Introductory Physics 20X Comparative Analysis

By
Brooke Frey

A THESIS

submitted to

Oregon State University

University Honors College

in partial fulfillment of
the requirements for the
degree of

Honors Baccalaureate of Science in Biochemistry & Molecular Biology

Presented May 28, 2020
Commencement June 2020

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Brooke Frey for the degree of Honors Baccalaureate of Science in Biochemistry & Molecular Biology presented on May 28, 2020. Title: Introductory Physics 20X Comparative Analysis

Abstract approved:

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KC Walsh

The Introductory Physics 20X series has developed an advanced, metacognitive curriculum which requires a high degree of active learning in order for students to succeed in the class. Recently, the series has been transferred to the online campus, Ecampus, and is now available for distance learners. My work is focused on the comparative analysis between all three cohorts: the traditional college classroom in Corvallis (OSU), the smaller branch campus in Bend (OSU-Cascades), and the online campus (Ecampus). This analysis is academically centered: how are students succeeding in class based on their chosen cohort? Which assignments in the gradebook influence exam grades the most? We also looked at the relationship between a student's demographic identity and their academic performance. From our data, we have found several indicators that influence a student's performance on exams. We have also determined the demographic compositions of all cohorts, thus enhancing our drive towards further inclusivity. Most importantly, we have outlined the significance and necessity of providing competent education remotely. We, as educators, must work together towards improving the accessibility and online instruction so that all students, no matter their geographic location or limitations, have a chance to succeed as easily as those in traditional classrooms.

Key Words: BoxSand, cohort, metacognition, Ecampus

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Toni Doolen, Dean, Oregon State University Honors College

I understand that my project will become part of the permanent collection of Oregon State University Honors College. My signature below authorizes release of my project to any reader upon request.

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Brooke Frey, Author

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I. INTRODUCTION

With the current on campus course structure following a hybrid flipped classroom model that is already closely aligned with Ecampus learning structure, an opportunity to compare local and distance learning cohorts arises. Additionally, with the rate of advancement in technology, many subjects are transitioning to online courses. Although previous research has justified equal academic performance among students in online or on-campus courses, there is a distinction between the evaluation standards themselves. Our purpose is to translate the entire set as an identical course online: same exams, assignments, and lectures. There are several differences in the curriculum of the three campuses, specifically within the remote delivery of Ecampus. There is no recitation for Ecampus and lectures are virtual, along with an optional asynchronous assignment. Additionally, the lab curriculum was restructured for the Ecampus students.

As distance learning becomes more prevalent, there is a need to understand the similarities and differences between traditional and online learners. We, as a research team, aim to compare these cohorts based on performance, engagement, affect, and transformative experiences. My work is specifically focused on the academic performance of all the Physics 20X students. I am also interested in the demographic composition of these cohorts and will be investigating potential correlations with course grades. We hypothesize that the academic performance amongst cohorts will be similar yet yield higher results for students taking the course offered on campus.

A. Research Questions

We have structured our research by narrowing in on specific questions. We want to know how the demographic composition compares for the Corvallis campus, Cascades campus, and Ecampus? Are there any correlations with demographics and academic performance? We will also be investigating how the gradebook and institutional data compares to exam performance.

B. Literature Review

In the fall of 2019 the Oregon State University (OSU) introductory algebra-based physics sequence provided an additional campus location for non-majors: Ecampus, the online campus. Since 2014 it has been implementing pedagogical changes to the traditional classroom structure with goals of improving learning outcomes [10]. A flipped classroom approach was adopted with tools enhancing student-centered and active learning. This included more than 300 pre-lecture videos with corresponding pre and post lecture assignments [10]. For the first time, this physics sequence is available to distance learners or students choosing to enroll in the online course. We are motivated to digest the differences between existing cohorts, OSU Cascades campus in Bend and OSU campus in Corvallis, with the new Ecampus cohort. With greater affinity to technological tools, we wish to analyze the academic performance trends that are dictated by one's chosen campus. We will also be looking at connections and correlations that demographics may impact. The Cascades campus represents a smaller community, with class sizes less than 30 students. These students are also older with jobs. The Corvallis campus resembles that of a typical college lecture, with over 500 total students enrolled and ages typically ranging from 18-22. The Ecampus course has students representing the largest scope of demographic data, some from all over the country and with a greater age range.

As online learning becomes more and more prevalent, a higher demand is required to teach courses effectively and inclusively. In the fall of 2017, the National Center for Education Statistics indicated that 6,651,536 students were enrolled in any distance education courses at a degree-granting postsecondary institution [9]. Of these students, the majority represented undergraduates at a public institution. A little more than half of online students were enrolled in at least one but not all distance education courses while a little less than half were enrolled in exclusively distance education course(s). At OSU, there were 6,565 students in Ecampus in 2018, with a 7.9 percent increase over the previous year [6]. Postsecondary education continues to grow, especially with the advancements in technology and communication, making learning easier than ever before. Online learning benefits the teaching of students. It offers a main delivery to train employees, allows instructors to answer questions anytime or anywhere, and allows for distance learners to evade time zones or location problems [1]. The implementation of online education can open doors for students unable to attend class due to work conflicts, geographical distance, or commitment restrictions. Several studies investigated the longitudinal effects of online learning, each providing evidence indicating that online learning yields similar results to offline learning. At the University of Sydney, a large group of first year, undergraduate biology students were provided with offline and online assessment resources to support them in their learning. For a decade, the researchers investigated the students' use of assessment resources and their perceptions of its usefulness. The results displayed that the majority of students use and find useful both online and offline assessment resources, with no differential impact on

learning outcomes [7]. Another type of online education to consider are Massive Open Online Courses (MOOCs), which can collect valuable data on student learning behavior: complete records of student interactions in a learning environment and large sample sizes [8]. About 108,000 participants were part of a study at MIT which looked at how students behaved in *Circuits and Electronics*. Researchers analyzed transitions between course components, such as demonstrating how student behavior differs when solving homework versus exam problems. Only about half of all participants attempted over 5% of the homework, but accounted for 92% of the total time spent in the course [8]. Students who invested less effort tended to leave sooner; finishers of the MOOC invested most of their time watching lecture videos with about a quarter watching less than 20% [8]. Although MOOCs offers a different style of education, its methods have been adopted into the structure of the introductory physics sequence at OSU. A MOOC can be qualitatively analyzed in several ways: attrition/retention, distribution of students' time amongst resources, fractional use of those resources, and use of resources during problem solving [8]. Cognitive psychology claims that learning involves the use of memory, motivation and thinking, aspects that must be valued in online learning [1]. While MOOCs provide valuable data and insight to online learning, their results do not heavily support the research we are conducting. Students enrolled in the Introductory Physics 20X series are required to take a full year of physics, as it's a required course for their degree.. The majority of these students are STEM majors with a background of the life sciences. The course has required assignments, exams, and labs that contribute to the student's final grade. Although MOOCs offer a similar level of teaching, they are not a valid representation of the physics course at OSU.

Research regarding the implementation of students enrolled in online courses versus their performance in on-campus courses is scarce. Overall, it appears that students perform similarly in online courses in comparison to on-campus; however, the withdrawal rates are much higher in online courses. This will be an important factor to consider, as it is estimated that withdrawal rates may be 10-40% higher for students taking online courses [2]. Research on online versus offline courses have dated back to 1998, when a six-thousand-student survey of mechanics test data was collected for an introductory physics course [4]. Another project assessed the comparative effectiveness of teaching undergraduate intermediate accounting in the online classroom. This developed into a longitudinal comparison of online versus traditional instruction [3].

Several challenges occurred while attempting to engage all students via self-paced electronic learning tutorials for introductory physics at the University of Pittsburgh in 2017. This project was research-based with self-paced electronic learning tools. Students in the course in which these interactive electronic learning tutorials were assigned as a self-study tool performed poorly on the paired problems. On the other hand, a majority of student volunteers in 1-on-1 implementation greatly benefitted from the tutorials and

performed well on the paired problems [8]. Students who were assigned to watch the tutorials suggest that students enrolled were not effectively engaged with the tutorials outside of class and have only used them superficially. Overall, the findings suggest that students need out-of-class remediation via self-paced learning tools may have difficulty towards motivating themselves and may lack the self-regulation and time-management skills to engage effectively with tools specially designed to help them at their own pace.

Previous research regarding effective online course instruction will now be expanded considering the current state of the country. At the beginning of this research project, we were unsure initially how to demonstrate the necessity of delivering online courses. There was a considerable amount of anxiety regarding the implementation of a real-time activity rich classroom setting being transferred to remote delivery. For the College of Science at OSU, we were the first science core series to deliver the entire class online. Of course, we faced many problems, some we anticipated and some we did not. However, in March of 2020 we faced a national emergency that has since altered the delivery of education completely. The virus, COVID-19, has now become a global pandemic. Schools all over the world have transferred to remote delivery until June. As a research team, our transition to online instruction has been a massive benefit to the Department of Physics. We originally restricted Ecampus enrollment to under 50 students, now we have over 500 students all engaging in the course completely through remote delivery. This dramatic shift in instruction has supported our research and emphasizes the necessity of opening possibilities for access across all students regardless of demographic differences.

II. METHODS

A. Study Location

This research project was investigated at Oregon State University's campus in Corvallis, Oregon. The city of residence for participants were all in Oregon (either Corvallis or OSU-Cascades campus in Bend) and all over the country (for Ecampus students).

B. Study Design

Target Enrollment

We initially selected our target enrollment number at 650 students. The enrollment in the on campus class is typically between 550 and 600 students so that maximum number of consenting participants is 600. For the OSU-Cascades campus, the target enrollment is around 25 students and for the Ecampus course it is around 40. Out of these numbers, we hoped to get a maximum of 650 participants for the study.

Of the three cohorts investigated, we had an enrollment number of 389 participants. There were 344 students from the Corvallis campus, 14 from the OSU-Cascades campus, and 31 from Ecampus.

Participant Demographics

The age ranges of participants were 18-89 years old. We selected this range because fewer than 0.1% of students taking introductory physics at Oregon State University are under the age of 18 or over the age of 89. Therefore, we are including a section that represents the large majority of students taking this course as our target enrollment.

Participants were OSU, OSU Ecampus, and OSU-Cascades students taking physics 201, 202, and 203. This is the only introductory physics series under Ecampus development and thus the only possible choice for the comparative study of this kind. The research was based on how students learn in an introductory physics course for the Ecampus and on-campus series, so it is necessary that the participants are students currently taking the series. Enrollment in this study is optional and has no grade penalty nor reward for participation. Students can choose to leave the study at any time. The instructor(s) did not know who had agreed to the study as all data, from grades to online engagement, were de-identified.

All participants were English speakers, any sex or gender identity, and any race or ethnicity.

Identification and Recruitment of Participants

On campus (both Corvallis and Cascades) the instructor presented the study to the students during the first half of fall term. All students were given a physical consent form that contained the verbal recruitment guide to sign if they chose to participate. The instructor left the room during the signing phase so that participation remained

anonymous. For the online course, students watched a video presentation and signed an online consent form that also contained the verbal recruitment guide.

C. Data Collection

We obtained student data and used this to better understand the correlations between cohorts of students and success in the class. Data was obtained from a number of sources:

1. College GPA and all previous college course grades
2. Percentage of credit hours attempted that were completed at the start of the course
3. ACT/SAT mathematics percentile
4. College math classes and grades, including retakes
5. High school GPA
6. Total credit hours earned at start of the course
7. ACT/SAT verbal percentile
8. AP credit hours
9. Transfer credit hours
10. ALEKS math placement score
11. Intro and exit survey results that contain questions about demographics, self-reported engagement, transformative experiences, and physics affect
12. A number of assessment tests delivered over the course of the series, including: 1) Intro Physics Math Readiness Assessment, 2) Force Concept Inventory, 3) Colorado Learning Attitudes about Science Survey, 4) Physics Lab Inventory of Critical Thinking
13. Click-stream data from the course website, boxsand.org
14. Course assignments and exam grades
15. Weekly survey questions regarding interests and study habits

Associate Dean Henri Jansen collected all student data above from CORE reports, our surveys, and the class gradebook. He coded an anonymous identifier to each student's data so that correlations between the data could be assessed by the study team. Indirect identifiers with visible indicators included: major, ethnic ID, age, gender, whether they identify as LGTQ+, and whether they're first generation college students will be voluntarily provided by the students in the surveys. The indirect identifiable data was treated with special care for undergraduate researchers accessing the data. Any combination of these indirect identifiers with a cohort of $n<10$ members will be

aggregated until n>10. To achieve an n>10, multiple years of data might be combined until the individual cohort is large enough.

D. Data Analysis

Data was analyzed using standard statistical tools and methods. The results are what will be made available for publication and presentation of findings. Excel, Box, and OneNote were all platforms utilized by the research team for data analysis.

III. RESULTS

A. Demographic Composition of Student Populations

As a research team, we investigated the demographic compositions of all three cohorts. We received data from an on-boarding introductory survey that was released in the middle of fall term. Table 1 illustrates a snapshot of the majority demographics in each cohort.

Campus	Race	Average Age	% Employed	% 1st Gen	Average Parent's Education	% Taken Physics Before	% LGBTQ+	Gender	Average Class Standing	Average GPA
Corvallis	66% White	20.6	80.0	22.1	Bachelor's	54.4	11.6	63% Female	Junior	3.37
Cascades	79% White	24.9	91.6	7.14	Bachelor's	64.3	21.4	57% Female	Senior	3.59
Ecampus	77% White	26.6	95.7	32.3	Associate's	64.5	12.9	53% Female	Senior	3.15

Table 1: Overall Demographic Composition of Student Populations in Physics 201 Fall 2019. The three cohorts are Corvallis, Cascades, and Ecampus. The majority of the students were white, female, had taken physics before, employed and of upperclassman standing. The largest differences were in age.

All three cohorts had similar demographics. We were interested in how the student populations compared, so we applied additional statistical methods to analyze the percent difference each cohort had to the overall mean of all three cohorts [Table 2].

Campus	Physics Class Before	Race	Employment	1st Generation	LGBTQ+	Parent's Education	Help from Staff	Prepare for Lecture	Use of Answer Repositories	Class Standing	Gender Identity	Age	City of Residence	Major
All	1.62	5.77	3.98	1.80	1.89	4.75	3.11	2.12	3.72	3.69	1.68	24.05	1.80	5.77
Corvallis	0.96	1.05	0.92	0.99	1.01	1.01	1.02	1.10	0.89	0.84	0.85	0.86	0.65	1.08
Cascades	1.01	0.96	1.00	1.07	0.95	1.07	0.94	0.94	1.04	1.05	0.98	1.04	1.11	0.58
Ecampus	1.02	0.98	1.08	0.94	1.04	0.92	1.04	0.96	1.07	1.12	1.17	1.10	1.24	1.37

Table 2: Comparison of Student Populations in Physics 201 Fall 2019. This table was organized to display the general similarities and differences between all three cohorts. The more similar the colors, the more similar the cohorts, this is shown on the left side of the table. The more different the colors (on the right side) the more different the cohorts are from each other.

Corvallis, Cascades, and Ecampus differ mostly in major, city of residence, age, class standing, and gender identity. Similarities occur in having taken physics before, race, employment, first generation, and LGBTQ+ identity.

B. Demographics and Exam Performance

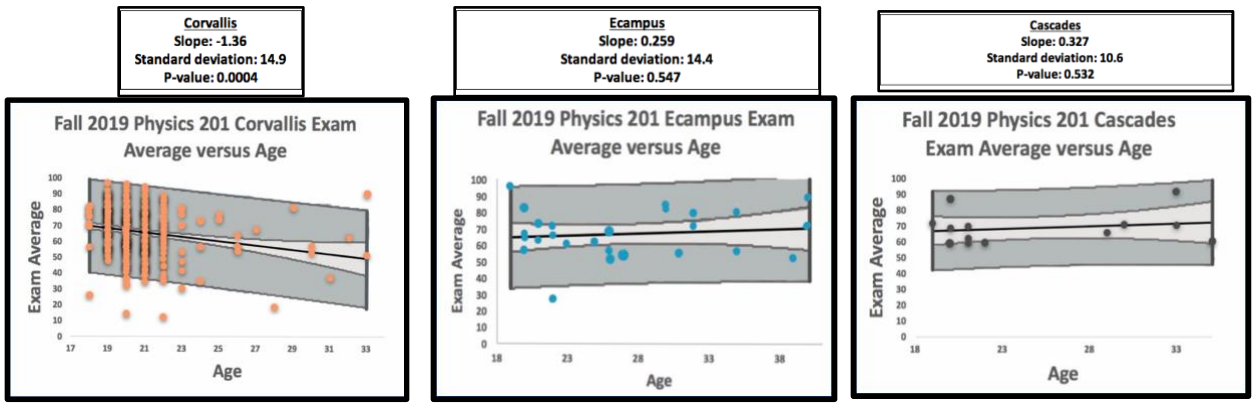

Figure 1: Correlations of Average Exam Percentage and Age. These plots analyze the relationship between age and average exam percentage. Corvallis has a negative correlation while Ecampus and Cascades have a slightly positive correlation.

We explored potential correlations between demographics and overall exam performance. The most significant findings are displayed in [Figure 1]. We found a negative slope in the Corvallis student populations. A higher age in Corvallis contributes to approximately a 1.4 % decrease in exam performance. This can be a result of the

general makeup of the Corvallis campus: a traditional classroom with the majority of students aged 19-22. We suspect that students who are older, senior standing or above, in Corvallis are less inclined to dedicate the same amount of time as their younger counterparts. Interestingly, we see a significant difference when looking at Ecampus and Cascades. For Ecampus students, there is about a 0.2% increase in exam performance with an increase in age. For Cascades students, there is approximately a 0.3% increase in exam performance. It should be noted that both cohorts, Ecampus and Cascades, have significantly less students than the Corvallis campus. Consequently, these correlations may not be completely representative due to the limitations of small sample sizes.

C. Gradebook and Exam Performance

Considering the importance of a flipped-classroom approach, we were interested in how performance and effort on assignments influence a student's overall exam average. We looked at a variety of graded assignments: Learning Catalytics score (lecture participation), online homework (pre- and post-lecture assignments), challenge homework (several more challenging physics problems delivered weekly), and lab grade. For each cohort, we found the most significant correlations for these assignments and students' performance on exams.

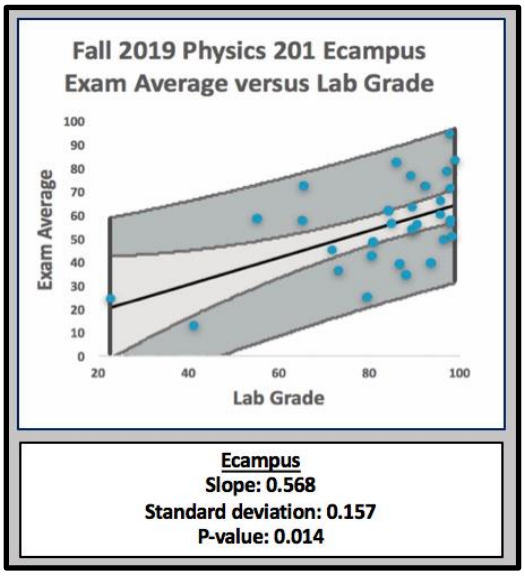

Figure 2: Ecampus Average Exam Percentage versus Lab Grade. The sample has a positive correlation with lab grade and average exam percentage. The p-value was 0.0136 indicating that this data

For the Ecampus classroom, the assignment that influenced exam performance the most was overall lab grade [Figure 2]. In the Physics 201 course, a major difference in delivering the curriculum online was incorporating a lab. On campus, students attend a three hour class that focuses on hands-on experiments to reinforce concepts learned in lecture. For the Ecampus course, this was not a possibility. Labs were redesigned to permit objective discovery and independent learning. Students received a lab kit with necessary supplies and a different set of lab instructions that allowed them to perform the labs at home. We found the most significant correlation for exam performance to be lab grade. There was approximately a 5.7% increase in exam performance. We suspect this may be due to the active learning mechanisms in place for students who have to take the Ecampus labs. These labs were restructured to emphasize independent discovery and scientific theory. Perhaps the necessity of metacognitive practices and the closeness to the physics curriculum permitted this kind of significance.

Next we looked at the Corvallis cohort. The most significant correlation was exam performance versus challenge homework grade [Figure 3]. In the Physics 20X series, students are required to work on weekly challenge homework problems. These problems are designed as synthesis word problems that require several steps and methods to solve them. They are written primarily with a focus on the current topic that students are learning in lecture. For example, a week focusing on Newton's Second Law of Forces will have one or two problems directly related to this subject.

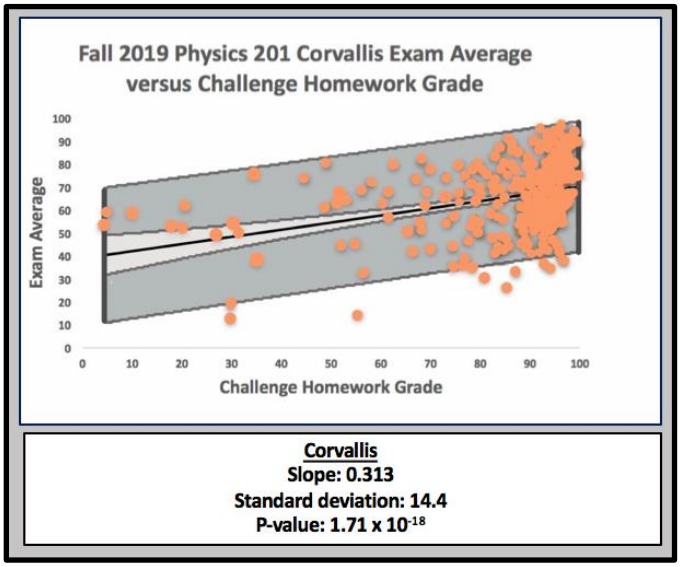

Figure 3: Corvallis Average Exam Percentage versus Challenge Homework Grade. This sample had a positive correlation with challenge homework grade and average exam performance. The p-value was 1.28×10^{-10} indicating that these findings were statistically significant.

For the Corvallis cohort, the most significant correlation was exam performance and challenge homework grade. There was about a 3.1% increase in exam average with an increase in the overall challenge homework grade. We suspect that this is due to the accessibility of on campus students. For the Corvallis campus, Learning Assistants (similar to Teaching Assistants but with undergraduates) hold Learning Assistant Homework Help Hours (LAHHH) weekly Monday and Thursday evenings. These hours are primarily for physics students working on challenge homework. The ability of students to attend these hours enables them to ask questions from instructional staff, get their work checked, and form groups while working on homework. With this in mind, it would make sense for there to be a significance in a student's challenge homework grade. Higher overall challenge homework grades suggests a behavior that ultimately utilizes the course's available resources. Students who regularly attend homework help hours have more opportunities to learn where they went wrong and how to accurately solve complicated synthesis problems.

Our final exploration was looking at the Cascades cohort. We found the highest correlation to be average exam performance and overall homework grade [Figure 4].

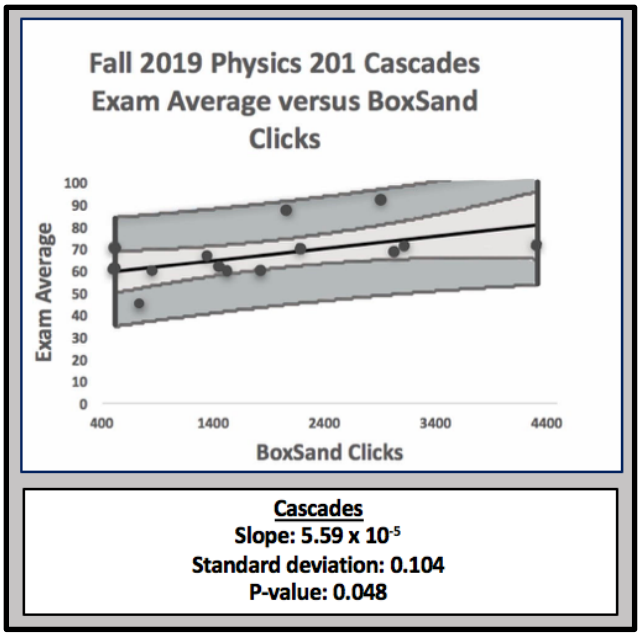

Figure 4: Cascades Average Exam Percentage versus BoxSand Clicks. There is a positive correlation between exam performance and BoxSand Clicks. The p-value was 0.048 indicating that the data was statistically significant.

The Cascades cohort had the most significant correlation between overall homework grade and BoxSand clicks. The course website, boxsand.org, is like an open source physics textbook that is organized to follow the general progression of the class. We were able to determine how many times a student clicks on the site, what assignments they click on, and what their general activity was like. We found a very slight positive correlation of about 5.59×10^{-5}. It should be noted that this cohort was also significantly smaller at about 3% of the student population in the Corvallis course.

D. Institutional Data and Exam Performance

Another area we wanted to look at was whether institutional data contributed to exam performance. We pulled data from OSU records and found the most significant contributor to be a student's overall OSU GPA.

We looked at several areas in institutional data including age, class standing, number of credits taken, OSU GPA, major, and secondary school GPA. This data enabled us to explore potential underlying influences that can predict a student's performance on exams. The most significant correlation occurred in the overall OSU GPA versus average exam performance. There was about a 14% increase for Corvallis, a 23% increase in Ecampus, and a 7% increase for Cascades. It is prevalent that a student's GPA can contribute to their performance on exams; however, there are some interesting differences between the three cohorts.

The Cascades campus has the lowest significance, but we suspect this is due to the overall GPA distribution of this sample. The majority of students have GPAs in the 3.0-4.0 range, which contrasts with what we see in Corvallis and Ecampus. Corvallis campus has a higher significance due to the greater range of GPA: more students fall in the 2.0-3.0 range than Cascades. It also has the largest sample size, with the majority of students within the 3.0-4.0 range. As for Ecampus, the range is similar to Corvallis but has more even distribution. We suspect that the variety of GPAs in Ecampus contribute to the highest significance in exam performance.

E. Academic Performance Distribution

Our final analysis explored the overall distribution of academic performance in all three cohorts. We determined the most representative measure of academic performance to be average exam grades and final letter grades in the course. Our data summarizes these distributions in Physics 201 of Fall 2019.

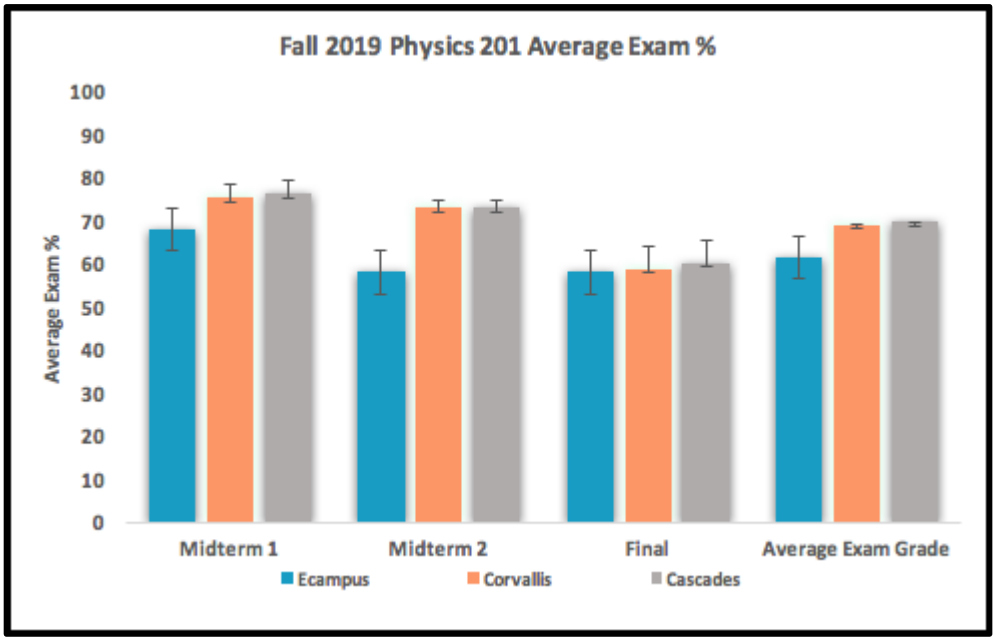

Figure 6: Physics 201 Fall 2019 Exam Averages. Ecampus is listed as a blue indigo, Corvallis is a mint green, and Cascades a light purple. Of the three cohorts, Cascades generally has the highest exam average while Ecampus has the lowest.

Due to the overall structure of the course, we highlighted the most significant measure of academic performance to be average exam performance. This is because all exams were identical regardless of cohort. According to Figure 6, Midterm 1 had the highest overall performance of around 75-80% while the Final had the lowest averages of about 58-60%. Cascades typically had the highest overall exam average throughout the course, with Ecampus having the lowest. Collectively, Cascades and Corvallis have similar values, only differing by a few percent. For Midterm 1, Cascades and Corvallis had an average of about 75% while Ecampus had approximately 68%. These values are somewhat consistent in Midterm 2, as Cascades and Corvallis have an average of about 74% and Ecampus of about 58%. Interestingly, the average final exam grades were quite similar between all three cohorts at around 60%.

Another area we were interested in was the clickstream data received through the course's website, boxsand.org [Figure 7]. We determined the average clicks per student and determined the percentage distribution of clicks for each campus.

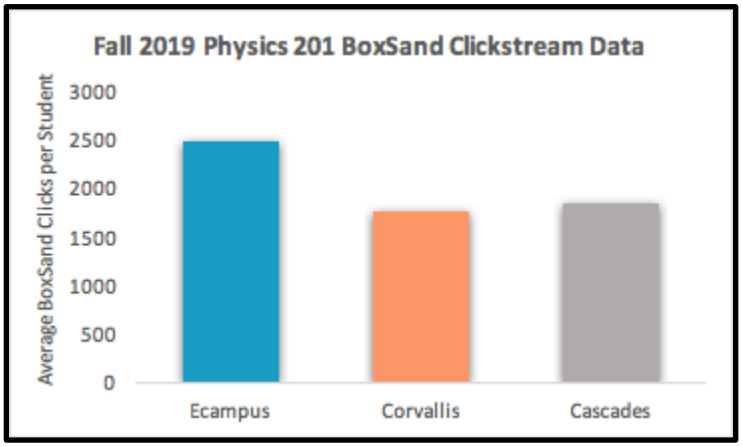

Figure 7: Physics 201 Fall 2019 BoxSand ClickStream Data. Ecampus is a blue indigo, Corvallis is a mint green, and Ecampus is a light purple. Ecampus has the highest percentage of clicks, about 10% more than Corvallis and Cascades.

We looked at the overall distribution of "clicks" on the BoxSand website. What we found was that Ecampus dominated with the highest average of clicks per student, at about 10% more than the other two campuses. We suspect that this is due to the remote delivery through Ecampus. Students taking physics fully online are consistently utilizing this website, as it is fundamental towards their understanding. For the on campus students, they have the ability to interact more easily with peers and instructors. They also can physically attend office hours or homework help hours. These attributes are available for Ecampus as well, yet all communication is done remotely.

We also wanted to look at the overall final letter grade distribution for the course [Figure 8]. We determined the amount of students for each letter grade and calculated the percentage of students per campus for each letter grade.

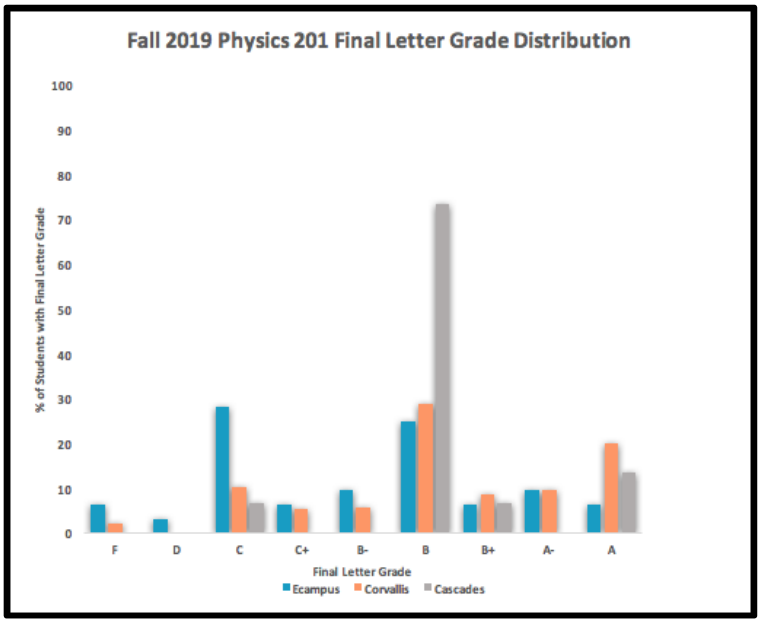

Figure 7: Physics 201 Fall 2019 Final Letter Grade Distribution. Final letter grade ranges from F-A. Ecampus is a blue indigo, Corvallis is a mint green, and Cascades is a light purple. The majority of students in Corvallis and Cascades receive a B in the class while the majority in Ecampus receive a C.

The ultimate measure of academic performance can be highlighted in the final letter grade. Overall, the majority of students received a passing grade in the class (C or above) and varied mostly in the distribution of As, Bs, and Cs. The Corvallis campus has a more evenly distributed representation of grades within the C-A range. About 20% of students in Corvallis received an A in the course and close to 30% received a B. Cascades had around 12% students receive an A and over 70% received a B. Ecampus had more students receiving Bs and Cs: around 25% achieved while approximately 28% received a C. The non-passing grades, Ds and Fs, are represented by the Ecampus population.

IV. CONCLUSION

A. Discussion of Results

This comparative analysis illuminated a number of discoveries and insights. It should be noted that both cohorts, Ecampus and Cascades, have significantly less students than the Corvallis campus. Consequently, these correlations may not be completely representative due to the limitations of small sample sizes.

Demographically, our cohorts have many similarities yet differ in various ways. Overall, the majority of students in all campuses are white, employed, female, and are either a junior or senior. Our campuses differed the most in majors, city of residence, age, and gender identity. These revelations were expected considering the general makeup of the college campuses. OSU in Corvallis is a medium-sized state school of about 30,000 students. Undergraduates typically fall within the age range of 18-23, so it's understandable that most students taking physics are 20, 21, or 22. As for Cascades, the branch campus exists in a more populated city. The general makeup consists of older students who are working in addition to attending classes. Ecampus has students from all over, and is not limited to the generalities that exist on the traditional campus.

Once we had a clearer picture of the demographic composition of our students, we wanted to see if there were any correlations with exam performance. We looked at each demographic measure compared to average exam grade and found that age displayed the most interesting data. In Corvallis, there is a negative correlation with age and exam score. We suspect this is because students who are older, senior standing or above, are less inclined to dedicate the same amount of time as their younger counterparts. A higher age in Corvallis contributed to approximately a 1.4% decrease in exam performance. Ecampus and Cascades had only a 0.2-0.3% increase in exam performance, indicating that age did not impact one's grade as much as Corvallis.

From an academic perspective, we were interested in how performance and effort on assignments influence a student's overall exam average. We looked at various graded assignments: Learning Catalytics score (lecture participation), online homework (pre- and post-lecture problems), challenge homework (several more challenging problems delivered weekly) and lab grade.

In the Ecampus cohort, the assignment that contributed the most to exam performance was the overall lab grade. This year, a major difference between the on campus and online campus in Physics 20X was the lab. On campus, students attend a three hour lab once a week to review physics concepts learned in lecture with hands-on experiments. This activity had to be altered in order to properly incorporate a lab into the Ecampus curriculum, as students do not have the ability to physically attend the labs on campus. With this in mind, labs for Ecampus were designed to permit objective discovery and independent learning. Students received a lab kit with necessary supplies and a different set of lab instructions that allowed them to perform labs at home. There was

approximately a 5.7% increase in exam performance with every increase in overall lab grade. Considering the other class assignments, the overall lab grade had the largest significance on exam performance for the Ecampus cohort. We suspect this may be due to the active learning mechanisms in place for students who enroll in the Ecampus cohort. These labs have been restructured and rewritten to adequately promote metacognitive practices and scientific inquiry. This allows students to make their own assumptions, design their own experiments, and come to their own conclusions with every lab. Consequently, Ecampus students are having more exposure to the physics content by actively engaging in the experiments, as they are required to work on them independently without the immediate help of a TA nearby.

The next cohort we looked at was the Corvallis campus. The one class assignment that influenced exam performance the most was overall challenge homework grade. This correlation had about a 3.1% increase in the overall exam average. Challenge homework is unique to the Physics 20X series, as it is written by the instructors and is a set of weekly complex synthesis problems that require more time than the typical online homework. We suspect that its significance in the Corvallis cohort is due to the accessibility and availability of class resources. In Corvallis, Learning Assistants (basically Teaching Assistants except are peer undergraduates) hold Learning Assistant Help Hours (LAHHH) weekly Monday and Thursday evenings. These hours are primarily for 20X students working on challenge homework. The ability of students to attend these hours enables them to ask questions from instructional staff, get their work checked, and form study groups while collaborating on homework. That being said, it would make sense for there to be a significance in a student's challenge homework grade and their exam performance. Higher overall challenge homework grades suggests a behavior that ultimately utilizes the course's available resources. Students who regularly attend LAHHH have more opportunities to learn where they went wrong and how to accurately solve synthesis problems.

We looked closely at the Cascades cohort and determined only one class assignment that played some significance in exam performance. This was the amount of BoxSand clicks, which refers to the number of times a student "clicks" on the course website, boxsand.org. All other class assignments had no relative significance to exam performance. We believe that this is due to the small sample size, as Cascades had the smallest number of participants at only 14 students, which is about 3% the student population in the Corvallis course.

Institutional data and exam performance was another area we were interested in. We pulled data from OSU records and found the most significant contributor to be a student's overall OSU GPA. There was about a 14% increase in Corvallis, a 23% increase in Ecampus, and a 7% increase for Cascades. These findings were not that surprising

considering the average GPA of each cohort: 3.37 in Corvallis, 3.59 in Cascades, and 3.15 in Ecampus. Collectively, each cohort has its own population of students with different backgrounds. Students typically follow their own learning style and patterns, so it would make sense for their performance on exams to be influenced by an underlying academic motivation, such as one's GPA.

Finally, we looked at the overall academic performance distribution of all three cohorts. Specifically, we investigated the exam averages for each test, the average number of BoxSand clicks per student, and the final letter grade distribution. On average, the Ecampus cohort had exam scores of approximately 10% less than the exam scores in Corvallis and Cascades. Ecampus ended up having the highest number of average BoxSand clicks per student, which was expected in the delivery of an online course. We also found that the majority of students in Corvallis and Cascades received As and Bs while the majority of students in Ecampus received Bs and Cs. With these statistics in mind, we now see the necessity of improving online education. It is apparent that students in the Ecampus cohort are less successful in the course than their on-campus counterparts even in an integrated curriculum with identical exams.

B. Future Work

Our research has opened many doors towards further investigation. Although we conglomerated an abundance of data, we are simply scratching the surface. My thesis only consists of data analyzed from fall term while the main research project will consist of all three terms. Interestingly, our results from spring term due to the COVID-19 pandemic will yield even further analysis and questions. This project will continue for several years which will help lessen the limitations of our small sample sizes in the Ecampus and Cascades cohorts as we compile yearly data.

A limitation of this study exists in the baseline analysis. The majority of our data is compared to exam performance, as we indicated this as the ultimate measure of a student's learning. However, we understand that this is not necessarily the one solution for quantifying a student's learning.

Additional research will narrow the scope of our current findings. Some of these ideas may look at an exploration into academic dishonesty (exam cheating, homework copying, etc.). Another interesting area to explore is characterizing "types" of students. Perhaps looking more closely at our students and defining their study habits, preferred methods of learning, and behavior. Even narrowing the scope on exam structure and who succeeds on what types of questions could be an interesting area to investigate.

Overall, this is only the beginning. Our research has developed into a deeper analysis of how the class is structured and how we can improve distance learning.

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