Students' Preferred Technology in an Ordinary Differential Equations Course

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Abstract

Many mathematics courses rely heavily on technology to enhance teaching and learning. One such course is Ordinary Differential Equations (ODE). There is an abundance of tablet- and computer-based technology options available that claim to help instructors deliver instruction, interact with students, and provide informal feedback to students. We began a resource library of innovations that were both effective and easy to use that included computer algebra systems (CAS), lecture notes from class, and video recordings of both face-to-face and live online lectures. Since the creation and management of these resources can be extremely time consuming, we wanted to investigate which instructional technology options students were gravitating towards. We surveyed students to find out which resources students were using and why. In this paper, we focus on which technology options ODE students found most beneficial for instruction, office hours, and formative assessment opportunities.

Keywords

Educational Technology; Ordinary Differential Equations; Supplementing Instruction; Online Resources; Video Recorded Lectures

Introduction

The creation and management of digital instructional resources can be extremely time consuming, so we wanted to investigate which instructional technology options students found most beneficial in our Ordinary Differential Equations (ODE) courses. We started a resource library that included computer algebra systems, lecture notes from class, and video recordings of both face-to-face and live online lectures. We surveyed students to determine which resources students were using and why. In this paper, we focus on which technology options ODE students found most beneficial for initial instruction, reviewing content, and formative assessment opportunities.

Computer algebra systems (CAS) include any software or online program that can manipulate or solve mathematical problems that have been entered in traditional mathematical notation, such as Maple, Mathematics, and GeoGebra. Lecture notes were captured as they were created during class on Microsoft OneNote and made available to students via the university's learning management system, Desire2Learn (D2L). Video recordings of lectures, which included both classroom audio and the example work done with a CAS or on a digital whiteboard, were captured using both the built-in recording feature on Microsoft Teams and Kaltura and made available to students via D2L.

Why Use Technology in an Ordinary Differential Equations Class?

Clayton State University (CSU), like many other colleges and universities, requires math and engineering students to take ODEs, a course that is often taught traditionally through lecture and board work. The problems that are worked in ODE are built from calculus, relying heavily on limits and derivatives, so students in the course need to have a strong prerequisite background. However, CSU's student population includes many non-traditionally aged students: spring semester enrollment in 2020 counted 36.9% of students as being age 25 or older[1].

These students may have a significant gap between their initial calculus instruction and their enrollment in ODE, and some may be pursuing a degree requiring ODE as part of a career change. Students who are not mathematics majors may have some inconsistencies in their understanding and use of common vocabulary. For instance, K. Beynon and A. Zollman[2] found that such students often use personal definitions of limits instead of the formal, precise definition. This causes issues for students when they need to solve problems involving limits or integrals and necessitates a review of prerequisite content.

To help overcome prerequisite deficiencies, ODE courses at various universities, including CSU, use a variety of technologies and teaching techniques. These allow for deeper investigation of ODE concepts by students while working independently. For example, J. Alzabut[3] found that using traditional lectures with PowerPoint presentations, student presented lectures, and a flipped classroom provided students more time to ask questions and a better understanding of content in his Differential Equations course. At CSU, technology features heavily in all computational math courses, typically in the form of CAS, which allow users to enter mathematical problems in traditional mathematical notation and graph, solve, or otherwise manipulate the given equations. Commonly used CAS include Desmos, GeoGebra, and Maple. S. Maat and E. Zakaria[4] found that by using Maple, students could better understand the content and see relationships between the course concepts and engineering applications.

Other institutions have explored using complex proprietary technology in the form of applets[5] or detailed online programs[6] that were carefully crafted to specifically teach ODE using models of real problems that engineering students will likely encounter in their careers. Students responded favorably to these digital instruction tools, stating that the tools made studying ODE more interesting and relevant to them, helped them avoid mistakes and solve questions faster, and made both coursework and instructor support more accessible when they dealt with recurring illnesses and limited mobility[7]. However, developing and implementing these innovative technologies requires significant investments of funding and time, two resources that are often limited in higher education.

Creating video content for student use, meanwhile, can be done using existing devices and programs. While many pedagogically-experienced instructors may be concerned about the technological or logistical difficulties of creating video content and delivering it to students, much has changed from the era of burning discs directly after class or needing additional software to capture writing on a screen[8,9]. Now, all that is needed to record a live or practiced lecture is a cell phone with a built-in editing app and some way of keeping it steady, or setting up Microsoft Teams, Zoom, or some other live video meeting program to record while sharing the screen that notes and diagrams are being created on.

Pre-Recorded Videos vs Recordings of Classroom Lectures

H. Kinnari-Korpela[10] investigated the use of instructor-created mini-lectures and example demonstration videos in supporting engineering students in a differential and integral calculus course. These videos consisted of instructor audio over slides or work done by hand on a tablet and were prepared in advance or otherwise separately from live classroom instruction. Student surveys indicated that a majority felt that the videos had been meaningful and increased their motivation towards practicing and learning the course content. They appreciated the ability to pause or re-watch videos on example problems as needed and indicated that the video explanations were preferable to written examples. Yet, students emphasized that the availability of the prepared videos did not replace their desire for live instruction. Additionally, these short videos required the use of editing software as well as instructor time to prepare and record.

Students in other studies who were provided access to recordings of full classroom lectures were recorded as strongly desiring similar or greater recording access in future courses[11] despite the increased length of the videos. Students were able to watch just the parts of the lecture that they needed to support their understanding of the material[12,13], which may be a useful skill to hone as the adoption of "video essays" or "research videos" increases [14]. Simply recording the lecture as it is delivered splits the difference between supporting students and efficiently utilizing instructional time. For this study, lecture was recorded via a laptop that was running Microsoft Teams during class while the instructor shared their screen as they made live digital notes and demonstrated the use of CAS in specific problems.

Anticipated Questions and Concerns

Some may ask, why not recycle the videos from one iteration of the course and use them to facilitate a "flipped" classroom (where students watch the lecture on their own and only attend the in-person classroom for practical application practice) or an entirely online course? D. Dolan and V. I. Prodanov[15] found that while students in a flipped classroom did find the pre-recorded video lecture useful, they were predominantly neutral as to whether it covered material better than a live or in-person lecture, and more than 50% missed the ability to ask questions. The students appreciated the ability to watch the lecture at their own pace, but over 80% wished that problem solving and lecturing could all be done live. V. I. Prodanov[16] also found that lecture recordings allowed students to review material before or instead of attending an instructor's office hours for clarification. While individualized time with students may be considered valuable, instructors with particularly large classes might appreciate students being able to resolve basic questions independently, thus reserving limited time in the office to breaking down difficult concepts or having deeper conversations with students about the implications of the material.

Primary concerns about recording live lectures include fears of decreased attendance or average grades. However, these concerns have yet to be legitimized[11]. Instructors might compare this concern to remote teaching experiences where students declined to turn on their cameras, resulting in an audience of silent black boxes. However, the reasons for a silent audience are far different for remote online teaching[17], and indeed the lack of privacy and low bandwidth in a student's home environment may prompt them to choose to attend in-person lecture despite knowing the video recording will be available later. While there have been concerns raised about student participation while being recorded, students in computer science and mathematics

courses seem to be no more hesitant to ask questions than they would in an unrecorded classroom[18].

One final concern is over copyright of recorded lectures. The American Association of University Professors established in their "Statement on Copyright" in 1999[19] that, "[I]t has been the prevailing academic practice to treat the faculty member as the copyright owner of works that are created independently and at the faculty member's own initiative for traditional academic purposes." They go on to specify that this includes not only syllabi but also class notes and educational software, all regardless of the medium used to create or capture them. Additionally, individual institutions may have their own policies about the copyright ownership of educational materials created by faculty or other educational employees. Thus, legal protections do exist to prevent and remedy the distribution of recorded lectures against the will of the creator or instructor.

Given the evidence in the literature supporting use of video recordings as part of instruction in the ODE classroom, as well as the successful use of CAS, we undertook an investigation of student use and perception of the various technologies available to them. Across the many courses that we had taught to date, the use of software and online tools in the classroom seemed to allow students to focus on the content of the lesson and process of the work over precisely copying equations into their personal notes during class. We wanted to optimize our time and focus on those efforts that our students would use and find supportive to their understanding of the material in the course, which served as the inspiration for our methodology.

Methodology

The purpose of this study was to determine which technologies students found to be useful in an ODE course. The technologies that were investigated were CAS, recorded video lectures, lecture notes, third-party resources, and various methods by which students contacted or received help from the instructor. Students were asked to electronically complete a short survey on their opinions of the various technologies they used during the semester in which they were enrolled in the ODE course. Participation was optional and confidential to the degree that the survey instrument permitted. Students who volunteered to complete the survey were awarded five points of extra credit on a test.

The study was conducted over five semesters of an ODE course at Clayton State University, beginning in fall of 2018 and ending in fall of 2021. Four semesters were delivered by the same instructor, while the class of spring 2019 was taught by another. Due to COVID-19 protocols, the students in the fall 2020 semester were taught in a synchronous online format, but all other sections were taught in a traditional face-to-face format. A total of 32 students responded to the survey.

Data

Students in the Fall semesters 2018-2021 and Spring semester 2019 classes (n=32) were surveyed to gauge their use of instructor provided resources such as class notes, Maple and GeoGebra worksheets, and video recording of class, as well as their use of third-party resources such as YouTube and Khan Academy. Students were asked to rate their perception of the usefulness of each resource that they were provided on a scale of 1 to 5, with 1 being "not useful" and 5 being "most useful".

Video Lecture Recordings

Of the resources included in the survey, the responses regarding the lecture video recordings were of particular interest because every respondent reported using them. Additionally, the lecture video recordings captured the lecture notes as they were being created, providing context, and including valuable student-instructor interactions that were often erased from the final notes. These in-class conversations might be legitimately confusing if they were included in the written lecture notes, but by recording the lecture these insights into the creation of the notes are preserved, which may make the lecture notes easier for students to follow. Figure 1 reveals that 75% of students rated the usefulness of the video recordings as 4 or higher out 5.

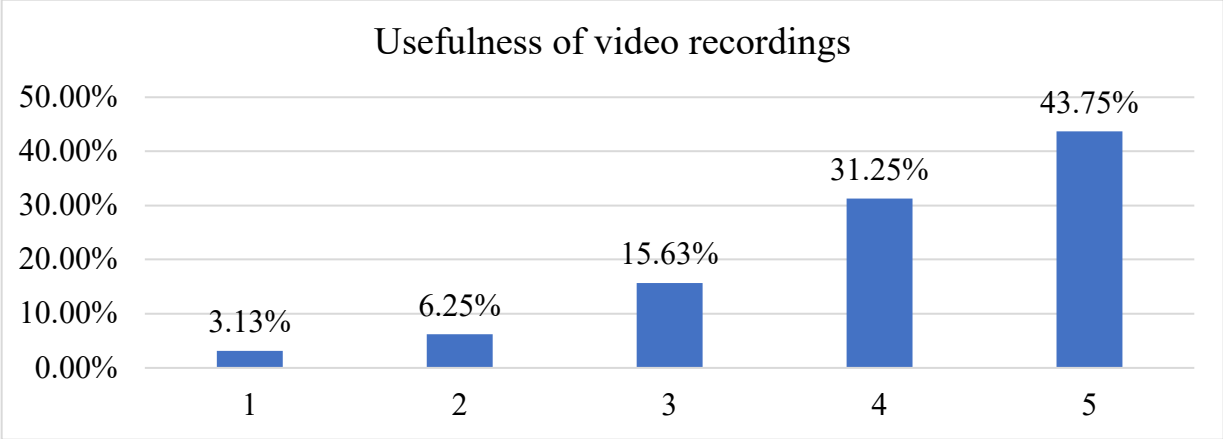

Figure 1: Usefulness of video recordings

Beyond capturing the perceived usefulness of the video recordings of lectures, the reasons students were reviewing these materials was also surveyed, as seen in figure 2:

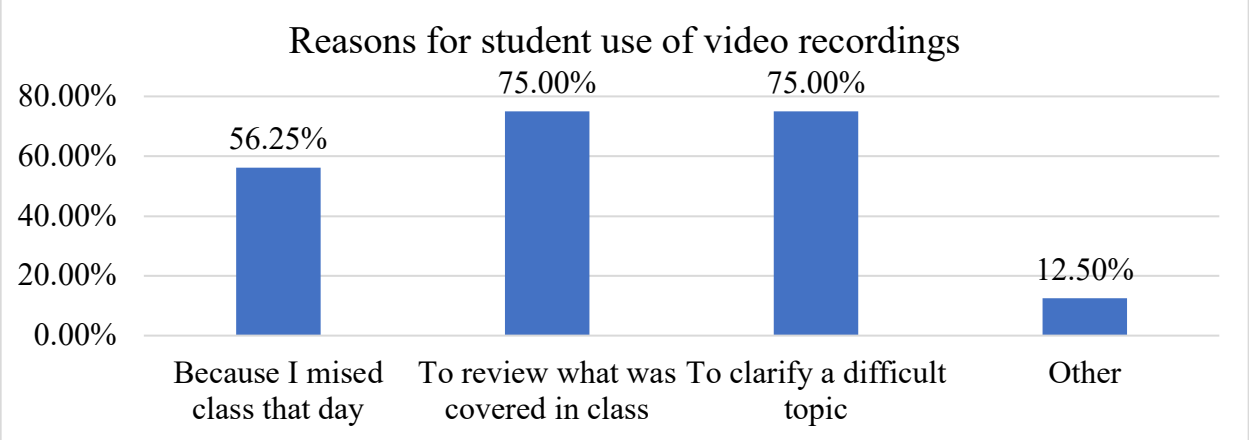

Figure 2: Reasons for student use of video recordings

Of the five semesters surveyed, four were conducted face-to-face in a traditional classroom and only one, in fall of 2020, was held as a "remote" online-only synchronous video lecture course. Thus, we decided to compare student opinions on and use of video recordings from the face-to-face classes to the remote class.

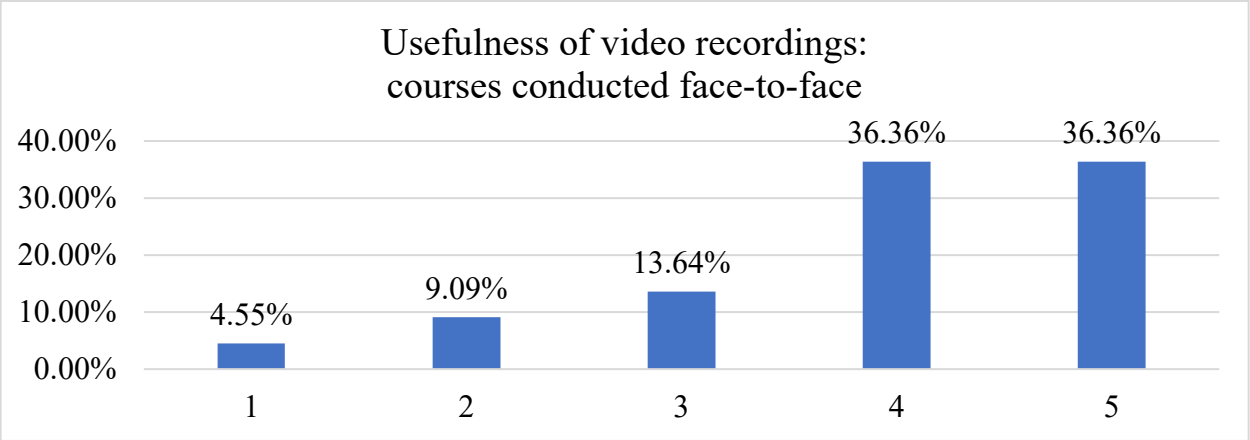

Figure 3:Usefulness of video recordings: courses conducted face-to-face

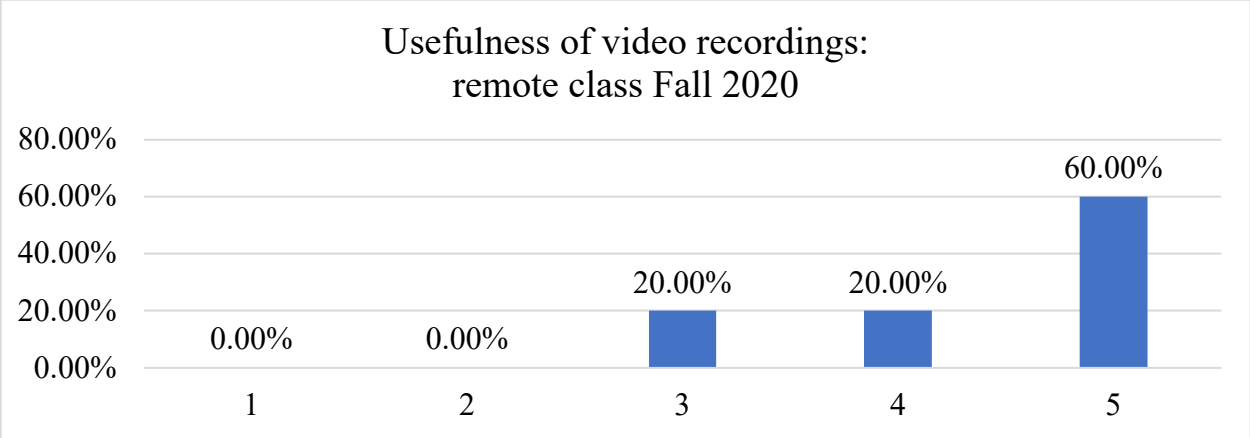

Figure 4: Usefulness of video recordings: remote class Fall 2020

Figures 3 and 4 show that the percentage of students rating video lecture usefulness 4 or higher is similar, but the remote class was far more likely to select a rating of 5 rather than 4 than the students in the face-to-face courses.

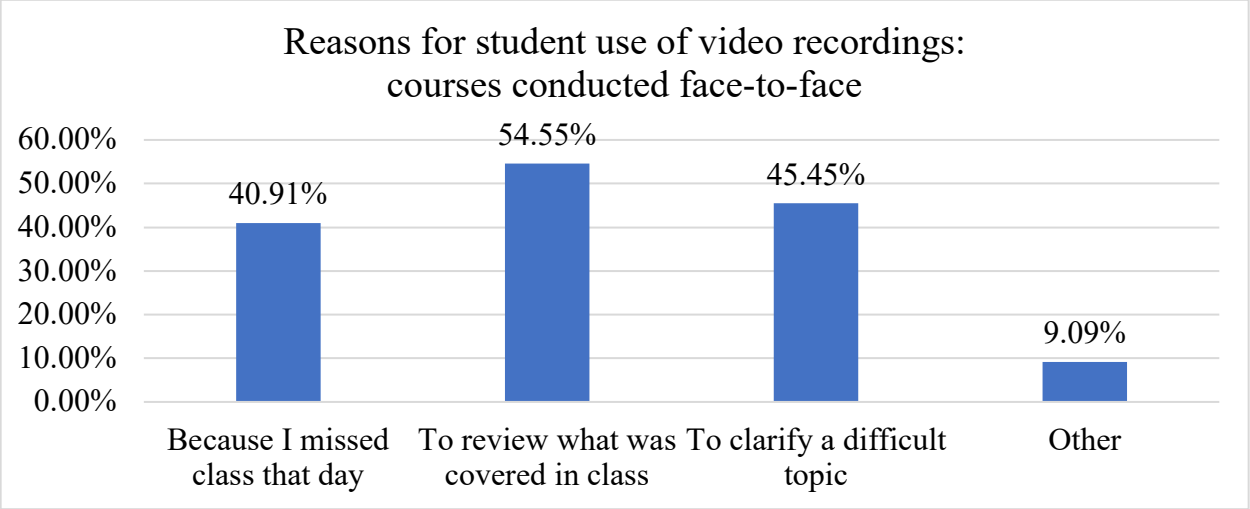

Figure 5: Reasons for student use of video recordings: courses conducted face-to-face

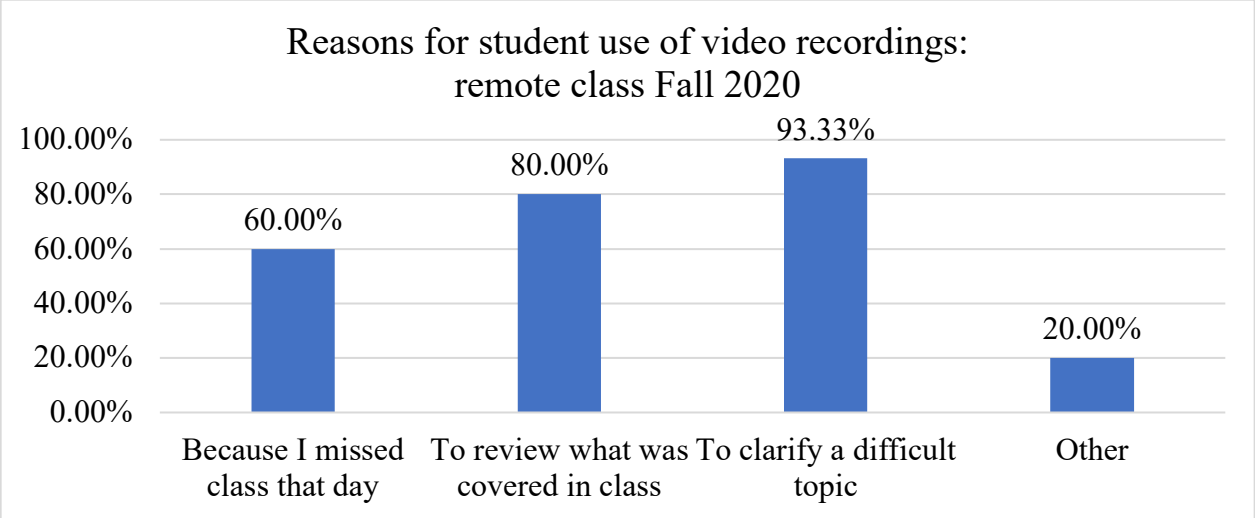

Figure 6: Reasons for student use of video recordings: remote class Fall 2020

While the percentage of the students who reviewed the video recordings due to missing the synchronous class session did increase when the class was conducted remotely via Microsoft Teams in Fall 2020 (figures 5 and 6), the top two reasons for reviewing the recordings continued to be "to review what was covered in class" and "to clarify a difficult topic". One student elaborated that they used the video lectures to ensure they were "writing [their] calculations correctly" and that they "found the lecture videos VERY helpful." Another student stated that they used the lecture videos to "see the difference in how the teacher worked the problems compared to online material."

Of note, the observed number of absences for these classes where students knew video recordings of the lecture would be available was no different to the general number of absences in other classes in the department. (Attendance rates are not officially tracked at the department or institutional level at CSU.) Indeed, the response rates of "to review what was covered in class" and "to clarify a difficult topic" each outpacing the response rate of "because I missed class" clearly demonstrates that more students were reviewing the lecture video recordings than were absent.

Alternate Online Resources

The use of alternate online resources was encouraged to support students in addition to instructor-provided resources. To better understand the types of alternate online resources students preferred, survey respondents were asked if they used any of a list of common websites to help them understand material covered in class and were prompted to add any others that were not on the list (figure 7).

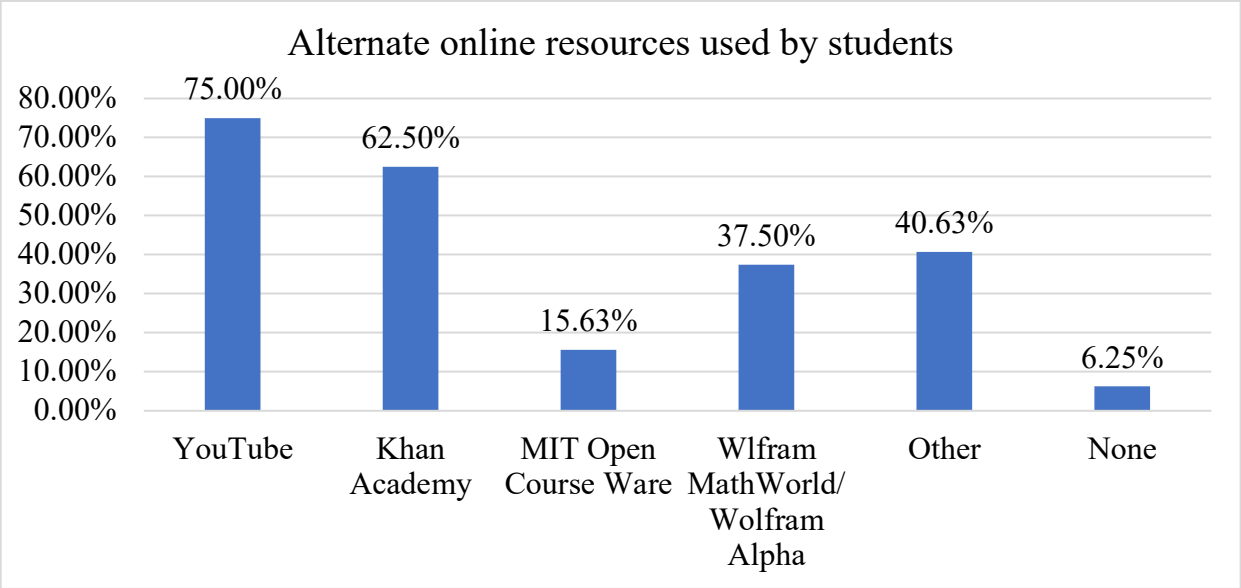

Figure 7: Alternate online resources used by students

The 40.63% "Other" category was further broken down, as only five sites were mentioned by the students who selected this category (figure 8):

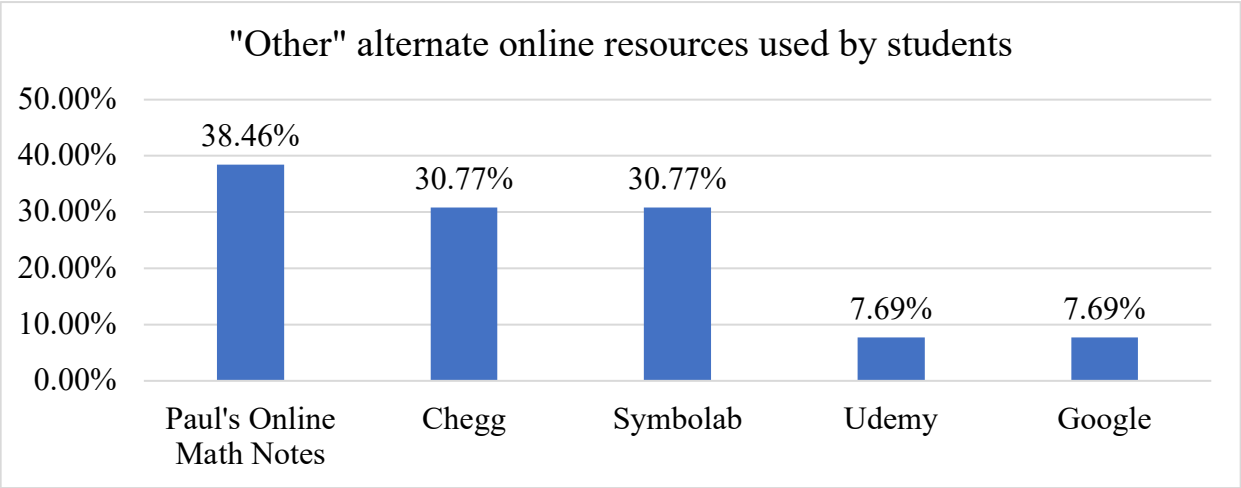

Figure 8: "Other" Alternate online resources used by students

Students frequently selected multiple responses to this question, so the number of alternate online resources used by each student was also assessed (figure 9):

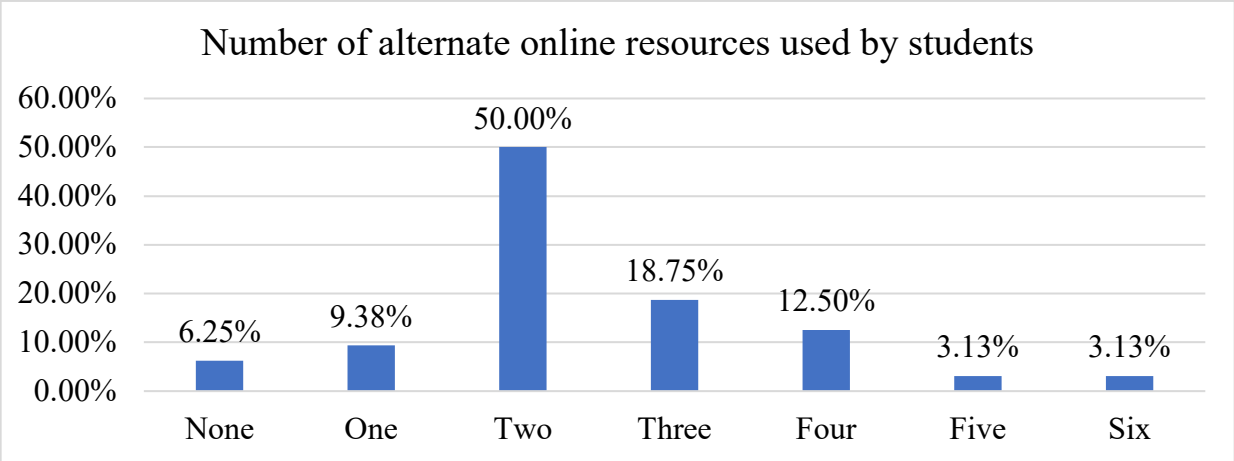

Figure 9: Number of alternate online resources used by students

While 100% of respondents used both the video recordings, over 92% used an alternate online resource for support. While some 75% of students used YouTube, it is interesting to note that about 11% used only a single alternate online resource, while 50% of students used two alternate online resources. It appears that students sought out multiple methods of support from online resources. Further, while Wolfram Alpha can be used as a calculator, Chegg and the pure calculator site Symbolab were each used by only four students across all semesters surveyed, suggesting that students were searching for support in understanding class concepts rather than merely solutions to problems.

Technology in General

When asked in general about the use of technology in the classroom, students stated that they appreciated having access to multiple examples and that having a variety of options made them feel "more secure about finding content [they] need". On specifically having video recordings of live lectures available, students stated that they "love it" and "fully support lecture recordings," noting "If there is a section of the notes that I don't understand I can always watch the video for clarification." Their use of YouTube and other online content suggest that it may be useful to curate relevant examples from frequently used online resources. Working in tandem with students to discover and curate a selection of videos and other resources that align with the instructor's methodology may prove more efficient than the instructor alone searching for examples plus support student engagement with these supportive materials.

Conclusions and Future Work

Our survey of Ordinary Differential Equations students at Clayton State University over the past four years has shed light on our students' use of class recordings and alternative third-party resources such as YouTube and Khan Academy. We found that if video recordings of the lecture are made available, students will use them, even if they attended the session in person. Moving forward, we would like to investigate the effects of these resources on attendance rates and grade point averages. Recording class lectures, whether in-person or online, provides a simple avenue for instructors to provide resources for use outside of class that students will make use of. Since posting video recordings supports students in higher level math classes, and the

process of recording and posting has become so simple, we strongly recommend that instructors at other institutions consider adopting this practice for their face-to-face math classes.

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