recommended a "forward-thinking college Calculus program, as one designed to support a diverse population of students to thrive, provide an example of a program aligned with this approach, and discuss key features to consider in designing a calculus program for the modern age."

Collins and Galbreath (2022) presented a case study comparing traditional and virtual teaching of Calculus. This study was the result of the COVID-19 pandemic when in the middle of Spring of 2020, students and instructors were forced to teach and learn, respectively, virtually, i.e., 100% online classes. The article talked about analytic reflection as a method of studying the similarities and differences of traditional (face-to-face or in-person) and virtual teaching (online). In the article on teaching Calculus at Urban HBCU through a Global Pandemic,

Stanberry & Payne (2023) "wanted to understand the students' perspectives on the impact of the pandemic on their learning" (Stanberry, M. L., & Payne, W. R. 2023, p. 353). One question was posed via an anonymous survey: ``Has the COVID-19 pandemic impacted you regarding learning calculus?'' A few students' comments were reported, and one comment stood out. "No, calculus has been a consistent course because we are constantly engaging by working examples." This comment reflects students' realizing that to learn Calculus, students must be engaged via meaningful and relevant real-world problem exercises and examples. This student response started with a "No". This means that the delivery or teaching modality (in person or online) is not a factor in the learning of important concepts in Calculus.

Open Access Movement

Headquartered in San Francisco, Creative Commons (CC) was officially launched in 2001 while Massive Open Online Courses (MOOCs) started in 2008. Lawrence Lessig started CC while Dave Cormier at the University of Prince Edward Island and Bryan Alexander of the National Institute for Technology in Liberal Education in Canada coined the term MOOC. MIT OpenCourseWare was announced in 2001 and uses Creative Commons Attribution-NonCommercial-ShareAlike license. This initiative has been creating new opportunities for millions of learners and educators, sharing Open Educational Resources (OER) from MIT, and helping to lead a global revolution in free access to knowledge."

Effectiveness of Open Knowledge Initiatives

Borwein et al (2008); Bouche (2008) talked about "digital mathematics library" and the possibility that "most published materials in mathematics be openly accessible to the public". Suber (2012) wrote a book discussing the "concise introduction to the basics of open access." The impact and effectiveness of Open Knowledge movement have been nuanced and multifaceted based on the article by Tenant et. al. (2016). While Open Access provides a strong foundation for increasing engagement and leveling the field, this movement can be unsustainable given the possibility of unregulated publishing environment. Conole and Brown (2018) critiqued the rise and impact of the open education movement on learning by describing the important aspects: Open Educational Resources (OER, e-textbooks and MOOCs). In this paper, we treat e-textbooks such as those provided by OpenStax© as part and parcel of the OERs.

Before the COVID-19 pandemic, some researchers, mostly instructors have already started providing the public free access to scholarly materials via their own personal and/or institutional webpages. Then CC and MOOCs made a broader impact worldwide. Kersey (2019) wrote as a conclusion of his published article on Open Praxis that "OER materials are effective but recommend that care is taken to ensure the free materials provide a quality experience." Delgado et. al. (2019) summarized the results of their study stating that "(i) OER materials do not, in general, lead to any significant change in student final exam performance; and (ii) OER materials have a significantly positive impact on both international students and Pell Grant eligible students."

When the pandemic arose in 2020, several universities and colleges had already collected materials that would

make the utilization, transition, and implementation of OERs in higher education courses. Higher education instructors made use of e-textbooks provided by OpenStax©, a part of Rice University nonprofit arm. As of this writing, OpenStax© reported that 70% of higher education institutions in the US utilize the e-textbooks which are free as pdfs. Free online homework platforms such as MyOpenMath became a highly beneficial and suitable tool to both students and instructors especially in the learning and teaching of Calculus. An appropriate example is how the mathematics community contributed to the creation of course materials to be shared, reused, and revised, if needed, to suit the specific needs of each course instructor and be aligned with the course student learning outcomes. Aside from the laudable cost of textbooks saving for students, the impact on students' learning have been reported. Newton & Rajagopal (2021) discussed in their paper that teachers, students, and researchers have benefited from all the open educational resources made available by these open access and knowledge movements. Austin (2023) wrote an article on how the mathematics community come together to create free textbooks accessible to students.

Most of published articles before the pandemic were focused on the cost, outcomes, usage, and perception model. Hilton et.al. (2013) reported that (a) significant cost savings was achieved; (b) mixed results as to student learning happened; (c) neither teachers nor students reported meaningful increases in student use; and (d) both teachers and students perceived OER as useful but could be improved. Beile, Penny and Avila, Sandy, (2019) described textbook affordability at University of Central Florida. Jung, Bauer, and Heaps (2017) described the successes and failures of OER implementation in higher education institutions. Colvard, Watson, and Park. (2018) researched and found from a large-scale study that OER improve certain metrics such as end-of-course grades, decrease drop, withdraw, and fail rates for all 21,822 students. Davis and Cartwright (2020) wrote that their book chapter "highlights the four-year results of faculty and students' OER course experiences. OER students have better grades, lower failure rates, and better attendance records than those using traditional textbooks. The attitude of OER students towards mathematics also improved." Van Allen and Katz (2020) helped instructors and administrators across the world by providing a rationale for using these learning materials and a strategy for educators to get started with OER.

During the pandemic, several higher education universities and colleges scrambled to transition and implement OER across all fields of study. Some institutions have succeeded while some have failed. Mi´cunovi´c, Rako, and Feldvari (2023) created a map of how OER was implemented at higher education institutions in Europe as collaborative work with Library of Information Science. They reported that COVID-19 pandemic served as an impetus for the adoption of OERs, particularly in the context of digital education and remote learning.

After one and half years of the pandemic, several articles have been published on how effective OERs have been. Van Allen and Katz (2020) raised awareness of OER by providing a rationale for using these learning materials and a strategy for educators to get started with OER during the collective crisis and beyond. There were mixed results published after the pandemic. Sunar, Yükseltürk, & Duru (2022) reported that academics who did not know about OERs were hesitant regardless of whether these instructors have or have not done online teaching. Holloway (2023) described her journey as she implemented OER in her courses. She wrote "My own implementation of OER involved a great deal of work creating new material and required technical

skills that the average instructor may not possess. I used my move to OER as an opportunity to better develop important ways of mathematical thinking that are often underemphasized. I hope that, as more courses transition to OER, instructors will use the flexibility of the medium to enhance and improve their teaching."

Methodology

To provide a little background about this study, the author who is the Calculus coordinator and all Calculus instructors used Larson & Edwards (2009) to teach the Calculus I (4 credit hours). The first five chapters of this textbook are thoroughly discussed for a 16-week Calculus I semester. The remaining chapters are used for Calculus II and III. The specific student learning objectives (SLOs) for this course are usually clarified the first day of the semester and revisited if necessary, during the semester. Refer to Figure 1.

Upon successful completion of the course, students will be able to:

(1) find limits of different kinds of functions;
(2) evaluate derivatives of many functions and relate them to rates of change;
(3) calculate basic integrals;
(4) apply knowledge of derivatives and antiderivatives to real-world situations.

Figure 1. Student Learning Outcomes for Calculus (Single Variable)

OER Used: OpenStax© Calculus – Volume 1

The author has been using *OpenStax© Calculus 1-3 textbooks* since 2019 (https://openstax.org/subjects/math). This activity was enhanced when the university incentivizes instructors to use OERs by offering mini grants of $1000 per course transitioned to OER (textbooks mostly). This university led OER transition and implementation have provided cost savings to STEM majors, allowed immediate access to all students on the first day of the semester, and granted an equitable approach to teaching mathematics courses. This was especially useful for talented but financially needy STEM students who couldn't afford expensive Calculus books which usually cost $200 or more. What is more important to note is the constant and continuous proofreading of these textbooks by Calculus instructors. The OpenStax© Calculus 1-3 series has been improved by feedback of instructors to the authors every semester ranging from fixing minor typographical errors to adding more relevant and meaningful exercises. The books are available online and can be downloaded for those who like hardcopy versions. They are published under a CC BY-NC-SA 4.0 license.

MyOpenMath: Online Homework Platform

The author has been using MyOpenMath (https://www.myopenmath.com/), as her courses' online homework platform. Tan (2021) published in LaGuardia OER Seminar an online review of MyOpenMath. Tan's 2021 online review lends credibility to the continued utilization of MyOpenMath by more mathematics instructors in the US.

In this research, after controlling most of the statistical confounds such as instructors and comprehensive final exam, this study utilizes trend and time series analyses of student learning outcomes and mastery of content at the level of specific learning objectives (SLOs) in Calculus from Fall 2016 - Spring 2023 was done. Seven hundred eighty-nine Calculus students' comprehensive final exams were organized, studied, and analyzed to understand better how OER implementation impacted students' learning of important concepts at the level of course SLOs.

One of the imperative and crucial Calculus reforms was the inclusion of real-world problems in teaching the materials to improve student learning and enhance retention of concepts. This paper examines the performance of students on one of the four specific Calculus learning objectives which is "At the end of the course, the students will be able to apply knowledge of derivatives and antiderivatives to real-world situations." At Texas Woman's University mathematics department, Calculus topics are developed and delivered as recommended by the Committee on the Undergraduate Program in Mathematics (CUPM).

The Calculus I textbook used during the pre-OER period (2016 - 2019) is the tested and proven Calculus book by Larson and Edwards. The first five chapters are covered as prescribed in the syllabus. A Calculus course coordinator assigned in the mathematics department meet with select Calculus instructors at the beginning of the semester and provide all relevant and appropriate materials needed for these instructors to teach effectively. A Calculus syllabus containing the sequence of topics to be discussed for the whole semester are given out and instructors are free to create their own teaching activities, quizzes, and chapter tests to engage students. The single uniform testing done for the whole department is the comprehensive final exam during the final exam week. In 2015, the assigned department Calculus coordinator and a few other mathematicians who had been established and experienced Calculus instructors brainstormed and created a comprehensive final exam that would assess the four major student learning objectives stated in the syllabus. The exam is composed of 20 multiple-choice questions covering all topics and two "essay or short answer" word problems that tests the students' understanding of the applications of differentiation and integration in the real world. To provide the readers with the full context of this process, these course materials (syllabus and comprehensive final exam) are in the appendix.

For brevity, the learning objective stated above and emphasized in this research paper has been assessed in a uniform fashion every semester. Five of the twenty multiple-choice questions have been classified to measure the students' end-of semester differential and integral Calculus knowledge and its applications plus the two-word problems classified as "essay or short" questions where students are required to write down their detailed answers. A special scantron sheet is provided so that this can be tracked every semester since Fall 2010. For this study, the data included in the research are Fall 2016 - Spring 2023 highlighting the three years of pre-OER implementation (Fall 2016 - Fall 2019) and four years of post-OER transition/implementation (Spring 2020 - Spring 2023).

During the final exam week, the students answered five specific multiple-choice questions addressing SLO 4. Four of these problems are shown in Figures 2 - 4 to serve as examples of questions in the exam: The file

containing the other questions are in the appendix.

5. A conical tank (with vertex down) is 12 feet across the top and 18 feet deep. If the water is flowing into the tank at a rate of 18 cubic feet per minute, find the rate of change of the depth of the water when the water is 10 feet deep.

(a) $\frac{9}{40\pi}$ ft/min
(b) $\frac{9}{100\pi}$ ft/min
(c) $\frac{81}{20\pi}$ ft/min
(d) $\frac{81}{50\pi}$ ft/min

Figure 2. Testing Students' Skills on Applying of Differentiation Knowledge

16. Find the area of the region bounded by the graphs of the equations

$$y = x^3 + x, \quad x = 4, \quad y = 0.$$

Round your answer to the nearest whole number.

(a) 96
(b) 84
(c) 72
(d) 64

Figure 3. Testing Students' Skills on Applying of Integration Knowledge

You must show all of your work to receive full credit. Write LEGIBLY. If you are INSTRUCTED to explain the answer, write in complete sentences.

1. A rectangular page is to contain 28 square inches of print. The margins on each side are $1\frac{1}{4}$ inches.

(a) **(2 points)** Draw what is described in **Problem 1** and label important parts correctly.
(b) **(6 points)** Find the dimensions of the page such that the least amount of paper is used.
(c) **(2 points)** Explain how come that you can prove that your answer is truly the least amount of paper.

2. Evaluate the definite integral.

$$\int_5^9 3|x^2 - 36|\, dx$$

(a) **(2 points)** Sketch the graph of the integrand to gain intuition.
(b) **(6 points)** Given the graph, write the equivalent definite integral and evaluate.
(c) **(2 points)** Using complete sentences, explain what you have just solved.

Figure 4. Two "Essay or Short Answer Questions Testing Students' Skills"

Results

The tables and figures below describe directly and succinctly what level of learning Calculus students achieved each semester from Fall 2016 to Spring 2023.

How did Calculus students perform in SLOs 1-4? Figure 5 provides a quick view of success rates from Fall 2016 - Spring 2023 and describes the seven-year trend of students' performance with each SLO.

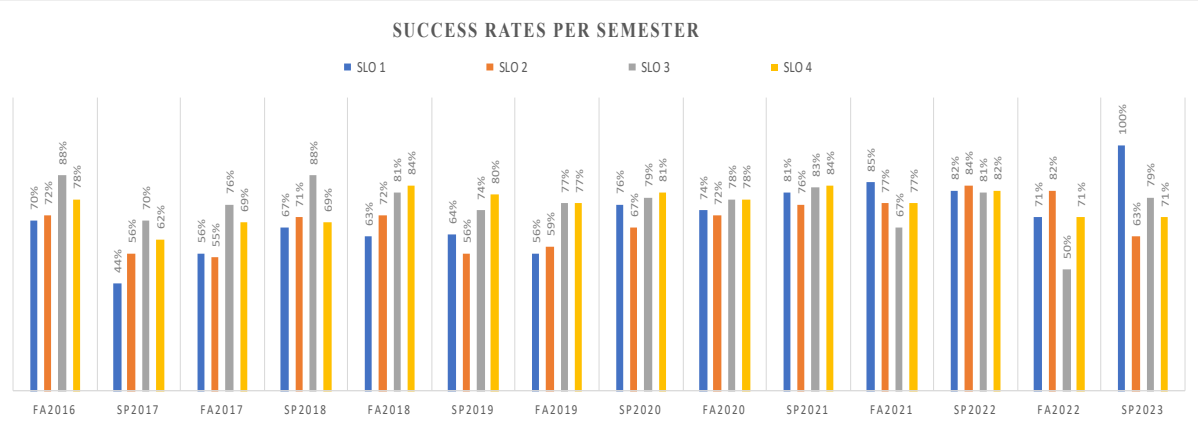

Figure 4. Success Rates Per Semester (Fall 2016-Spring 2023)

Success Rates Before, During and After the Pandemic

To better understand the SLO performance rates before, during and after the COVID-19 pandemic, a zoomed in graph (Figure 6) is provided. In this graph, "Pre-pandemic" covers years Fall 2016 - Fall 2019, "Pandemic" covers Spring 2020 - Fall 2021, and "Post-pandemic" covers Spring 2021 - Spring 2023. Figure 6 shows a snapshot of percentages for each SLO per group.

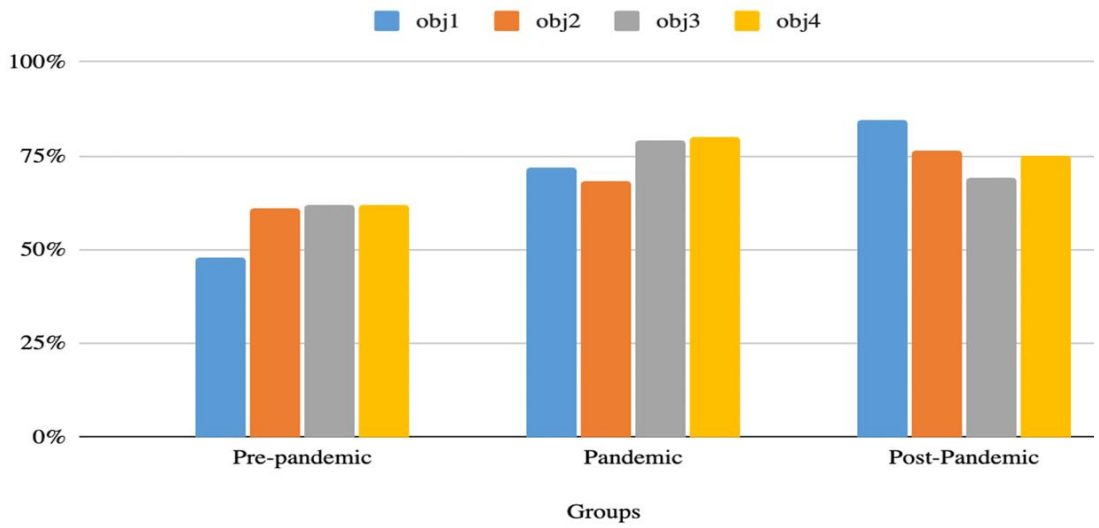

Figure 6. Success Rates (Pre-, During, and Post-Pandemic)

There was no dramatic dip in achievement rates for all SLOs during the semesters classified as during the pandemic. The trend described by the histogram is essentially "no extensive decrease in student learning outcomes" during the pandemic". In fact, success rates increase slightly during post-pandemic. More specific trend studies below shed added details to this generalized trend histography study.

Examining the Success Rates (Pre-OER versus Post-OER)

To make this research tell the whole story or describe the students' success rates on measurable course learning objectives in Calculus with or with the use of OER, the data set was also organized into two separate time frames: (1) before and (2) after the OER implementation. Fall 2016 - Fall 2019 final exam results represent the "before OER implementation" while Spring 2020 - Spring 2023 represent "after OER transition and implementation.

Table 1. Success Rates in Four SLOs per Group (OER)

	Student Learning Objectives (SLOs)			
Groups	SLO 1	SLO 2	SLO 3	SLO 4
Pre-OER	60%	63%	79%	74%
Post-OER	78%	73%	74%	78%

Table 1 describes the success or achievement rates of students in three separate time frames. It is quite interesting to note that there is 18%, 10% and 4% averaged increase in the achievement and success rates of students for SLOs 1,2, and 4 pre- versus post-OER, and a 5% decrease in success rate for SLO 3.

Figure 7 provides the full story at a quick glance. As stated above with detailed percentage rates, the histogram describes the increases in the achievement rates of students on three SLOs, SLO1, SLO2, and SLO 4. The minimal 5% decrease in performance rates of students on SLO 3, i.e., there is a 5% decrease on students' "integration skills" post-OER.

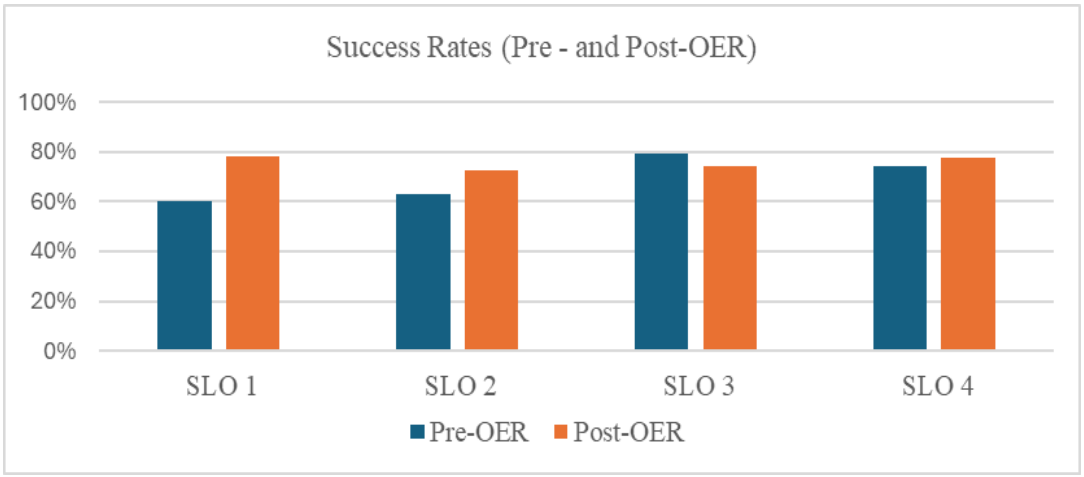

Figure 7. Success Rates (Pre- and Post-OER)

Statistical Tests and Analyses

Since this study describes the pre-OER versus post-OER implementation, SPSS and R were utilized to perform some statistical tests. Multivariate as well as univariate tests were performed. Table 2 shows that the OER implementation of Calculus has a statistically significant positive impact on students' learning outcomes.

Table 2. Multivariate Tests

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.
Intercept	Pillai's Trace	.967	116.657[b]	4.000	16.000	<.001
	Wilks' Lambda	.033	116.657[b]	4.000	16.000	<.001
	Hotelling's Trace	29.164	116.657[b]	4.000	16.000	<.001
	Roy's Largest Root	29.164	116.657[b]	4.000	16.000	<.001
group	Pillai's Trace	1.131	2.723	12.000	54.000	.006
	Wilks' Lambda	.170	3.391	12.000	42.624	.002
	Hotelling's Trace	3.122	3.816	12.000	44.000	<.001
	Roy's Largest Root	2.381	10.715[c]	4.000	18.000	<.001

a. Design: Intercept + group

b. Exact statistic

c. The statistic is an upper bound on F that yields a lower bound on the significance level.

Table 3. Univariate Tests

Univariate Tests

Dependent Variable		Sum of Squares	df	Mean Square	F	Sig.
obj1	Contrast	.565	3	.188	13.207	<.001
	Error	.271	19	.014		
obj2	Contrast	.093	3	.031	2.308	.109
	Error	.256	19	.013		
obj3	Contrast	.318	3	.106	2.888	.062
	Error	.697	19	.037		
obj4	Contrast	.396	3	.132	5.748	.006
	Error	.436	19	.023		

The F tests the effect of group. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

Checking on the statistical significance per student learning objective, Table 3 confirms that OER implementation has a statistically significant effect on improving the skills of students on understanding different kinds of functions and finding their limits (SLO 1). For the all-important question on whether there is a statistically significant increase in the application to real-world problems of differentiation and integration skills after OER implementation, the answer is in the affirmative. The *p*-value of 0.006 justifies this conclusion. The other two SLOs, SLO 2 and SLO 3 were not significant at the significance level of alpha = 0.05.

Discussion

Studying the impact of special educational interventions on student learning outcomes can be highly nuanced and difficult. There is a need to track uniformly and ascertaining that biases and confounds are minimized if not fully removed. This trend analysis research on how open access and knowledge in the form of OERs has shed some light and inform the mathematics community of the results if student learning outcomes are tracked at the level of course leaning objectives.

The successful completion of Calculus I (4 credit hours), i.e., achieving a grade of A, B, C, in the Calculus sequence of 12-credit hours is considered an achievement on its own and most research articles on student learning outcomes report this number. This paper is going beyond these completion-type learning outcomes and delves with the specific learning objectives in Calculus 1. The pass, drop, failure and withdrawal rates may provide a good big-picture story but does not supply enough details as to what types and levels of learning truly occurred for a batch of students.

Analyzing the Success Rates per SLO

The pre-OER batches of students did not experience the COVID-19 pandemic effects. Classes were mostly taught face-to-face while the post-OER students have transitioned to a semi-digital type of teaching and learning environments. Looking at SLO 1, the transition and implementation of OER did not affect the learning outcomes. In fact, OER use improve the success rates at identifying different kinds of functions and finding their limits. The same is true for SLO 2. The negative success rate of 5% for SLO 3 is interesting. The integration skills of students were 5% lower on average. This could be due to the change in textbook. The post-OER students has been using the OpenStax© Calculus 1 free e-book.

Additionally, the HW platform, MyOpenMath may also have caused this decrease. As a statistically non-significant result, this can be due to several reasons aside from just the OER implementation. There were some classes taught 100% online during the pandemic and post-pandemic. Even though this decrease is only 5%, the TWU Calculus team will investigate the OpenStax© e-book and MyOpenMath HW and see if certain improvements can be prepared and executed.

For the research focus of this paper, there is a statistically significant increase in achievement of SLO 4 based on Table 3 showing the row for student learning objective #4. The cohorts of students post-OER showed an increase in their application skills when applied to differentiation and integration of functions.

Conclusion

Reporting the impact of an intervention, in this case, OER implementation using OpenStax© Calculus – Volume 1 and MyOpenMath homework platform, can be a challenging task. The sample size in this research study may not be large, but the tracking of the success rates per SLO per semester for seven years is one of its strengths.

OER impact research has been slightly improved by this report. Other institutions may have done larger group and trend analyses. The use of specific SLOs will inform the mathematics community especially the Calculus community of instructors, course coordinators, department of mathematics chairs, and STEM specialists who are highly involved in shaping the minds of STEM majors.

Recommendations

One of the possible ways to improve this type of report is the addition of more information about the students. TWU is considered the largest university in the United States of America focused on women and has been classified as Hispanic-Serving institution. Another research paper describing the detailed demographics of each Calculus students/cohorts is currently under review by TWU Institutional Review Board.

Another type of student learning outcomes research at the level of SLOs between at least two comparable mathematics departments will offer an interesting discussion. The bigger the sample size the better. To start the intra- and inter-university study, the author is about to collaborate with a couple of mathematicians who are also Calculus coordinators of their mathematics departments.

Notes

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References

Austin, D. (2023). The Mathematical Community Working To Create Better (And Free!) Textbooks.

Beile, Penny and Avila, Sandy, (2019) "Textbook affordability at UCF: A Report of research Using the COUP Framework and Practical Tips on Working with Faculty". Faculty Scholarship and Creative Works. 784. https://stars.library.ucf.edu/ucfscholar/784

Borwein, J., Rocha, E. M., & Rodrigues, J. F. (2008). *Communicating Mathematics in the Digital Era*. CRC Press.

Bouche, T. (2008, July). Some thoughts on the near-future digital mathematics library. In *DML 2008 workshop* (pp. 3-15). Masaryk University.

Bullock, Doug; Callahan, Janet; and Cullers, Jocelyn B. S.. (2017). "Calculus Reform: Increasing STEM Retention and Post-Requisite Course Success While Closing the Retention Gap for Women and Underrepresented Minority Students". *2017 ASEE Annual Conference & Exposition*, 18474-1 - 18474-15.

Collins, C.A., & Galbreath, D.R. (2022) A Case Study of Teaching Single Variable Calculus Traditionally vs. Virtually: A Semester Bifurcated. *PRIMUS*, 32:7, 798-811, DOI: 10.1080/10511970.2021.1931997

Colvard, N.B, Hyojin, P. & Watston, C.E. (2018) The impact of open educational resources on various student success metrics. International Journal of Teaching and Learning in Higher Education, 30(2), 262-275.

Conole, G., & Brown, M. (2018). Reflecting on the Impact of the Open Education Movement. Journal of Learning for Development, 5(3), 187-203.

Davis, J. D., & Cartwright, S. B. (2020). The effects of using open educational resources on minority achievement in undergraduate mathematics. In *Open Educational Resources (OER) Pedagogy and Practices* (pp. 20-41). IGI Global.

Delgado, H., Delgado, M., & Hilton III, J. (2019). On the efficacy of open educational resources: Parametric and nonparametric analyses of a university calculus class. *International Review of Research in Open and Distributed Learning*, *20*(1).

Ferrini-Mundy, J., & Graham, K. G. (1991). An Overview of the Calculus Curriculum Reform Effort: Issues for Learning, Teaching, and Curriculum Development. *The American Mathematical Monthly*, *98*(7), 627–635. https://doi.org/10.2307/2324931

Hagman, J. (2019). Towards a Forward-Thinking College Calculus Program. *Theorizing STEM Education in the 21st Century*, 137.

Hahn, A. (2022). Calculus in Context. Johns Hopkins University Press.

Hilton, John III; Bliss, TJ; Robinson, T. Jared; and Wiley, David A., (2013)"An OER COUP: College Teacher and Student Perceptions of Open Educational Resources" Faculty Publications. 1355. https://scholarsarchive.byu.edu/facpub/1355

Jung, E. Bauer, C.and Heaps, A, (2017) "Strategic Implementation of Open Educational Resources in Higher Education Institutions". Educational Technology.

Larson, R. & Edwards, B. H. (2009). *Calculus: Early Transcendentals*. Houghton Mifflin Company.

Kersey, S. (2019). The effectiveness of open educational resources in college calculus. A quantitative study. *Open Praxis*, *11*(2), 185-193.

Mi´cunovi´c, M.; Rako, S.; Feldvari, K. Open Educational Resources (OERs) at European Higher Education Institutions in the Field of Library and Information Science during COVID-19 Pandemic. Publications 2023, 11, 38. https://doi.org/10.3390/ publications11030038

Newton, C., & Rajagopal, K. (2021). Reflecting on the Impact of the Open Education Movement. Journal of Learning for Development, 5(3), 187-203.

Stanberry, M. L., & Payne, W. R. (2023). Teaching undergraduate calculus at an urban HBCU through a global pandemic. International Journal of Education in Mathematics, Science, and Technology (IJEMST), 11(2), 340-357. https://doi.org/10.46328/ijemst.2557

Suber, P. (2012). *Open access* (p. 256). The MIT Press.

Sunar, A. S., Yükseltürk, E., & Duru, İ. (2022). Analysis on Use of Open Educational Resources during Emergency Remote Education due to Covid-19: A Case Study in Turkey. *SAGE Open*, *12*(4). https://doi.org/10.1177/21582440221130299

Tan, J. (2021). *MyOpenMath:A Review*. LaGuardia OER Seminar. https://laguardiaoerseminar.commons.gc.cuny.edu/myopenmath-a-review/

Van Allen, J. and Katz, S. (2020). Teaching with OER during pandemics and beyond. International Journal of Multicultural, 14(3/4), 209-218. https://doi.org/10.1108/JME-04-2020-0027

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