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Poor Performance in Undergraduate Math: Can We Blame it on COVID-19 Despair?

Jeffrey Ludwig
Ph.D., University of California, CA, Irvine, USA.
Corresponding author email id: jtludwig@uci.edu

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***Abstract* – The COVID-19 pandemic has been described as an invisible terrorist, spreading in a matter of weeks across the globe despite the best efforts of public health agencies to temper its virulence. As COVID-19 cases grew exponentially in early 2020, a cascade of university closures in the United States of America ensued. Both students and teachers alike were thrust into an emergent and unprecedented situation where classes transitioned from in-person to online almost overnight. The negative ramifications of COVID-19 were widespread and especially detrimental to educational systems that have traditionally relied on in-person interactions to prosper. In this environment, general anxiety towards learning mathematics was amplified. Despair due to COVID-19 emerged in society and impeded life in a multitude of ways, and remote learning presented its own unique challenges to university education. In this paper we set out to investigate the causes of poor performance in an undergraduate math finance class containing 120 students in the Spring of 2021. Three potential causes were considered and evaluated based on online student surveys given at the beginning of the class: 1) general anxiety towards mathematics, 2) despair due to the COVID-19 pandemic, and 3) aversion to remote learning. In contrast to prior studies, math anxiety did not correlate strongly with poor performance. Furthermore, students with COVID-19 despair who believed that COVID-19 significantly impaired their ability to learn math, scored the worst. And finally, remote learning had a relatively neutral effect on performance. Our study suggests that COVID-19 despair and all of the social, psychological and emotional stress that comes with it, may play a significant role in determining poor student performance.**

***Keywords* – COVID-19, Math Anxiety, Remote Learning, Active Learning, Adaptive Learning.**

I. INTRODUCTION

Coronavirus disease 2019 (COVID-19), caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), made a grand entrance into the world in December of 2019 [1] causing a cluster of lung infections that were linked to a seafood and wet animal market in Wuhan City, Hubei Province, China [2]. The highly infectious respiratory disease spread rapidly and was soon declared a global pandemic by the World Health Organization [3]. By March 6, 2020, a New York Times article by Baker, et al. [4] declared that the first college to transition to online classes was the University of Washington to curb a local outbreak of COVID-19. Other Universities quickly followed suit causing a cascade of school closures nation-wide. Both students and teachers alike were thrust into an emergent and unprecedented situation where classes would transition from in-person to online almost overnight. The negative ramifications of COVID-19 were immediate and especially detrimental to educational systems that have traditionally relied on in-person interactions to prosper [5], [6].

As infection rates and mortality rapidly increased, feelings of extreme hopelessness, anxiety, stress, depression, insomnia, and mental health problems [7]-[10] rose in parallel. In April 2020, the unemployment rate for the United States of America reached 14.8% which was the highest rate observed since data was first collected by the Congressional Research Service in 1948 [11]. The combined psychological and emotional stress with financial pressures and forced social isolation created a challenging learning environment for many

students [12] and led to limited educational gains during the COVID-19 era [13].

The focus of this paper is on a new mathematics class that was created in September 2020, right in the middle of the COVID-19 era, at a large research-intensive university in the Western United States. The class enrolled upper-division undergraduates in mathematics and taught *Modern Portfolio Theory*. The class was centered on teaching about a revolution in finance that began in 1952 and ended 21 years later, with 10 Nobel Memorial Prizes in Economic Sciences awarded along the way. In this paper we seek to discover what subjective factors contributed to students' educational outcomes, as measured by midterm exam scores during the COVID-19 era.

We begin with a thorough review of the literature in three domains that may affect educational outcomes during the COVID-19 era, namely COVID-19 despair, anxiety towards learning mathematics, and remote learning.

A. *COVID-19 Despair*

Generation Z (Gen Z), ages 18-23, suffered significant consequences from the COVID-19 pandemic. A large-scale study by the American Psychological Association [14] conducted surveys on 3,409 adults and specifically found that the Gen Z adults were facing the highest negative health impacts due to the pandemic, felt the loneliest, scored the worst for mental health and depression, and felt that the pandemic negatively impacted their relationships as compared to other adults. In this same study by the American Psychological Association [14], 78% of the Gen Z adults state the pandemic is a significant source of stress in their lives. Furthermore, the Healthy Minds Network [15] survey which collaborates with the American College Health Association surveyed 18,764 students on 14 campuses in March through May 2020 and found that 86% of the students were concerned for their own personal safety, 60% of the students state that the pandemic made it more difficult to access mental health care, and a large proportion of students reported that their mental health negatively impacted their performance in school.

Additional studies corroborate the profound negative impact that COVID-19 had on students. Jones et al. [16] surveyed 2,282 college students in New York City in April of 2020 and found that students had high rates of anxiety and depression and were worried about financial instability during the pandemic. Son et al. [17] found in another college student survey that 71% of the 195 college students surveyed had significant increased stress and anxiety due to the pandemic and specific stressors include: fear of their health or the health of a loved one, disruptions in sleep, difficulty concentrating, lack of social interactions due to social distancing, and increased worry about academic performance.

We introduce the term *COVID-19 Despair* to encapsulate the multi-faceted components contributing to the deterioration of social, psychological, and emotional health due to the COVID-19 pandemic. These components include:

1. Financial stress due to loss of employment.
2. Worry about the ability to find employment.
3. Crowded living spaces due to children, pets, and parents at home.
4. Severing of social ties to love ones and social support networks, community, and fellowship.
5. Increased risk of morbidity and mortality.

6. General lack of joy due to closure of restaurants and bars, theme parks, playgrounds, wedding venues, movie theaters, shopping malls, athletic fields, dance clubs, music venues, churches, gyms, national and state parks.
7. Restrictions on airline travel.
8. Social isolation during home quarantining.
9. Grandparents cut-off from personal interaction with their grandchildren.
10. School closures.
11. Home schooling and childcare responsibilities.
12. Transition to remote learning.
13. Increased computer interfacing and reliance on telecommunication networks.
14. Closure of office buildings, college campuses, and other specialized facilities for focused activities.
15. Abrupt deportation of international college students.

B. *Anxiety towards Learning Mathematics*

Tobias & Weissbrod [18] describe math anxiety as "the panic, helplessness, paralysis, and mental disorganization that arises among some people when they are required to solve a mathematical problem". Prior literature shows that math anxiety has a negative correlation with student performance [19]-[21]. An article by Blazer [22] states that approximately 93% of Americans indicate that they have some level of math anxiety. Of the student population, some articles state that 17% of the mathematics students have high levels of anxiety [20] whereas other articles state that up to 68% of the students have high math anxiety [19]. Richardson and Suinn [23] claim that close to 11% of university students show such high levels of math anxiety that they require counseling. These percentages cited in prior literature are cause for concern, especially with the understanding that high math anxiety may lead to lower performance.

There have been many explanations as to why math anxiety cripples a student's ability to perform well which involve emotional, physical, and psychological components. Spicer [24, p.1] states that math anxiety is "an emotion that blocks a person's reasoning ability when confronted with a mathematical situation." Physically, students may have symptoms such as clammy hands, dizziness, increased heart rate, upset stomach [22], feeling of sickness, inability to concentrate, or a blank mind [25]. Psychologically, math anxiety can cause "feelings of tension and anxiety that interfere with the manipulation of numbers and the solving of ordinary life and academic situations" [23].

Furthermore, there is an idea of a negative math self-concept described in prior literature, where students with math anxiety have a low self-concept of mathematical ability and are simply not convinced that they can do well [26]. Lastly, there is a notion that math anxiety causes an "affective drop", or a decline in performance when math is performed under pressure situations [27], [28]. Math anxiety causes worry and then that worry reduces the processing capacity of the working memory system available for the task [29], [30]. Therefore, students with high math anxiety have smaller working memory capacities which leads to slower reaction time and increased errors [31].

C. *Remote Learning*

While the literature supports the fact that the COVID-19 pandemic unearthed a massive amount of stress, fear, and worry, the transition to remote learning may have been an influential factor in educational outcomes as well. While some students welcomed the accessibility, flexibility, and affordability [32] that came with remote learning, others were distraught by the disorganized teaching infrastructures, the inexperience of the teachers with new technologies, the distracting home environment [33], network connection problems [34], and the lack of face-to-face social interactions.

II. METHODOLOGY

We constructed a student survey in an effort to understand what factors contribute to students' performance on the midterm exam administered during the 6th week of the 10-week quarter. The survey contained the following 3 questions:

1. How do you rate your current anxiety towards learning math remotely?

   (1 = low anxiety, 5 = neutral, 10 = high anxiety)

2. How do you currently think COVID-19 has affected your ability to learn math?

   (1 = negative effect, 5 = no effect, 10 = positive effect)

3. Rate your current experience with remote learning.

   (1 = dislike, 5 = neutral, 10 = prefer)

The students were asked to respond with a numerical answer on a scale from 1 to 10. For the first question, a response of 1 corresponded to a low level of anxiety, while a response of 10 corresponded to a high level of anxiety. Similarly for survey question 2, a response of 1 corresponded to the condition that COVID-19 has severely impeded the student's ability to learn math, while a response of 5 corresponded to the condition that COVID-19 has not at all affected the student's ability to learn math, and a response of 10 corresponded to the condition that COVID-19 has had a positive effect on the student's ability to learn math. Finally, for question 3, a response of 1 corresponded to the student disliking remote learning while a response of 10 indicated the student actually preferred remote learning over traditional in-person learning.

Student performance data for the introductory math finance class at a large research-intensive university in the western United States was meticulously collected over the course of 5 weeks during the Spring quarter of 2021. The course required the students to complete 4 homework assignments, 4 team-based adaptive online quizzes taken during class, and a midterm exam. The midterm exam material was cumulative, testing the students on all the subject matter presented during the 5-week period. There were 120 students enrolled in the class.

The 4 homework assignments were all completed individually by each student, at home, each with a 1-week deadline for completion. The 4 adaptive team-based online quizzes were given once per week during the 5-week period in class, with a 2-hour duration.

The quizzes were administered online, and auto-graded instantaneously once submitted. The quizzes were adaptive in nature as the difficulty week-to-week was dynamically adjusted in accordance with students'

quantitative and qualitative feedback. The quizzes were structured to test the students on material presented in the previous 2 lectures. The students were allowed to form their own quiz teams of 2 to 3 students per team to collaborate and take the quizzes together on the quiz days, fully open book, open notes, and free to use the internet. Over the first few weeks, teams learned to split up the questions between the team members and then share answers, checking each other's work. There may have been reduced anxiety in the team collaborative effort, compared to a solo quiz-taking effort, and this may have improved students' ability to calmly solve the mathematical problems. Over time, the teams were allowed the option to merge, and some did naturally and organically with various competitive strategies to improve performance.

The data set included each of the 3 survey questions and midterm exam score for each student. These four metrics, along with each student's gender, complete the data set used in this study.

III. Results and Discussion

The student survey data is depicted in Fig. 1, Fig. 2, and Fig. 3. We show histograms of the students' numerical responses to the student survey questions 1, 2, and 3, respectively. We see based on visual inspection of the histograms that on average, the 120 students in the class felt strong anxiety about learning math remotely (mean 6.3/10), negatively about the way COVID-19 has affected their ability to learn math (mean 4.0/10), and neutral on their experience with remote learning (mean 4.7/10).

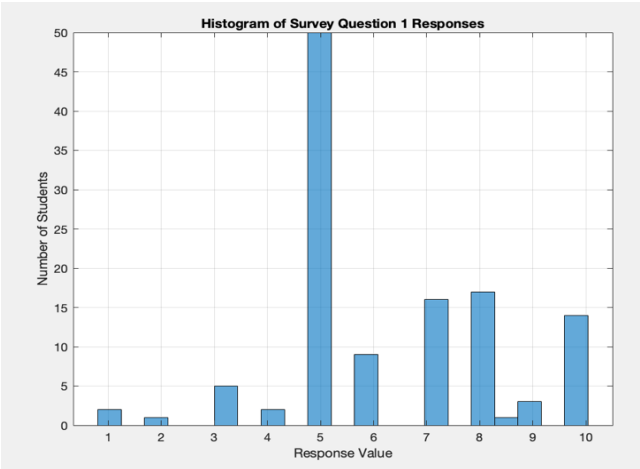

Fig. 1. Histogram of Survey Question 1 Responses: Mean value is 6.3.

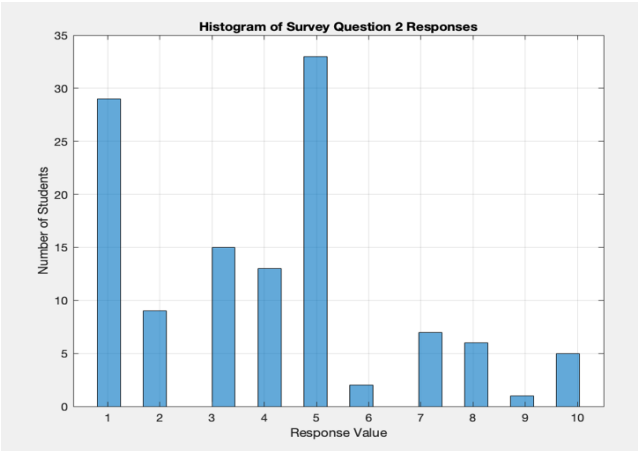

Fig. 2. Histogram of Survey Question 2 Responses: Mean value is 4.0.

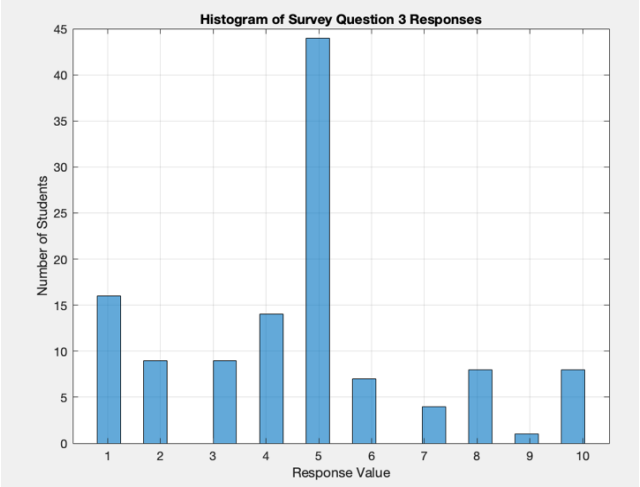

Fig. 3. Histogram of Survey Question 3 Responses: Mean value is 4.7.

A summary of the results of a linear regression analysis using the least squares method to explore the linear dependency of the midterm exam score on the survey questions data is summarized in Table 1. We see the R-square values are very low, indicating that the midterm exam scores are not strongly correlated with the survey questions.

Table 1. Summary of linear regression analysis using method of least squares.

No.	Constant Coef.	1st Order Coef.	R-square	F-stat	Est. Error Var.
1	99.7	-1.0	0.0247	3.0	178.8
2	89.9	0.84	0.0232	2.8	179.1
3	88.8	0.96	0.0294	3.6	177.9
All	93.9	-0.87	0.0533	2.2	176.6
		0.69			
		0.44			

Scrutinizing the data further, we note a perfect 100 midterm exam score for 2 students who responded to Survey Question 1 with a "1" corresponding to "low anxiety." The average midterm score for 14 students who responded to Survey Question 1 with a "10" corresponding to "high anxiety" was 91.4, almost a full 2 points below the overall average midterm score of 93.25.

Additionally, we discovered that the average midterm score for the 17 students (14%) who reported an anxiety level of 9 or 10 was 6.2 points, or 0.4 standard deviations below the overall average midterm score of 93.25. This suggests extremely high levels of anxiety are associated with poor educational outcomes, as has been well established in the literature previously. We see in this case that extreme anxiety is associated with underperformance on the midterm, even though as illustrated in Table 1 the correlation between the midterm score and anxiety is negligible.

Interestingly, this exact level of underperformance (6.2 points, or 0.4 standard deviations, below the overall average midterm score of 93.25) was achieved by a distinct group of 17 students. This group of 17 students

reported to be severely negatively impacted by COVID-19 with a 1 or 2 response to survey question 2 along with a 1 or 2 numerical response to survey question 3, indicating they also strongly disliked remote learning. The average level of anxiety for this group of 17 students was 7.5, just slightly above the overall average anxiety level of 6.3.

If we break the cohort into 27 distinct subgroups, based on a partitioning of the numerical response to each survey question into "low" (1-3), "medium" (4-7), or "high" (8-10), we can explore the performance of each subgroup on the midterm and illuminate further insights into factors affecting performance on the midterm.

Table 2. Summary Average Midterm Score by Student Subgroups: Overall Mean is 93.25.

	Q2 LOW Q3 LOW	**Q2 LOW Q3 MED**	**Q2 LOW Q3 HIGH**	**Q2 MED Q3 LOW**	**Q2 MED Q3 MED**	**Q2 MED Q3 HIGH**	**Q2 HIGH Q3 LOW**	**Q2 HIGH Q3 MED**	**Q2 HIGH Q3 HIGH**
Q1 LOW	90	100	NONE	100	95	100	NONE	NONE	NONE
Q1 MED	90.83	92.11	96.67	93.33	94.44	100	NONE	97.5	100
Q1 HIGH	87.69	80	NONE	93.33	100	100	100	86.67	NONE

First, we note that "Q2 LOW" identifies the subgroups with COVID-19 despair. The nine subgroups represented by the leftmost 3 columns in Table 2 encompass the COVID-19 despair group.

The average midterm exam scores of each student subgroup are listed in Table 2. The color blue denotes an average subgroup score above the overall average midterm score of 93.25. The color red denotes an average subgroup score below the overall average midterm score of 93.25. If there are no students in a particular subgroup, the entry in Table 2 is "NONE."

What stands out most in Table 2 is the severe underperformance of the student subgroup partitioned in Q1 HIGH, Q2 LOW, and Q3 MED. This particular subgroup reported to feel high anxiety, strongly negative about the way COVID-19 has affected their ability to learn math, and neutral on remote learning. There were 4 students in this subgroup: 3 females and 1 male. The average score on the midterm exam for the students in this subgroup was 80, the lowest of any subgroup and 1 standard deviation below the overall mean midterm score of 93.25.

Furthermore, in Table 2 we see a general flow of red color to the left almost everywhere, spanning 5 out of the 6 leftmost subgroups. This may be explained by poor performance for those students self-reporting a strongly negative effect of COVID-19 on their ability to learn math, no matter what their level of anxiety or aversion to remote learning was. This powerful COVID-19 despair wreaked havoc on educational outcomes in a multitude of ways. Indeed, the average midterm score for the 53 students belonging to subgroups spanning the 3 leftmost columns in Table 2 was 3.1 points below the overall average midterm exam score. In Fig. 4, we show a scatterplot of midterm exam scores vs. the numerical response to student survey question 2 (COVID-19 despair rating, 1 = intense despair, 10 = no despair). The size of the bubbles in the scatterplot is proportional to the number of students that fall into each particular data point. Visual inspection of the scatterplot illuminates the finding that students with high self-reported COVID-19 despair struggled on the midterm exam.

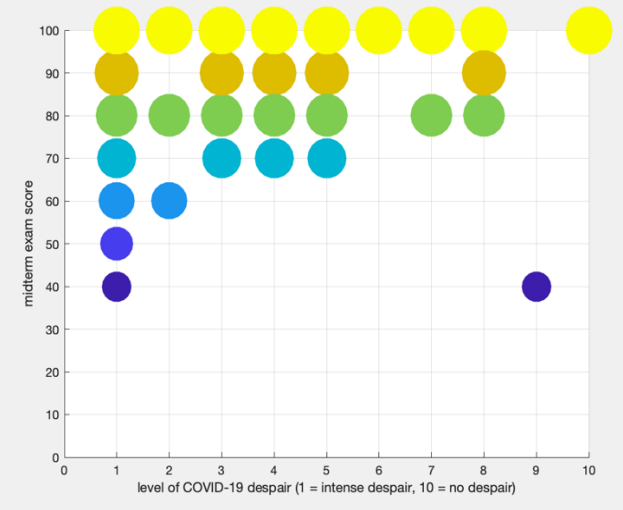

Fig. 4. Scatterplot of midterm exam scores vs. COVID-19 despair rating.

In terms of performance based on gender, 5 women who reported extreme anxiety, with a survey question 1 equal to 10, performed 5.25 points below the overall average. This level of underperformance was not as extreme for the 8 men who reported extreme anxiety, with a survey question 1 equal to 10, who performed just 0.75 points below the overall average.

Finally, both the 2 men and 6 women who indicated low levels of anxiety, with a survey question 1 less than 4, outperformed the overall average by 5.08 and 1.75 points, respectively.

IV. Conclusions

In this paper we set out to investigate the causes of poor performance in an undergraduate math finance class. Three potential causes were considered and evaluated based on online student surveys given at the beginning of the class: 1) general anxiety towards mathematics, 2) despair due to the COVID-19 pandemic, and 3) aversion to remote learning. Student performance was measured by the midterm exam score.

Although prior studies have shown that high anxiety towards math has a strong correlation with poor student performance, our study, conducted during the COVID-19 era, found little to no correlation.

Surveyed students who self-reported that COVID-19 had a negative impact on their ability to learn math performed poorly in this study. Most striking was a particular subgroup of students with high anxiety, high COVID-19 despair, and neutral feelings towards remote learning that performed a full standard deviation below the mean.

In sum, we conclude that high COVID-19 despair had a negative impact on student performance. We found no correlation between performance and general anxiety towards learning math. We also found no correlation between performance and aversion to remote learning.

The COVID-19 era in education is extraordinary. Impedances to educational outcomes due to COVID-19 despair should not be confused with those associated with remote learning and anxiety towards learning math.

V. Limitations

In this study, we measured student performance by midterm exam scores. Midterm exam scores are a conven-

-ient measurement of learning but suffer from biases when there is test-taking anxiety or other factors affect the students on exam day. A perfect assessment of content knowledge would not be affected in this way.

Additionally, COVID-19 despair and anxiety towards learning are inherently entangled. Our study attempted to separate the distinct effects of each factor via specific survey questions. Inevitably the subject self-reporting may not achieve perfect separation.

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AUTHOR'S PROFILE

Jeffrey Ludwig was born in Peoria, IL on November 23, 1968. He has a S.B. in aeronautics and astronautics (1991) and an S.M. (1993) and a Ph.D. (1997) in electrical engineering and computer Science, all from the Massachusetts Institute of Technology, Cambridge, Massachusetts, U.S.A. He served as Director of Jump Labs, the research division of Jump Trading, a Chicago-based high frequency proprietary trading firm. Before that he was a portfolio manager at SAC Capital Management, New York where he managed quantitative futures strategies spanning equities, fixed income, commodities, and volatility, and also the Director of the Algorithmic Trading Group at Barclays Capital in New York and London. Prior to that, he was a Senior Vice President and Portfolio Manager for Pacific Investment Management Company (Pimco) for 5 years, where he served as Head of Equity Derivatives. Pimco recruited him from Credit Suisse First Boston in New York where he was a successful proprietary equity arbitrage trader. He has 20 years of investment experience. Professor Ludwig is an Assistant Professor of Teaching in the Department of Mathematics at University of California, Irvine, U.S.A. since 2018. He serves as the faculty advisor for the math finance concentration and specializes in innovative teaching and collaborative research with industry in mathematical finance and quantitative trading.