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Exploiting a Grading Option to Measure Mathematics Confidence of Engineering Students

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Background

In the study [1], we investigated the impact of COVID-19 on Applied Mathematics (APMA) courses in our Engineering School. Our survey of students who took at least one APMA course during Spring 20, Fall 20, and Spring 21 found that they were more likely to choose credit/no-credit grading for APMA courses than for their major-related courses. We hypothesized that students lacked confidence in their APMA skills and preferred to focus on the major courses. This suggests that COVID-19 has significantly affected student performance and perception of APMA courses. Further research is needed to understand the underlying reasons for these trends and to identify strategies to support students during times of crisis.

Introduction

We have expanded our analysis by incorporating data from our undergraduate registrar's office, which includes information about students who participated in our Engineering school survey. Our goal is to identify correlations and patterns between the survey results and the academic data, such as attitudes toward the engineering program, study habits, and participation in extracurricular activities.

We used the registrar's data to determine differences in academic performance between different majors and demographic groups. Moreover, we can identify students struggling academically or facing challenges and develop targeted programs and resources to help them achieve their academic goals.

Using supervised learning methods, we identified patterns in students' grading choices, specifically to find students with low math confidence. We found that some demographic factors were more likely to lead a student to opt for CR/GC/NC grading, while other factors were not significant. A student's overall GPA was an important factor, inversely related to choosing CR/GC/NC grading. We also found that the demographic factors most strongly associated with the decision to opt for CR/GC/NC grading included race, gender, and socioeconomic status. We noticed significant differences among majors, as well.

In the Fall 22 semester, our Institution offered the CR/GC/NC grading option again due to exceptional circumstances. As we collect and analyze the most recent data on students' use of the CR/GC/NC grading option, we hope to gain valuable insights into how students perceive their performance in APMA courses. The information will be useful in shaping future policies and practices related to grading and assessment. Additionally, we hope to analyze corresponding data from similar programs/options at other institutions, and, possibly, identify any significant or relevant patterns across the country.

Motivation

We try to determine the extent to which the COVID-19 pandemic impacted higher education learning. This information can be used by institutions to identify and address any negative effects experienced by students as they transition back to more typical learning environments. The pandemic has had a significant impact on nearly all aspects of our society, including higher education. The purpose of this paper is to provide insight into how the pandemic has affected college students at the University of

Virginia. As far as we know, this is the first paper to examine the impact of the pandemic on college students' experiences specifically in Applied Mathematics within the Engineering School.

To put our analysis into context, the University of Virginia is a public research university with over 24,000 undergraduate and graduate students. The academic programs are organized into 12 schools and colleges, including the School of Medicine, the Darden School of Business, and the School of Law. The target of our analysis are students from the School of Engineering, which includes about 5000 undergraduate students. The Applied Math program provides all required math courses for Engineering students. This means all math courses for our engineering students are labeled “Applied Math” courses.

The pandemic has had numerous negative impacts on the physical, mental, and economic well-being of nearly everyone. Students were confronted with potential difficulties such as losing housing, struggling with food insecurity, facing financial problems, dealing with physical and mental health issues, and feeling increasingly isolated from their peers [2]. In addition to these challenges, online learning posed new difficulties, as almost all our students had only experienced traditional in-person classroom instruction before the pandemic.

Studies have shown that online education had a specific impact on engineering students. In [3], authors found that a considerable number of students changed their short-term plans about scheduling courses in future semesters. Additionally, a noteworthy portion of students expressed concerns about the effectiveness of online instruction. STEM students had to spend more time on self-directed learning and increased time on their coursework overall [4]. Research has shown that blended (or hybrid) learning generally leads to better learning outcomes for STEM courses compared to non-STEM courses. However, paradoxically, students enrolled in hybrid STEM courses often report lower levels of satisfaction and may not view the courses as highly effective [5]. This highlights the need to redesign our Applied Mathematics (APMA) courses while retaining the tools and techniques that proved effective during online-only instruction.

The pandemic has had a disproportionately negative impact on minorities, first-generation students, and students with disabilities or health concerns, according to researchers [6]. These groups of students expressed concern about their access to educational resources and their ability to perform well in online education formats, and they faced more COVID-related challenges. The pandemic and online learning have created new obstacles to entering and continuing/completing their studies [7].

The impact of the pandemic and online instruction on our Applied Mathematics (APMA) courses is still not well understood. As indicated in [8], mathematics courses are a significant factor in student attrition, and many engineering faculty members are dissatisfied with students' mathematical abilities. It is also well known [8]-[16] that engineering students quite often view mathematics courses as a necessary evil to achieve their Engineering degree. The decision of our institution to implement a CR/GC/NC (Credit/General Credit/No Credit) grading option for three semesters (Spring 20, Fall 20, Spring 21) and two summer terms (Summer 20, Summer 21) gave us the opportunity to investigate this grading option as a proxy for students’ sentiment towards Applied Mathematics (APMA) courses.

Grading Options

Since the onset of the pandemic, to mitigate high levels of stress, anxiety, and personal and family challenges among our students, our Provost introduced the grading option CR/GC/NC (Credit/General Credit/No Credit) for 3 semesters (Spring 20, Fall 20, Spring 21), and 2 Summer sections (Summer 20, Summer 21). For undergraduates who opted into CR/GC/NC grading:

- CR grade was awarded when meeting course requirements for credit (i.e., C or higher),
- GC was awarded when receiving a passing grade below a C, and
- NC was awarded when receiving a grade of F.

Students were still given the choice to opt for the GRADED option (A+ through F). There are two important features in this grading option:

1. CR/GC/NC grades are not factored into students' GPAs.
2. Students had to choose the grading option before the end of the semester at a specific deadline: 04/28/2020, 11/06/2020, or 04/30/2021. All deadlines, even in Spring 21, were before Final Exams.

Description of Survey

Our study participants (second, third-, and fourth-year students who had taken at least one APMA course) completed a ~50-question online survey [1] early in Spring 22 semester about their experiences in APMA course(s) from Spring 20 to Spring 21 semesters. Survey questions were related to demographic data, motivation, technological tools/ applications used, office hours, help sessions, quizzes/tests in an online setting, grading options, and questions comparing APMA courses with major-related core courses.

Analysis Methods, Results, and Discussion

Different statistical methods were used to identify any patterns in the data:

- Correlations
- Linear, multivariate, and logistic regression
- Boxplots
- k-Nearest Neighbor Clustering

We considered all possible factors that could have affected a student's grading method choice. Eventually, we will extend this general analysis to other semesters, but to start off, we are primarily studying the data from the Spring 2020 semester - the transition semester from in-person to remote format. First, we check the fraction of courses taken for CR/GC/NC for 1) Physics courses 2) Major-related courses 3) APMA courses 4) All other courses. The results of the correlation analysis are in Table 1.

Table 1. Correlation among 4 different categories

Physics	Major Courses	APMA	Other
0.74	0.66	0.50	0.36

Contrary to our assumptions, the data suggests that a student was more likely to take a Physics or a major-related course for CR/GC/NC compared to an APMA course. In fact, 74% of Physics courses taken were for CR/GC/NC, compared to only 50% for APMA courses.

Section 1: Analysis of Demographic Data

Next, we performed multivariate and logistic regression analysis on specifically the demographics data (year in school, gender, race, in-state vs out-of-state). For the Logistic Regression, the model indicates few features as significant (GPA and Academic Major), with an accuracy of about 0.77. In general, there was practically no difference between how different genders or students in different years or first-generation/ non-first-generation students answered the survey.

Out-of-state students were more likely to opt for CR/GC/NC grading. There is a significant difference between in-state (~$28k) and out-of-state tuition (~$66k) at our Engineering School. We do not have a clear explanation why out-of-state students are more concerned about impacting their GPA.

However, students of certain races disproportionately opted for CR/GC/NC grading for APMA courses, but we also found that the same pattern holds true when we look at the GPA by Race. So, GPA, instead of Race, may be a primary factor. From Fig. 1, we see that races with a lower GPA are more likely to opt for CR/GC/NC grading.

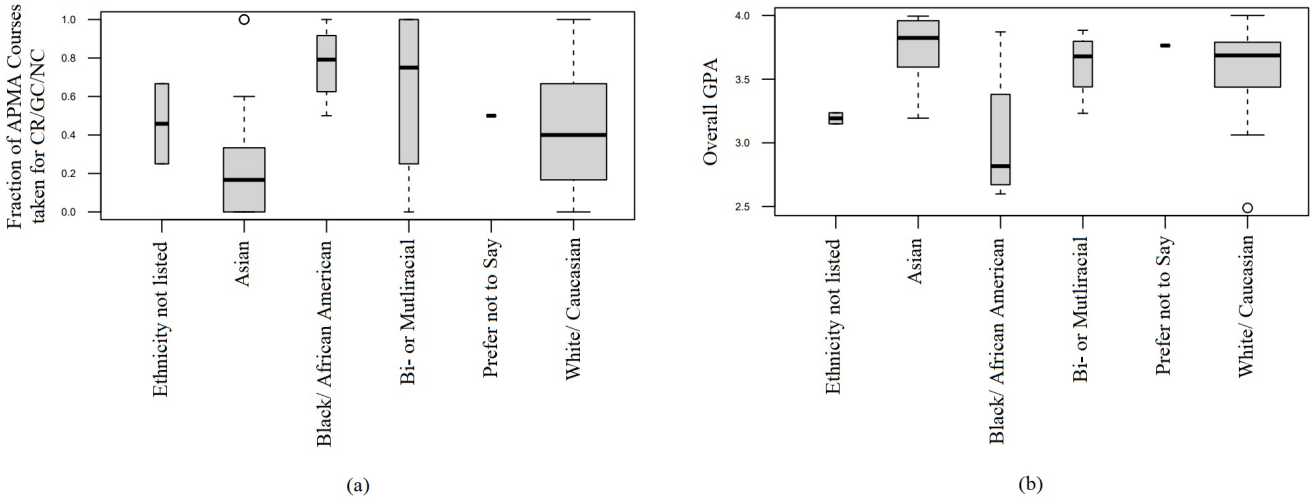


Figure 1: Different races vs (a) fraction of APMA courses taken for CR/GC/NC (b) overall GPA.

For the Spring 20 semester data, we also used k-Nearest Neighbor clustering, to predict whether students, who have taken at least 1 course from APMA, would choose at least one CR/NC (not necessarily APMA). The accuracy of our k-NN model is 76% despite our low sample size. This model includes all answers to survey questions and demographic and it is less interpretable.

Section 2: Analysis of Majors of Survey Participants

We specifically asked the students 1) if they faced problems due to the pandemic that made working towards their degrees difficult, 2) if they opted for CR/GC/NC because they were less confident about their APMA courses and/or wanted to study for their major-related courses, 3) if they would still opt for CR/GC/NC if they had to choose at the beginning of the semester, and 4) if they would rather have the opportunity to go for CR/GC/NC grading in a normal semester as well.

Interestingly, our Civil Engineering students were an outlier (compared to other majors) in saying the pandemic did not make working towards their degrees (much more) difficult and that they would prefer a letter grade in a normal semester (Fig. 2). One possible reason for this may be the nature of the discipline. Civil Engineering requires more hands-on experience, practical training, and site visits (than, for instance, Computer Science), and such students may be more adaptive to a changing environment. Our Computer Science students were an outlier in disagreeing with the statements that they were less confident about their APMA courses and that they would still opt for CR/GC/NC if they had to choose at the beginning of the semester (Fig. 3). We have evidence that our computer science students tend to be more proficient in math. This may be explained by the fact that computer science relies on mathematical concepts and problem-solving skills, such as logic, algorithms, and discrete mathematics more than any other major. In some other universities, the Computer Science program is not even part of

the Engineering School. This may create a self-selection bias, where students who excel in math and enjoy abstract thinking are more likely to choose Computer Science as their major.

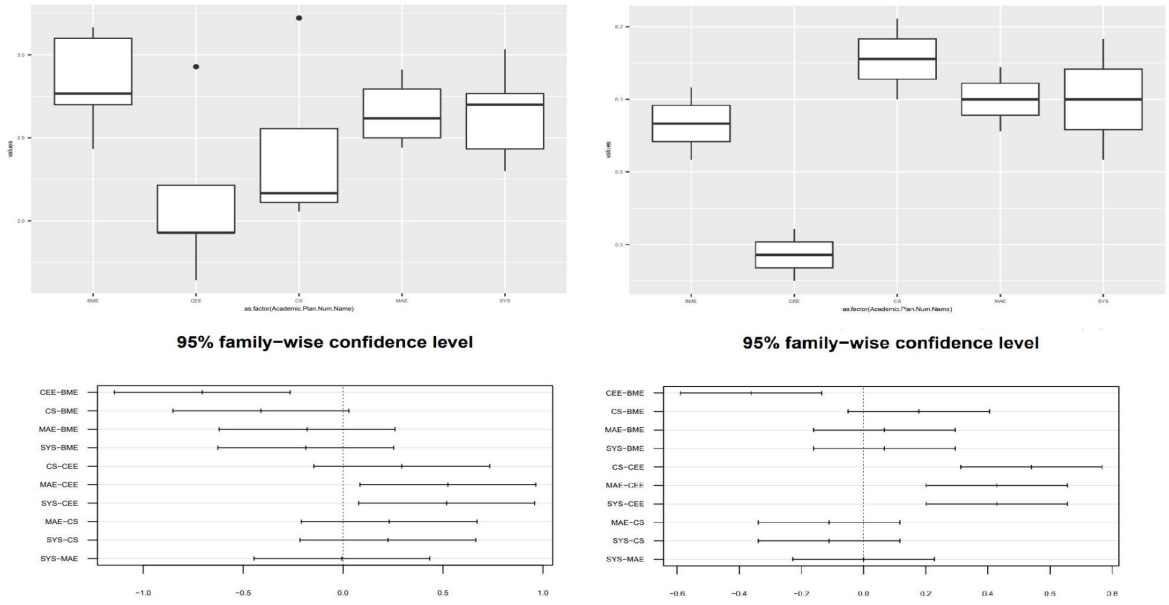


Figure 2: Civil Engineering Students Answered 2 Groups of Survey Questions Very Differently

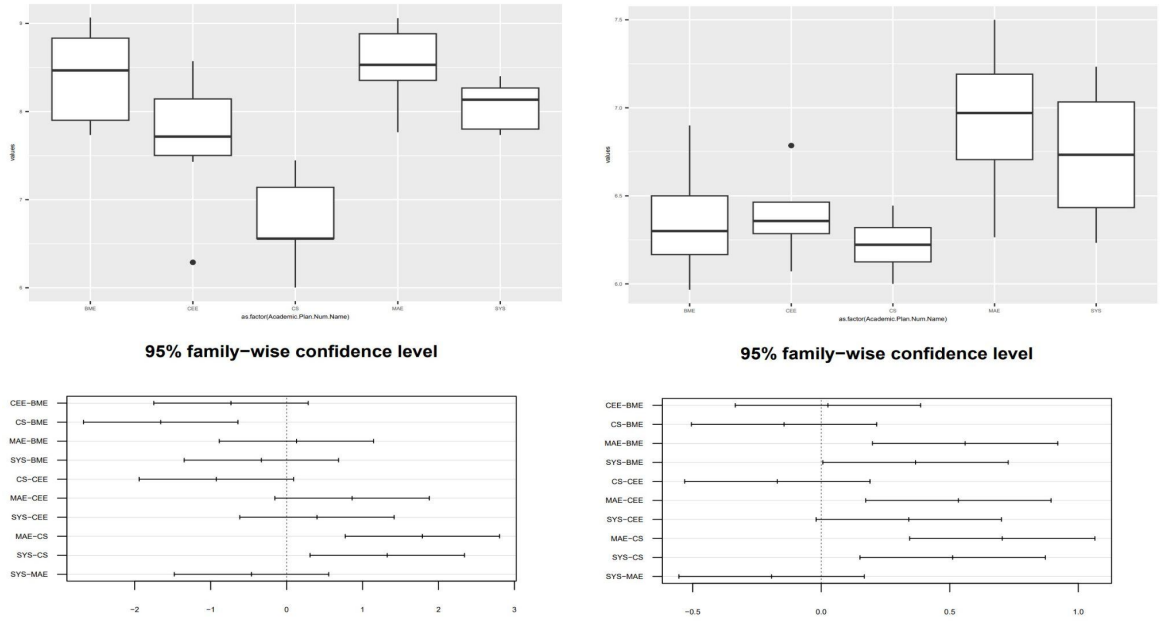


Figure 3: Computer Science Students Answered 2 Groups of Survey Questions Very Differently

Section 3: Analysis of GPA of Survey Participants for all 3 Semesters

Spring 2020 semester:

We tried to find a possible relation between the number of courses taken for CR/NC/GC and factors such as demographics, in-state/ out-of-state status, year in school, gender, etc. The one factor that stood out the most was the GPA of the student. Our overall conclusions are that a student with a lower GPA is more likely to choose the CR/NC/GC option. Still, the GPA was much less of a factor (although we can identify a weak negative correlation) when choosing the CR/NC/GC option for an APMA course (Fig. 4).

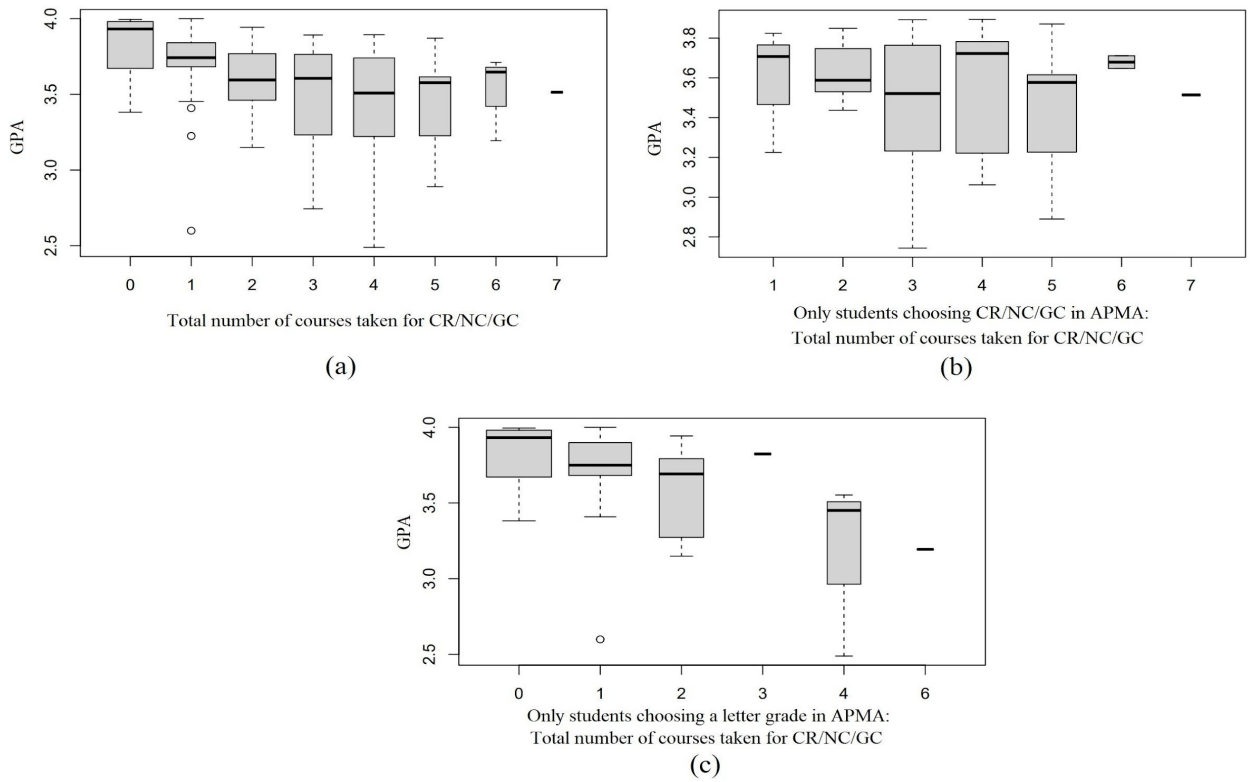


Figure 4: Total number of courses taken for CR/NC/GC (a) all students, (b) only those choosing CR/NC/GC in an APMA course, (c) only those choosing a letter grade in an APMA course.

A student with a higher GPA, in general, is more likely to opt for a letter grade. However, as far as choosing a letter grade in an APMA course is concerned, GPA is not a big factor. We divided the survey participants into two groups: those who opted for a letter grade in their APMA course, and those who did not, and plotted the results separately. Our conclusion is supported by observations from the survey responses that students in general are less motivated to do well in their APMA course, and/ or would rather reserve their time and energy to spend on their major-related coursework. The fact that the pandemic gave them the option to do so was welcomed by many. Next, we look at the total number of courses taken, and also the fraction of courses taken for CR/NC/GC as a function of a student's GPA.

From Fig 5(a), we see that most students, including those with high GPA's, took the usual number of courses (5 or 6), and therefore the usual number of credit hours, despite the pandemic-affected semester. From Fig. 5(b), we confirm the results already seen from the boxplots in Fig. 1 (a) – (c). There is a significant negative correlation (of -0.41) between a student's GPA and the fraction of courses taken for CR/NC/GC. As seen earlier, a student's GPA is much less of a factor in choosing CR/NC/GC grading for an APMA course. When we remove this effect, the negative correlation is even stronger, -0.56.

Finally, in Fig. 6, we separate students by their majors and check if the negative correlation between GPA and the fraction of courses taken for CR/NC/GC is present in all majors. For each of these majors:

Systems Engineering, Biomedical Engineering, Computer Science, and Mechanical Engineering, there indeed are negative correlations (-0.46, -0.13, -0.45, and -0.47 respectively).

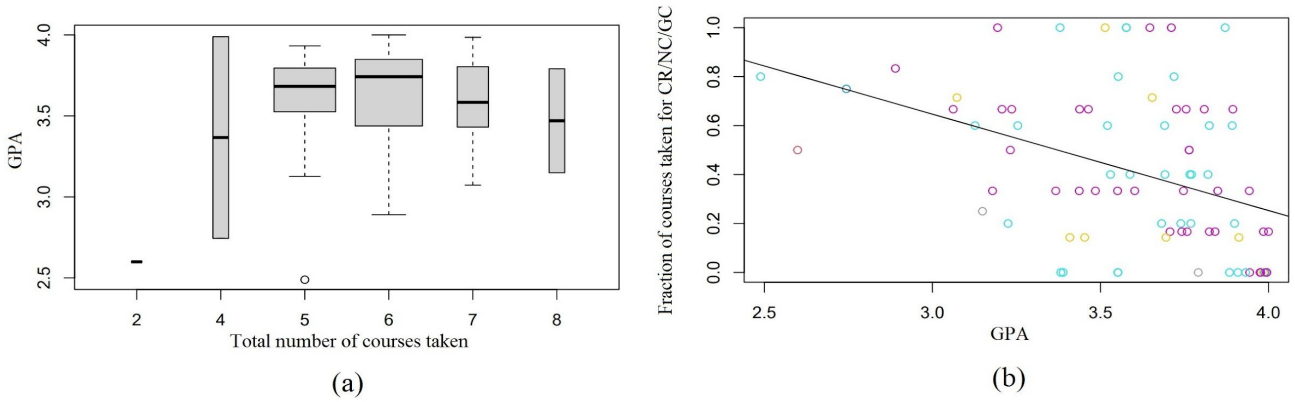


Figure 5: (a) a Total number of courses taken (for any grading choice) vs GPA, and (b) Fraction of courses taken for CR/NC/GC vs GPA, for all students

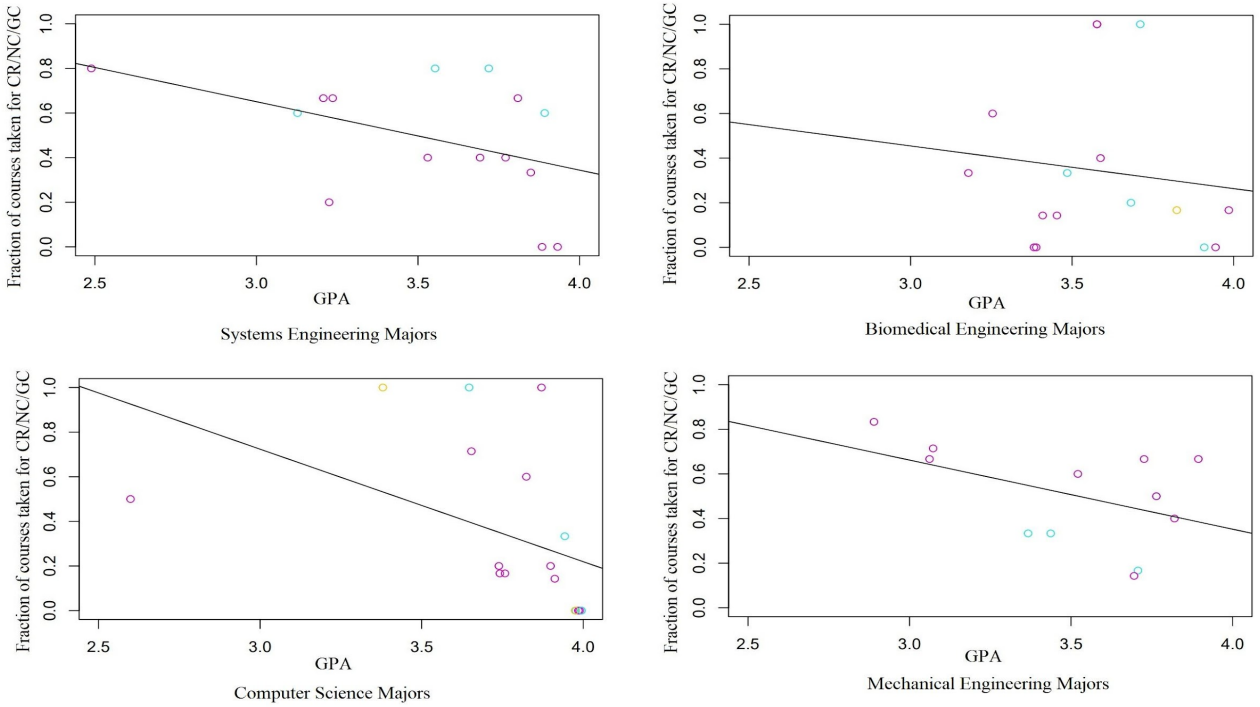
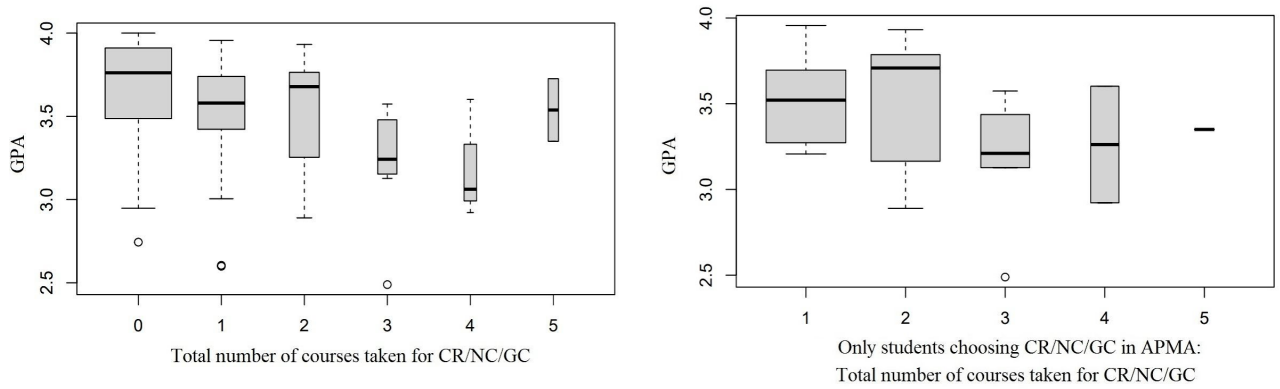


Figure 6: Fraction of courses taken for CR/NC/GC vs GPA for students from the four largest majors

Fall 2020 semester:

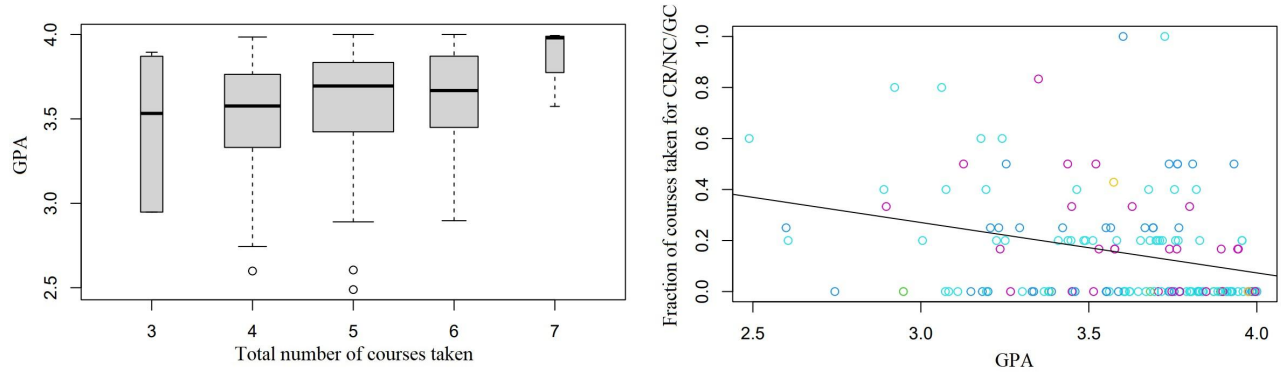
This was an in-between semester. The pandemic was raging, vaccines were not in sight, all courses were online or hybrid, and the students thought this was the new normal. As with the data from the Spring 2020 semester, our overall conclusions are still that a student with a lower GPA is more likely to choose the CR/NC/GC option, but the GPA was much less of a factor when choosing the CR/NC/GC option for an APMA course. We illustrate our conclusions in Fig. 7.



(a) (b)

Figure 7: Total number of courses taken for CR/NC/GC (a) all students, (b) only those choosing CR/NC/GC in an APMA course.

Next, we look at the total number of courses taken, and the fraction of courses taken for CR/NC/GC as a function of a student's GPA. From Fig 8(a), we see that most students are still taking the usual number of courses (5 or 6), and therefore the usual number of credit hours, despite the pandemic. From Fig. 8(b), we find a negative correlation (of -0.30) between a student's GPA and the fraction of courses taken for CR/NC/GC. However, the correlation is weaker compared to that from the Spring 20 semester. In fact, for only those students who opted for a letter grade in their APMA course, the negative correlation is weaker: -0.19.



(a) (b)

Figure 8: (a) a Total number of courses taken (for any grading choice) vs GPA, and (b) Fraction of courses taken for CR/NC/GC vs GPA, for all students

Finally, in Fig. 9, we separate the students by their majors and check if the negative correlation between GPA and the fraction of courses taken for CR/NC/GC is indeed present in all majors. For each of these majors (Systems Engineering, Biomedical Engineering, Computer Science, Mechanical Engineering), there is indeed a negative correlation as may be expected. The exact values are -0.49, -0.48, -0.21, and -0.13 respectively.

The interesting results come from our Electrical and Chemical Engineering majors (Fig. 10), although admittedly our datasets are small. For these majors, students with a higher GPA are more likely to opt for CR/NC/GC grading (in general) and the correlations are positive (0.06 and 0.27). Once again, we are investigating possible reasons for this.

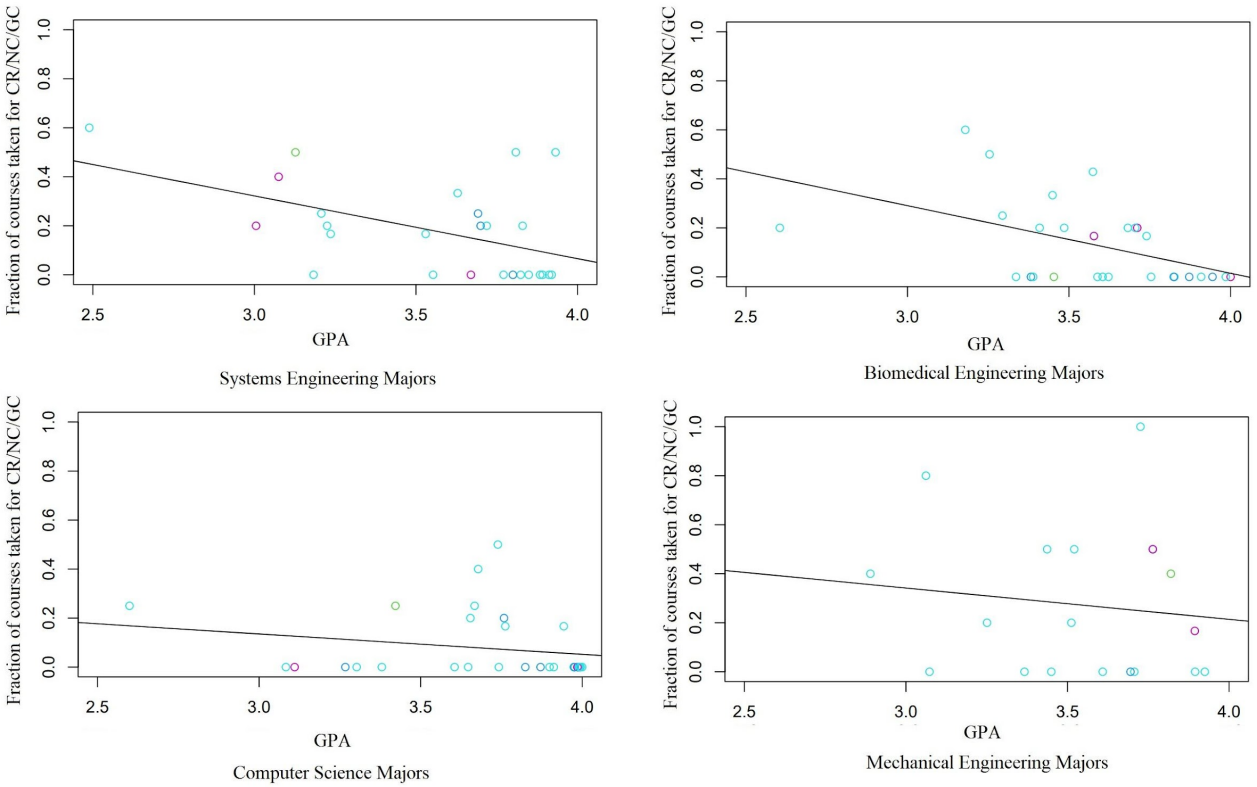


Figure 9: Fraction of courses taken for CR/NC/GC vs GPA for students from the four largest majors

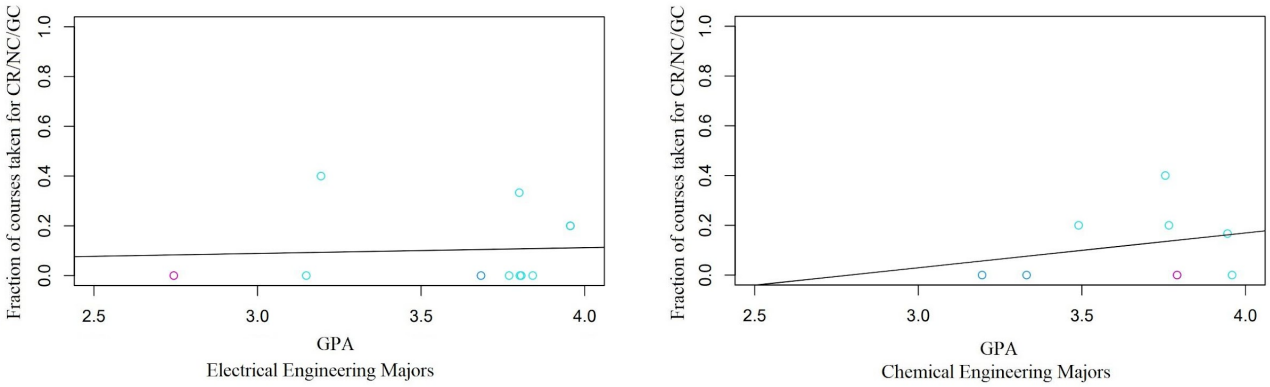


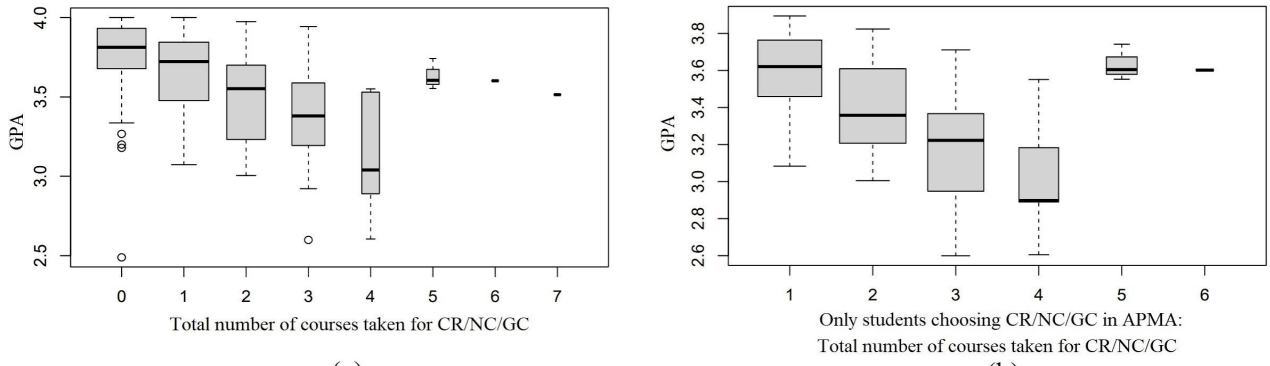
Figure 10: Fraction of courses taken for CR/NC/GC vs GPA for students from two other majors

Spring 2021 semester:

Students with lower GPAs still were more likely to choose the CR/NC/GC option, but the GPA was much less of a factor when choosing the CR/NC/GC option for an APMA course (Fig. 11).

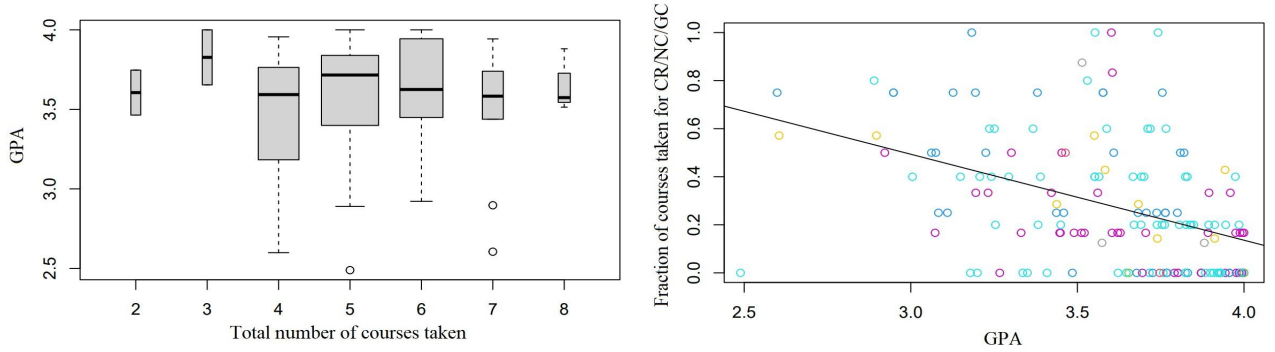
Next, we look at the total number of courses taken, and the fraction of courses taken for CR/NC/GC as a function of a student's GPA. From Fig 12(a), we see that most students are still taking the usual number of courses (5 or 6), and the usual number of credit hours. From Fig. 12(b), we find a negative correlation (of -0.43) between a student's GPA and the fraction of courses taken for CR/NC/GC. This general observation is true for all three semesters examined.

Looking at only those students who opted for a letter grade in their APMA course, the negative correlation is weaker, -0.28. For the subset of those students who opted for a CR/NC/GC grade in their APMA course, the negative correlation was -0.28. There was no practical difference from students opting for a letter grade in their APMA course(s).



(a) (b)

Figure 11: Total number of courses taken for CR/NC/GC (a) all students, (b) only those choosing CR/NC/GC in an APMA course.



(a) (b)

Figure 12: (a) a Total number of courses taken (for any grading choice) vs GPA, and (b) Fraction of courses taken for CR/NC/GC vs GPA, for all students.

Finally, in Fig. 13, we separate the students by their majors and check the negative correlation between GPA and the fraction of courses taken for CR/NC/GC. For the majors Systems Engineering, Biomedical Engineering, Computer Science, and Mechanical Engineering, there indeed is a negative correlation as may be expected (-0.31, -0.30, -0.45, and -0.55 respectively)

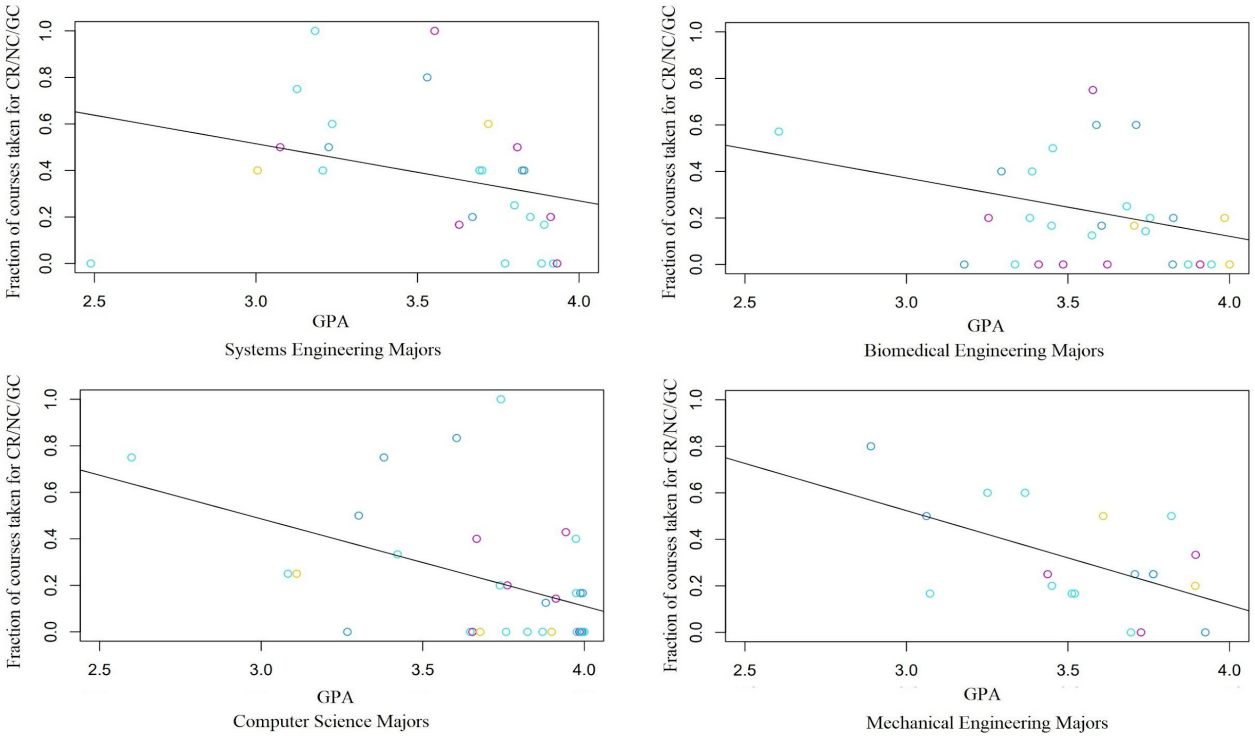


Figure 13: Fraction of courses taken for CR/NC/GC vs GPA for students from the four largest majors.

The interesting results come from our Aerospace and Chemical Engineering majors (Fig. 14), although admittedly our datasets are small. For these majors, students with a higher GPA are more likely to opt for CR/NC/GC grading (in general) and the correlations are positive (0.10, 0.14).

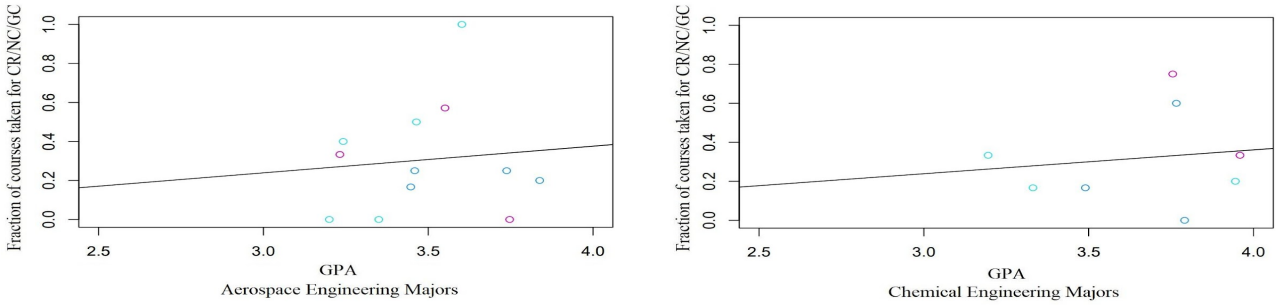


Figure 14: Fraction of courses taken for CR/NC/GC vs GPA for students from two other majors.

Significance of our Work and Conclusions

In the Spring 20 semester: Students, in general, were less likely to opt for CR/GC/NC grading in APMA courses compared to their Physics or major-related courses. Students of certain races had lower GPAs in general and opted for CR/GC/NC grading for APMA courses. Out-of-state students were also more likely to opt for CR/GC/NC grading, which could be due to the challenges of adjusting to a new environment or more pressure due to higher tuition fees. Other demographic factors, such as gender or socioeconomic status, did not seem to have a significant impact on students' grading preferences. However, certain majors, notably Civil Engineering and Computer Science students, answered some survey questions very

differently. This could be due to the unique demands of these majors, which may require a higher level of technical proficiency or a different approach to learning.

Throughout the pandemic: Students, in general, took the same number of credits they would have taken in a normal semester. This is a testament to the dedication and commitment of many students who remained focused on their academic goals despite the disruptions caused by the pandemic. Across all three semesters and across all majors, in general, students with a higher GPA were less likely to opt for CR/GC/NC grading, indicating a strong desire to maintain academic excellence and strive for higher grades, with some exceptions (such as Chemical Engineering students). As the pandemic progressed, students were more likely to opt for a letter grade in their APMA course(s) in spite of lower GPAs. This may be due to a number of factors, such as increased competition for scholarships and internships, or a desire to demonstrate mastery of a particular subject to future employers. While the challenges presented by the pandemic have been significant, students have continued to persevere and strive for academic excellence, demonstrating their unwavering commitment to their education and future goals.

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