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Student Learning Outcomes in a Statistics and Probability Course with a Credit/No Credit Option

Gary Koenig

Professor Gary Koenig is an Associate Professor in the Department of Chemical Engineering at the University of Virginia. He received a B.S. in 2004 from The Ohio State University and a Ph.D. in 2009 from University of Wisconsin-Madison, both in chemical engineering. He followed graduate studies with postdoctoral research in the Electrochemical Energy Storage Group at Argonne National Laboratory before starting a faculty position at University of Virginia. His current research interests include nucleation and growth of energy storage materials, batteries for transportation and stationary applications, electrochemical phenomena and systems, materials characterization, colloid and interface science, and science of teaching and learning within engineering curriculum. Gary has taught courses at both the undergraduate and graduate level for offerings from the chemical engineering and applied math programs at University of Virginia.

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Gary M. Koenig Jr.

University of Virginia

Introduction

The Fall semester of 2020 brought many challenges to student learning. The pandemic brought health, family, and economic stress. Although there was not the disruption from the abrupt transition to online learning at the onset of the pandemic as in the Spring 2020 semester, in many cases the following Fall semester courses that were normally taught via in person instruction were only offered in online instruction modes. An additional factor in 2020 that was different from previous years at many institutions was the option to take courses credit/no credit, even if these courses generally were only allowed to be taken for graded credit in the past.

At the institution which was the focus of this study, the majority of courses were delivered via online instruction mode in Fall 2020. The course that was the focus of this work was a statistics and probability course which was offered by an engineering department. This course is generally only offered for in person instruction, but in Fall 2020 only online delivery was available for all sections. All students were given the option of choosing to take the course for either a grade or on a credit/no credit basis. There was a set decision point window during the semester when students had to select which grading option they would be evaluated on, and the selection was an option for each course individually. This paper will describe efforts to understand the potential outcomes of the credit/no credit decision on student learning.

Literature Review

Student motivation is one factor that influences learning outcomes in a course. In this study, there were at least three major factors that influenced student motivation that were unique to the Fall 2020 course relative to offerings prior to Spring 2020. Stress brought on by the pandemic would be expected to impact motivation [1]. All students were impacted by the pandemic, and although the magnitude would be expected to differ widely for each individual student, such factors are challenging to quantitatively assess. Additionally, students were adapting to a primarily (if not entirely) online learning environment as opposed to the typical all in person learning environment. Individual students would respond differently to the transition to online learning [2], however; accounting for the individual learning outcomes impacts for different students on the basis of their adaptation to online learning environments was not quantitatively assessed in this work. In this study, the differences in learning outcomes for students who chose credit/no credit compared to those who selected to receive a course grade were compared. It is expected that the pandemic and transition to online learning influenced the student decision on whether to take a course credit/no credit or for a grade, however, the analysis focus in this study will be on the association between the grading decision and learning outcomes.

This study of student learning and motivation can be considered in the context of the broader research on student motivation, and any differences observed based on demographic factors. For example, previous research has provided evidence for the importance of student motivation in grading outcomes through increased engagement with the course by incorporating an application focus [3]. There is also an existing literature with regards to the history of grading [4], and in how grading incentives impact student learning outcomes [5]. Another relevant study found evidence to support that exam performance has the least improvement from those students that have the most to gain (due to low scores before the exam) from additional study and motivation [6]. In summary, student motivation is complex, however, it has been found that 1) student engagement with the material is important for encouraging student learning and 2) grading can motivate students, but it can be a stronger motivator for those students already achieving higher grades. It is expected that this analysis of the impact of the credit/no credit decision point will be an important addition to the research area of how grading motivators impact student learning.

Purpose and Research Questions

The primary research question that was investigated was:

1. What is the change in test outcomes in a statistics course for students who choose credit/no credit compared to those who choose to be graded when offered the option in the middle of the semester?

To further address this research question, and additional research question was:

2. How does the selection of a credit/no credit option impact student test scores relative to their expected outcome in the course based on grades from prior courses?

Where the first question investigates whether the students had different outcomes based on an initial assessment within the course (i.e., the first test), the second question investigates student learning outcomes (quantified via test scores) compared to predicted outcomes based on grades in previous courses. To address the second question, analysis had to be conducted to determine the correlation between prior courses outcomes/grades and the statistics course which is the focus of the study.

Description of the Course and Situation

The course that is the focus of the study is a single semester statistics course offered at a research-intensive university. The students who take the course are pursuing undergraduate degrees in engineering, and the course is typically taken by students during their third or fifth semester in college. The course is offered in three sections with three separate instructors, but the tests and most other assignments are consistent across all the sections. The main prerequisite is a Multivariable Calculus course, although to take that course students also must have completed Single Variable Calculus. In some cases, students have also taken a semester of Ordinary Differential Equations before taking statistics. These other three math classes are specifically mentioned here in part because grades were used from these other math courses to predict the expected outcomes for students in the statistics course.

Methods

Participants

For the Fall 2020 statistics course, there were 129 students in total. 79 students chose to take the course for a grade and 50 students chose to take the course credit/no credit. For these 129 students the data included all test scores and their grades in the three other math courses mentioned earlier.

To build predictions of grades/test scores for students in the Fall 2020 cohort, the grades in math courses for students who previously took the statistics course were analyzed. Institutional data was obtained for prior students who took the statistics course from 2015 to 2019. For the prior course grades, data for 1,667 students was analyzed.

Data Analysis

For the prior course year data, all student grades available for the statistics course and the three other math courses were converted to the corresponding numerical grade point average value via processing with a Matlab script (e.g., A = 4.0, A- = 3.7, B+ = 3.3, B = 3.0, etc.). Not all students had inputs for all the math courses due to course credit from other sources/institutions, and thus the correlation between the grade in the statistics course and the average grade for all other math courses was calculated for each combination of math course grade inputs. Linear regression was performed to provide a line of best fit with the statistics course numerical grade as the dependent value and the average numerical grade for the other math courses as the independent variable. For a given student, the input math grades with the highest correlation to the statistics course grade was used to calculate their "predicted" course grade for Fall 2020.

After all of the predicted course grades (in numerical form) were calculated, these grades were converted to a predicted test score for Fall 2020. To calculate the predicted test score for Fall 2020, first the assigned grades for all students in one of the sections (n = 43) was extracted. Then, a linear regression was conducted using these final course grade numerical scores as the independent variable and the total sum of only the test scores as the dependent variable. The outcome is a linear model that relates student test scores to their final assigned grade. For every student a grade was predicted using prior student cohort linear models and the data for each student's prior grades in math courses. The predicted numerical course grade for each student was then converted to a predicted final test score based on the linear model from the single student section. Thus, comparison could be made between the predicted and observed total points on tests in the course for each student who took the statistics course in Fall 2020, regardless of whether they opted to take the course for a grade or for credit/no credit.

In addition, the difference in the scores on the first test and the second test were compared for the graded and credit/no credit student cohorts. The students were notified that there would be a credit/no credit option for the course after the first test had already been taken, and they had to make their final decision on whether they would choose the credit/no credit or graded option before the second test.

Results

For the 1,667 students that took the statistics course from 2015-2019, the students were pooled depending on how many of the other math courses had grades available. As can be seen in Table 1, the highest correlations were achieved for the students where course grade data was available for both of the Single Variable Calculus and Multivariable Calculus courses. For all seven cases of course grade cohorts, linear regression was performed. The linear models were then applied to the students in the Fall 2020 cohort to predict their course grades based on the most appropriate situation with regards to the prior math course grades available.

Table 1. Correlation between the grade in the focus statistics course and the average grade in three other math courses. Number of students indicates how many from the total pool had grades available for the subset of the other three courses in a given row.

Courses with Data			Correlation	Number of Students
Single Variable Calculus	Multivariable Calculus	Differential Equations	0.707	350
Single Variable Calculus	Multivariable Calculus		0.793	40
Single Variable Calculus		Differential Equations	0.552	60
	Multivariable Calculus	Differential Equations	0.570	489
		Differential Equations	0.654	319
	Multivariable Calculus		0.392	31
Single Variable Calculus			0.298	9

At this stage linear models had been used to predict the grade in the statistics course, but it was desired to convert this outcome to a test score for direct comparison with those assessments. To do this, grades were assigned to all students in one of the sections based on their total score for all assignments regardless of whether the students had chosen credit/no credit or the graded option, and then linear regression was applied for the numerical GPA as the independent variable and test score as the dependent variable. The coefficient of determination for this linear regression was 0.955, indicating a very good fit.

The linear models for predicted numerical GPA in the statistics course based on prior math courses, combined with the linear model of the assigned numerical GPA in the course and total test scores, allowed a final test score to be predicted for every student in the course based on prior math course grades. Then, comparison could be made between the predicted and actual test scores for the graded and credit/no credit cohorts.

The students took the first test on October 7. As mentioned earlier, the announcement of a credit/no credit option did not occur until October 9. Thus, when the first test was taken, students did not know that there would be an option to switch from graded to credit/no credit for the semester. The students had to set their decision by November 6, and it could not be changed after it was set. The second test was then taken on November 11. Thus, the students made their decision on graded versus credit/no credit before both the second test and the final exam.

First, the difference between the score on the second test and the score on the first test was evaluated (Figure 1). Student cohorts that were evaluated included those who chose graded and credit/no credit, and then further splitting those two cohorts by gender. As can be seen in Figure 1, all of the student cohorts had confidence intervals which included zero and all averages were also near zero, suggesting that student performance on the second test was essentially unchanged relative to how they performed on the first test.

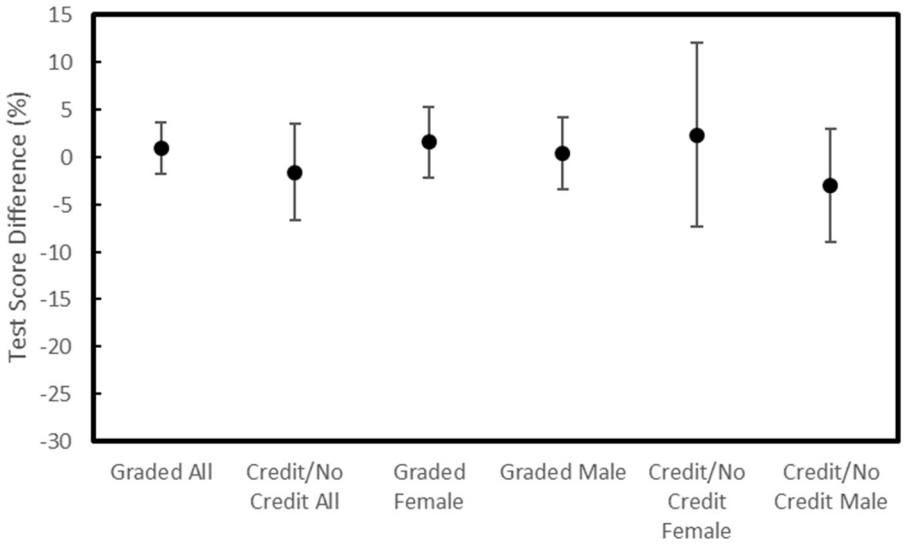

Figure 1. Difference in test score between the first and second tests in the course for the indicated student cohorts. Error bars represent 95% confidence intervals.

Similar analysis was conducted for the final total test score relative to the score predicted based on the grades for each student in previous math courses. As can be seen in Figure 2, the students in the credit/no credit cohort had lower test scores relative to those predicted based on prior course grades compared to students who took the course for a grade. When looking at the gender differences, the male and female students both were on average above the predicted values for the students who selected to receive a course grade. The confidence interval for all students in the graded cohort was centered at +4.0%. This outcome could have been due to a number of reasons, for example slightly less challenging test questions in this semester. In any case, the increase was similar for both genders. For the credit/no credit cohort, however, the male confidence interval was centered at -0.8 %, while the female cohort was at -6.5 %. It is noted that the interval width for the female credit/no credit cohort was relatively wide.

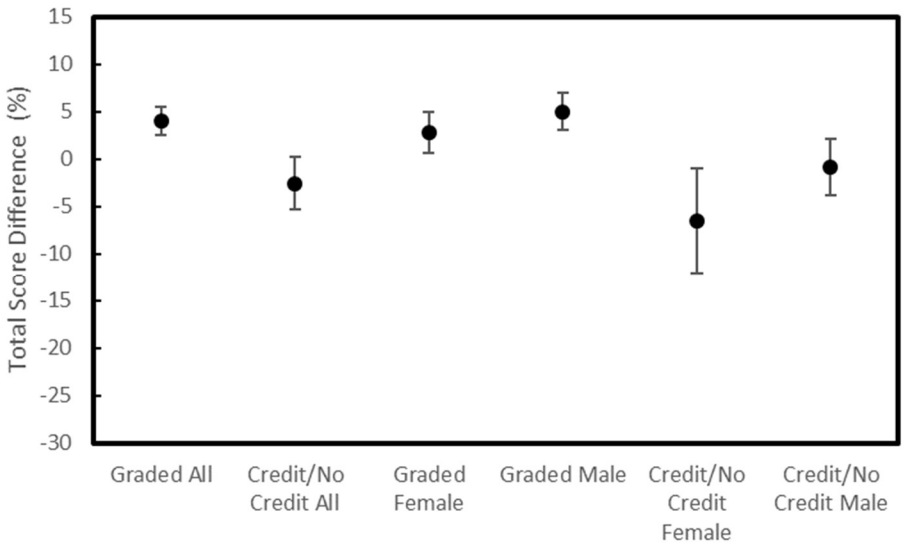

Figure 2. Difference in final total test score (sum of all three tests) observed compared to predicted in the course for the indicated student cohorts. Error bars represent 95% confidence intervals.

Conclusion

The results indicated that student test performance did not change for the tests before and after the announcement and decision points on taking the course for a grade or credit/no credit. However, the credit/no credit cohort had overall lower test scores relative to predictions based on previous math course grades. Also, female students in the credit/no credit cohort had lower test scores compared to predictions relative to male students. When combined, these results suggest that students who chose credit/no credit were experiencing lower test scores relative to those expected based on prior math course grades before the credit/no credit option was even known to be available. Thus, the observed credit/no credit differences relative to predictions of student performance likely reflected other confounding factors outside of changes in student motivation due to the knowledge of the credit/no credit option. Confounding factors may have included different student experiences with regards to adaptation to a virtual learning environment. Other possibilities include the relative stress and increases in responsibilities outside of academic studies brought on by the pandemic. With the decision point of the credit/no credit option not having significance with regards to student test outcomes, this study suggests that students that chose credit/no credit may have been aware they would struggle academically during the semester from the beginning of the course. The credit/no credit option then provided a mechanism to limit the impacts to their aggregate GPA.

References

[1] P. Subakthiasih and I. G. V. W.Putri, "An Analysis of Students' Motivation in Studying English During Covid-19 Pandemic," *Linguistic, English Education and Art (LEEA) Journal*, vol. 4, no. 1, pp. 126-141, 2020.

[2] R. A. Abumalloh, S. Asadi, M. Nilashi, B. Minaei-Bidgoli, F. K. Nayer, S. Samad, S. Mohd, and O. Ibrahim, "The impact of coronavirus pandemic (COVID-19) on education: The role of virtual and remote laboratories in education," *Technology in Society*, vol. 67, 101728, 2021.

[3] L. Zetterqvist, “Statistics for chemistry students: how to make a statistics course useful by focusing on applications,” *Journal of Statistics Education*, vol. 5, no. 1, 1997.

[4] J. Schinske and K. Tanner, “Teaching more by grading less (or differently),” *CBE—Life Sciences Education*, vol. 13, no. 2, pp. 159-166, 2014.

[5] T. N. Docan, “Positive and Negative Incentives in the Classroom: An Analysis of Grading Systems and Student Motivation,” *Journal of Scholarship of Teaching and Learning*, vol. 6, no. 2, pp. 21-40, 2006.

[6] D. Grant and W. B. Green, “Grades as incentives,” *Empirical Economics*, vol. 44, no. 3, pp. 1563-1592, 2013.