ASEE 2022 ANNUAL CONFERENCE
Excellence Through Diversity
MINNEAPOLIS, MINNESOTA, JUNE 26TH-29TH, 2022 ASEE
Paper ID #37276

Impact of Covid-19 on Applied Mathematics Courses for Engineering Students

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This is a Work in Progress

Introduction

This study investigates the impact of the COVID-19 pandemic on Applied Mathematics (APMA) courses in the Engineering School at our institution. We investigate which subset of students may have been impacted more by the change/disruption in our instruction methods due to the pandemic, and then design and implement strategies to mitigate any negative impacts of three semesters of (mostly) online teaching, for instance by reaching out immediately with an ad-hoc recovery path. We also want to understand the level of (dis)comfort of Engineering students (possibly a subset) with online teaching as implemented by the APMA program, and revise APMA fundamental courses to mitigate/remove bias and inequity. Finally, we compare motivation, performance and outcomes between APMA courses and major-related courses (those required to graduate in a particular major), and find whether students consider(ed) APMA courses a "roadblock" on the way to their degree.

Motivation

At the onset of the pandemic in March 2020, students at our institution (University of Virginia) were quickly sent back home, and all courses were moved to 100% online format. Students and instructors had very little time or experience to prepare for a smooth transition. Online courses, and very few in a hybrid format, continued right up to the end of Summer 2021. (*Online*: All class lectures are delivered and attended online. *Hybrid*: The instructor and a certain percentage of the students, depending on classroom capacity and COVID-19 protocols, are present in the classroom during class meeting times. Other students attend lectures online. *Face-to-face*: All lectures are delivered in person, all students attend in person. In each of the three cases, other aspects of the course, such as preparatory materials, lecture notes, assignments and tests may be delivered, and collected online.)

The once in a lifetime pandemic we are living through has had many adverse effects on physical and mental health and livelihood of almost all of us. In addition to the challenges familiar to everyone, our students had to experience something that they were not prepared for: online learning. The only environment they had been exposed to (so far) was face-to-face instruction in a traditional classroom. Our students faced potential loss of housing, food insecurity, financial troubles, physical and mental health issues, and increased isolation from peers [1]. The rapid change of situation in all parts of their lives, including their education, was made more challenging by the new vehicle of instruction.

There have been reported specific effects of online education on engineering students. In [2] the authors report that a significant fraction of students were planning to modify their short-term future plans about scheduling courses in subsequent semesters. A non-insignificant fraction of students also reported concerns about online instruction and its effectiveness. STEM students were forced to spend more time on self-learning, and more time in general on their coursework [3].

Blended (or hybrid) learning results in better learning outcomes for STEM courses (compared to non-STEM courses). Paradoxically, students taking those hybrid STEM courses report lower satisfaction

and/or did not perceive the courses as highly [4]. This is a great motivation to redesign our APMA courses retaining the tools and techniques that were effective during the online-only instruction.

Researchers have also looked at the disproportionately negative impacts of the pandemic on minorities, first generation students, students with disabilities and/or health concerns [5]. The authors report that these groups of students were concerned about how well they could access the educational resources or perform in an online format of education, and they faced more COVID-related adversities. The pandemic (and the online courses) has created new barriers for both entry and continuing/completing their studies [6]. Many institutions that primarily serve students of color, low-income groups, minorities and/or first generation students have reported much lower enrollment numbers. It is not hard to conclude that certain student demographics were hit harder, and therefore it stands to reason that the impacts of the pandemic were felt differently by minority students attending other institutions too.

What is not well known is the effect of the pandemic and online instruction on Applied Mathematics classes for students in Engineering Schools. Engineering students in general neither understand nor appreciate the importance of mathematics (or physics for that matter) in their chosen engineering major. As [7] reports "*Since mathematics courses are a significant source of attrition and many engineering faculty are unhappy with students' mathematical abilities, more engineering departments are increasingly looking at drastic options of taking students out of mathematics courses and teaching students mathematics themselves".* Our institution has followed this path, and we are concerned how COVID may have exacerbated this relationship between students and Mathematics courses.

There is a simple fact: Engineering students enroll in an Engineering school to get an Engineering degree. Mathematics courses are often perceived as an unavoidable price for that goal, as evident in a wide body of literature [7] - [13]. At this juncture, it is prudent to mention that at our institution, all engineering students take Applied Mathematics courses (at least 15 credits) rather than pure Mathematics courses. The Applied Mathematics program resides in the Engineering School, and the courses are tailored for engineering students, while the Mathematics program is part of the College of Arts and Sciences. This situation is at least somewhat unique. All engineering students are also required to take 2 Physics courses, on which we report in our analysis, but we are Applied Mathematics faculty interested in the effects of the pandemic on our courses. At our institution COVID-19 has provided us with an opportunity to test whether online format has had any impact on the sentiment about Applied Mathematics courses. Since the onset of COVID-19, in order to mitigate high levels of stress, anxiety, and personal and family challenges among our students, our Provost introduced a CR/GC/NC (Credit/General Credit/No Credit) grading option for 3 semesters (Spring 20, Fall 20, Spring 21), and 2 Summer terms (Summer 20, Summer 21).

For undergraduates who opted into CR/GC/NC grading:

- CR grade was awarded when meeting the class requirements for credit (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' GPA.
2. Students had to choose the grading option before the end of the semester at a specific deadline before Final Exams.

The University of Virginia is not the only institution to provide this type of grading option to students. For instance, our sister ACC schools, the University of North Carolina at Chapel Hill, Clemson

University, and Virginia Tech also utilized a grading system very similar to ours to support students during the pandemic/ transition from in-person to online course delivery. Additionally, there are examples of other schools with a two tier grading system, i.e. CR/NC (Satisfactory/Unsatisfactory or pass/fail). For example, Florida State University, Louisville University, Syracuse University, Wake Forest University, and Duke University all provided their undergraduate students with such an option.

A *preliminary* survey conducted in Spring 2021, while courses were still all online, showed that after switching to an online format, our Engineering students taking APMA courses reported: low motivation, lower time-management skills, worse performance in grades, and very low engagement with course material, instructor, teaching assistants, and other students taking the same course. They also reported feeling isolated, using more resources outside of traditional lectures, and that a CR/GC/NC option reduced their anxiety levels. We hypothesize that students disproportionately selected the CR/GC/NC option in APMA courses compared to their major-related core courses.

To conduct our analysis we designed a survey about their experiences and observations while enrolled in APMA courses first online (mid Spring 2020 to Spring 2021) and later face-to-face (Fall 2021). We plan on using these results, combined with other data from the School administration, to:

1. identify successful strategies and techniques to be retained even in traditional classrooms;
2. identify certain at-risk demographics in APMA courses who may need extra help and guidance;
3. understand different perceptions students have towards APMA courses (vs major courses);
4. receive inputs to redesign APMA courses as needed.

Description of Survey

Our study participants (second-, third-, or fourth-year students) completed a ~50 question online survey early in the Spring 2022 semester about their experiences taking one or more online/ hybrid APMA classes at our institution from Spring 2020 to Spring 2021 semesters. In addition to their demographic data, questions were placed in eleven categories, asking about technological needs/ problems, access to resources, balancing different priorities, CR/ GC/ NC option for Applied Mathematics vs major-related courses, motivation to do well in Applied Mathematics courses, etc.

Initial Results and Discussion from IRB Approved Survey

In Figures 1 and 2, we present the relative fractions of students choosing CR/ GC/ NC grading in APMA and Physics courses, compared to their Eng-major (X-Depts) courses, and their reasons for doing so. Our students indicate that they choose CR/ GC/ NC grading in APMA courses because they were not as confident in doing well and did not want to damage their GPA, and/ or because they would rather spend more time studying for their major courses.

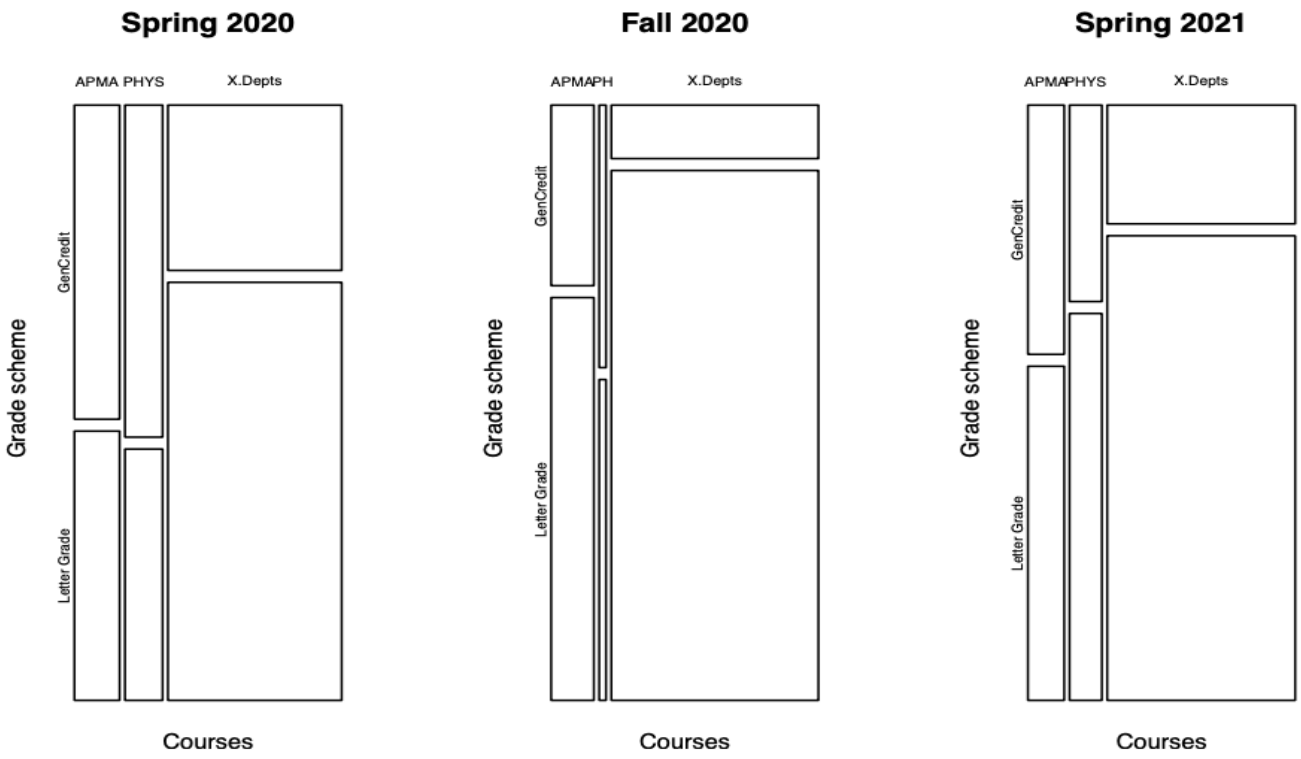


Figure 1: Students disproportionately choose CR/ GC/ NC grading in APMA courses

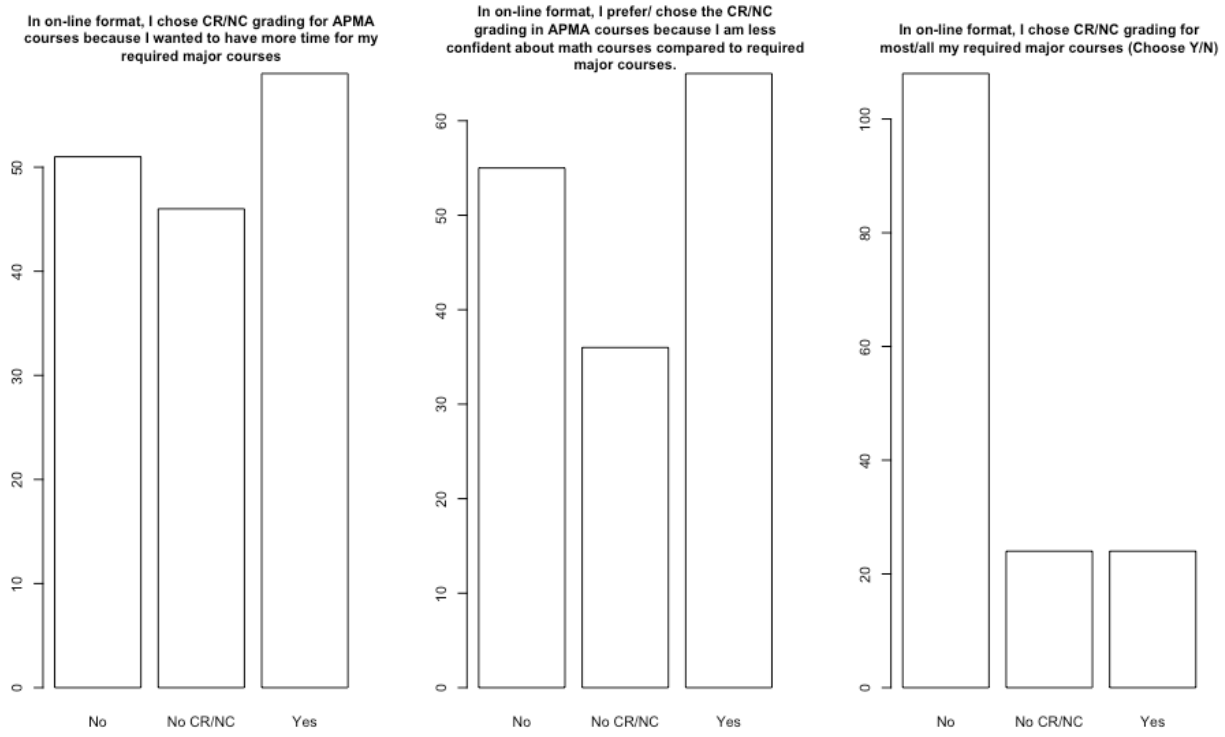


Figure 2: Choosing CR/ GC/ NC in APMA due to low confidence/ to spend time on major courses

As a first and direct analysis form the survey, we can also already report the following:

- 90% agree or strongly agree that they had difficulties focusing or paying attention to remote instruction
- 67% agree or strongly agree that they faced problems communicating with classmates
- 63% agree or strongly agree that they had problems balancing school with other priorities
- 75% agree or strongly agree that they were easily distracted by social media/non-course related sites during class
- 73% agree or strongly agree that they faced mental issues, stress and isolation.

We are still collecting data from the school in order to understand how representative our sample is in replicating the student population. With the addition of the second part of the survey, we plan on expanding the set of statistical analysis, to include Anova and Categorical Data Analysis. The survey is not anonymous and we hope to be able to identify patterns in the data based on classification and clustering methods, including unsupervised analysis.

Significance of our Work and Conclusions

We will analyze data from the survey, the course software statistics, and grade**s** from our registrar, to find out learning strategies and techniques that were effective as we navigated the pandemic situation inside and outside our classroom, and identify tools and mechanisms that can be retained, perhaps with modifications, for a better learning experience in the post-pandemic situation. We will be able to identify certain at-risk groups/demographics of students who may have somewhat fallen behind during the pandemic situation, and help them catch up. We will also understand the different perceptions students have towards APMA courses compared to major-related core courses, and receive inputs to redesign our APMA courses as needed.

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