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Collapse of Pre-COVID-19 Differences in Performance in Online vs. In-Person College Science Classes, and Continued Decline in Student Learning

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Abstract: Studies comparing student outcomes for online vs. in-person classes have reported mixed results, though with a majority finding that lower-performing students, on average, fare worse in online classes, attributed to the lack of built-in structure provided by in-person instruction. The online/in-person outcome disparity was normative for non-major geology classes at the University of Mississippi prior to COVID-19, but the difference disappeared in the years after 2020. Previously distinct trendlines of GPA-based predictions of earned-grade for online and in-person classes merged. Of particular concern, outcomes for in-person classes declined to match pre-COVID-19 online expectations, with lower-GPA students disproportionally impacted. Objective evidence of continued decline in student learning, masked by sliding grading scales, is also presented with a long-term record of exam scores drawing from the same question pool for over a decade. Average scores remained relatively constant until COVID-19. Scores then declined in each successive year, attributed to an increase over time in the percentage of enrolled students who had been in high school during the pandemic shutdowns. At the close of 2023, exam scores showed no signs of returning to pre-COVID-19 outcomes. The negative impacts of the shutdowns, with greater impact on those who were in high school during the pandemic, appear to be due to a loss in the developmental life-skills (e.g., self-motivation, focus, critical thinking, social development) needed to thrive in college, not just reduced exposure to preparatory subject material. These results provide a global cautionary message for the management of future pandemics.

Keywords: COVID-19 impact; pandemic; online vs. face-to-face; educational modality; learning loss

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1. Introduction

Many studies have investigated potential differences in the performance of students in online vs. in-person courses, and on the immediate impact of the COVID-19 shutdowns on student learning. The current study adds two unique findings to the existing body of work. The first is documenting a significant post-COVID-19 change in the predictive value of GPA on student outcomes for a suite of non-major introductory geology classes at the University of Mississippi. Previously distinct trendlines of GPA vs. earned-grade for online and in-person courses merged into a single trendline post-COVID-19. Our data indicate that the decline in student performance in college classes was more severe for students who experienced COVID-19 shutdowns while still in high school.

The second unique contribution, which lends support to the findings above, is objective evidence of a continued negative impact on student learning through the end of 2023. Exam scores for classes that draw from the same question pool in successive semesters document a marked change following COVID-19, with concerning declines that showed no signs of recovery at the time of this writing.

2. Literature Review

The literature is rich with studies comparing student performance, satisfaction, and completion rates in traditionally taught in-person classes versus online, with variable results. A larger percentage of studies have reported lower success rates in online classes relative to in-person classes. Lower outcomes for online classes include a lower rate of course completion [1–13], lower grades or quantitative assessments [3,7,10,13–23], lower self-reported student satisfaction [16,20,21,24], or lower level of skill development [25]. In general, such differences have been attributed to the greater need for students to supply their own structure to online classes, requiring a higher level of self-discipline and self-directed learning [26–31].

In contrast, a smaller number of studies reported either no significant difference, or higher success in online versus otherwise equivalent in-person classes. Higher outcomes for online classes include higher performance on course assignments and examinations [6,32–35], higher self-reported student satisfaction [35,36], and greater engagement in student discussions [37] or deeper forms of learning [38]. Other studies across a spectrum of disciplines have found no significant difference in online verses in-person classes in either performance or student satisfaction, including fields of nursing [39–41], business/finance [42–45], psychology [46,47], social work [36], and sociology [48].

Most studies also considered a suite of potentially compounding variables, including gender, race, age, GPA, prior online experience, family collegiate history, economic status, major, year in school, and non-traditional student status. Studies have reported higher rates of success (in-person and online) for female students [14,19,43,49–52], lower success rates among minority students relative to white or Asian students [52,53], minority students less likely to take online courses [52,54], non-traditional students more likely to take online courses [52,54] though not necessarily performing better [55], and freshmen with limited academic experience earning higher levels of D or F grades in online classes [56].

Of most significance for the current study, several investigations reported a significant correlation between overall GPA and final grade, but with low-GPA students faring relatively worse in online courses compared to in-person courses [36,50,57,58]. These findings are consistent with a precursor study at the University of Mississippi comparing grades in online and in-person non-major geology courses. Of variables including GPA, age, major, credit hours, gender, race, and number of previous online courses, GPA served as the primary predictor of success. Grades predicted by GPA were similar for high-GPA students independent of modality, but low-GPA students fared worse in online classes relative to in-person classes [59].

The negative impacts of COVID-19 shutdowns and social distancing on educational outcomes were recognized quickly, with many studies reporting on the short-term impacts. Negative developments were documented for general academic performance [60–64], emotional health [60], and learning experience [62,64–66]. More specific studies included variable impacts associated with geography [64], gender, personality, and educational level [67], and socioeconomic status [68].

In the few years following the peak of the pandemic, many additional studies investigated the lingering effects, including pandemic-prompted changes to online education [66], changes in student expectation [69,70], impacts on mental health or psychological preparedness [71–75], and impacts on educational achievement [72,76–81].

In summary, previous work has explored the primary predictors of success for different instructional modalities, potential differences in performance in online and in-person courses based on a suite of student and institutional variables, and the short-term impact of COVID-19 on student learning and emotional health. The current study builds upon this work, extending the time frame of the COVID-19 impact on student learning through to the present, investigating an unanticipated collapse in a previously observed difference is online and in-person courses at one institution following COVID-19, and documenting a disproportionately negative impact on college students who were still in high school during the pandemic.

3. Methods

Data for comparing online and in-person performance was obtained from the University of Mississippi data archives managed by the office of Institutional Research, Effectiveness, and Planning, with a research plan approved by the university Institutional Review Board. Data for the objective assessment of student learning before and after COVID-19 included exam scores obtained directly from instructors still working at the university (described in more detail at the end of Section 3). Instructor and student identification numbers were employed for internal quality control, but any information traceable to a specific instructor or student was removed before final analyses and uploading to a publicly accessible data archive.

Introductory geology classes for non-majors at the University of Mississippi were sampled for Fall 2015 through Fall 2023, including Physical Geology (Geol 101), Historical Geology (Geol 102), Environmental Geology: Hazards (Geol 104), and Environmental Geology: Resources (Geol 105). Laboratories for each have separate course listings that were not included in the analysis. Sampled classes were taught by 15 different instructors, with 4 instructors accounting for 76% of all records, and 6 accounting for 90%.

Variable course lengths (excluding final exams) include Fall and Spring (14 weeks), Full Summer (8 weeks), 1st and 2nd Summer (4 weeks), and Intersessions (2 weeks). Total contact hours for all versions are 35 h and cover the same material. Assessment is required to be of equivalent rigor for all versions of each course, but the mode of assessment may vary for offerings of different length. The variables considered to have a potential impact on grade earned included age, total credit hours attempted, total credit hours earned, number of previous online courses, ethnicity, gender, whether major is in a STEM field, size of class, calendar year, pre- or post-COVID-19, instructor, overall GPA, and whether online or in-person (Figure 1).

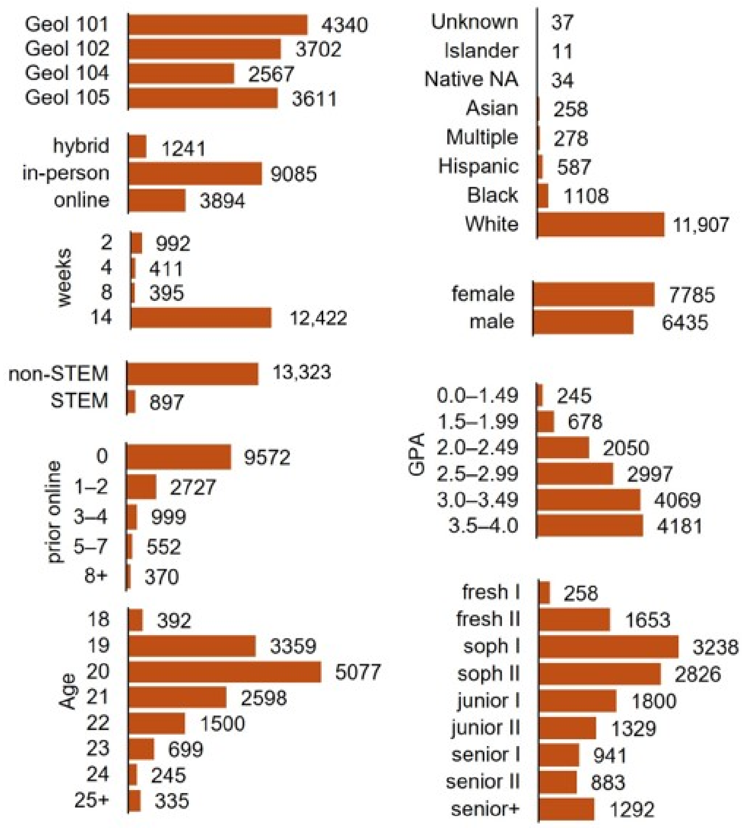

Figure 1. Number of records for course titles, instructional modality, course length, student major (STEM vs. non-STEM), prior online classes, student age, ethnicity, sex, overall GPA, and academic classification (based on 15 credit-hour increments).

The initial dataset contained 15,326 records. Records were excluded from analysis due to missing grades (2), missing GPA (12), I or W grades for incompletes or withdrawals (113), and Honors College sections (72). In Spring 2020, emergency transition of all in-person classes to remote instruction included a university decision to give students the option, after grades were posted, of accepting the letter grade or opting for a non-numerical grade of P or Z (no impact on student GPA). This produced a bias in the recorded letter grades for Spring 2020 by eliminating nearly all low grades. Records for this semester were also excluded (907), resulting in a total of 14,220.

In Fall 2020 and Spring 2021, large in-person classes were conducted in a hybrid mode with students alternating between being in class and logging in via Zoom. Classes were synchronous and lecture-based, but with a partial loss in the structure provided by being in a classroom for every meeting (designated as hybrid in Figure 1). These factors were taken into consideration by evaluating the impact of including or excluding the effected classes in the data analyses.

3.1. Statistical Methods

Dependent Variables

The education outcomes of the students were measured by the course grades obtained. Not all instructors employed +/− grades, resulting in a much smaller number of records of scores such as B+ or B− relative to B grades. Table 1 shows the conversion of letter grades to numerical scores and the total number of records for each.

Table 1. Numerical value of letter grades and number of records in each category. "Hybrid" refers to COVID-19 shift in in-person classes to hybrid mode in Fall 2020–Spring 2021 (see text for details).

Letter Grade	Numerical Value	Number of Records		
		Online	In-Person	Hybrid
A	4.0	1198	3545	519
A−	3.7	105	20	0
B+	3.3	140	33	0
B	3.0	854	3018	380
B−	2.7	137	5	0
C+	2.3	171	16	1
C	2.0	640	1680	207
C−	1.7	45	2	0
D	1.0	328	500	75
F	0	276	266	59
	totals	3894	9085	1241

Independent Variables

Numerical variables: GPA, calendar year, course enrollment, course length (weeks), total credit hours attempted, total credit hours earned, concurrent credit hours (number of hours enrolled during that semester), age, and number of prior online courses taken.

Categorical variables: instructional mode (online or in-person), gender, semester, course, section, instructor, ethnicity, and major (STEM/non-STEM).

3.2. Significance Tests

Correlation analyses were carried out to determine the variables with the greatest influence on student outcome (grade earned). To assess the significance of correlations between the independent variables and the student outcome, *t*-tests were performed on the numerical-grade distribution (a group response) between student bodies parametrized by different independent variables, with t-scores calculated indicating the ratio of the differences between two groups relative to differences within each group. The larger the t-score, the greater the difference between the groups. *p*-values are a measure of the probability that the results from the sample data occurred by chance, ranging from 0 to 1 (0 to 100%). Depending on the confidence level desired, *p*-values of 0.05 or 0.01 are typically used as a test of significance.

Chi-square tests were performed using the letter grade distribution (dependent variable) to assess the significance of correlations with each categorical independent variable. Given the low number of +/− grades employed, these records were combined into a single letter grade for the statistical analyses (e.g., C+, C, C− grades combined and represented by C grade).

3.3. Linear Regression Trendlines

For the independent variable found to be the most significant predictor of grade (GPA), linear regression trendlines were plotted and assessed for data for all years and separately for data pre-and post-COVID-19, with further divisions analyzed when separated into groups based on academic classification (freshmen–seniors), length of course, course title (Geol 101, 102, 104, 105), and instructor. Regression lines for in-person classes were analyzed when including and excluding the hybrid courses from Fall 2020 and Spring 2021 to determine if these data significantly skewed results.

3.4. Direct Measures of Performance

For a subset of the courses, raw scores were obtained for individual exams to compare assessments of performance before and after COVID-19 that were not captured by final grades. This is particularly useful where grades are based on a sliding scale. If the average score on exams drifts downward in successive years, final grade distributions may remain the same even though actual performance or mastery of the subject matter has declined. Raw scores from grade spreadsheets were provided for this study by instructors still employed by the university. Of those, not all were equally useful. For most instructors, assigned courses were not consistently the same in each year of the period of investigation, or the instructor taught a particular class only once per year, limiting the number of student records for the same class and instructor. Of the two instructors with a consistent history of the same course at least twice each year over the period of investigation, one offered extra credit options to students with points wrapped into recorded test scores, obscuring possible differences in performance levels from one year to the next.

The other instructor (first author of this paper) had the longest record of continuous instruction of the same course (Physical Geology, Geol 101: online), going back to 2014, and a consistent history of instruction and assessment, which was particularly useful for identifying changes in student performance independent of final grades. All quizzes and exams drew from the same bank of questions created by the instructor, binned by unit and specific subject material, which eliminated the possibility of drifts in exam difficulty over time. Improvements were made over time to the quality of geologic images, videos, voice recordings, and recent geologic events, but the subject material, pace, and assessment methods remained the same. The one exception was during the emergency shift in all classes to hybrid. For two semesters (Fall 2020, Spring 2021), the normal midterm and final exams were divided into four-term exams, but otherwise covering the same material. For all years, a geography test was given in the second week of class. Student enrollment in each Fall/Spring semester ranged from 40 to 60, with an average enrollment of 51.

3.5. Limitations

The University of Mississippi draws students from across the USA and internationally, but the student body does not fully represent all student types or distributions. UM is a PhD granting institution (R1 Carnegie classification), with a 4-year, liberal arts undergraduate design. The undergraduate student makeup over the years of this study was 95.5–96.3% US citizens, 50.8–60.1% MS residents (in-state), 88.3–91.8% full time, 54.7–56.7% female, 18.9–20.6% minority, and 9.2–12.1% first-generation college students. By virtue of focusing on non-majors geology classes, the study also assesses predominantly non-STEM students; 93.7% of records were non-STEM majors.

4. Results

4.1. Correlation Analysis: Predictors of Student Outcome

Pearson correlation coefficient r is computed between a number of independent variables and the course grade. Table 2 lists the results, as well as the associated p-values for the classical two-tailed null-hypothesis test. The single most significant predictor variable for the response variable (course grade) is the student's GPA at the start of the course, with a Pearson correlation coefficient of 0.626. All other variables have correlation coefficients below an absolute value of 0.15, indicating minimal or no influence on expected grade. (Note equivalent results for attempted hours and earned hours are because these are the same for most students, varying only for those who failed one or more classes.)

Table 2. Correlation coefficients for grade earned vs. independent numerical variables for all courses and modalities in all years, ordered by absolute value of correlation (r).

Numerical Grade vs.	Correlation (r)	p-Value
GPA	0.626	$<1 \times 10^{-80}$
previous online courses	−0.147	3×10^{-69}
course length (weeks)	−0.134	3×10^{-58}
age	−0.085	6×10^{-24}
concurrent hours	−0.023	0.006
course enrollment	0.020	0.017
credit hours attempted	−0.006	0.47
credit hours earned	−0.006	0.47

4.2. Distribution of GPA and Grades in Online vs. In-Person Courses

Figure 2a shows a slightly higher distribution of GPAs for students taking online courses compared to in-person courses. Given the correlation between GPA and grade earned, the expectation based on GPA alone would be higher grades in the online courses relative to in-person, but the opposite is observed. Figure 2b shows a lower distribution of grades earned in the online classes, despite the modestly higher entering GPAs relative to the students in the in-person courses. Note the stair-step appearance of the distribution in Figure 2b is an artifact of the much lower number of +/− grades assigned (Table 1).

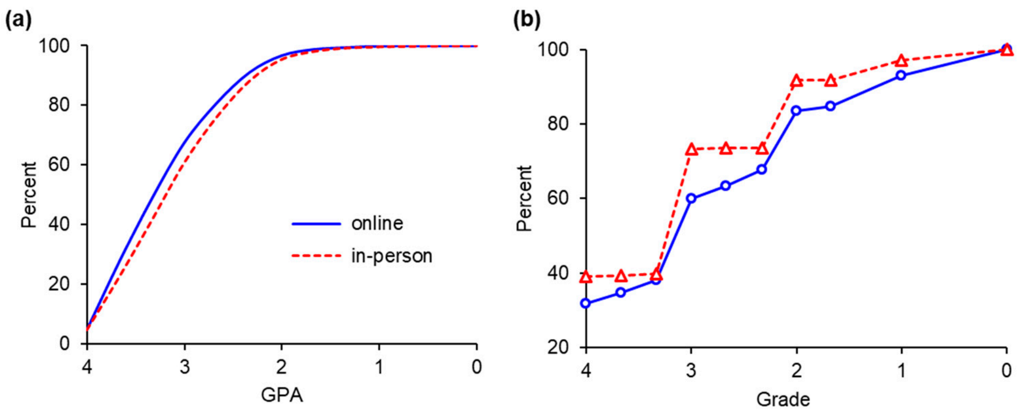

Figure 2. Cumulative distribution of (**a**) GPA and (**b**) grade earned (numerical) for students taking online (solid blue line) and in-person (dashed red lines) courses. Note the horizontal scale is inverted, starting with the highest GPA and grade (4.0).

4.3. Chi-Square Test of Independence

We used the Chi-square test of independence to quantify possible differences between categorical variables and student performance (grade earned). For example, the distribution of earned grades for online vs. in-person courses has a Chi-square value of 206 (or 217 if hybrid mode is also included), with a p-value of 10^{-43} (Table 3). This result means the difference illustrated in Figure 2b is statistically meaningful. As a comparison, students divided into even and odd ID numbers (populations that should not be distinct) have a Chi-square value of 8.9 and p-value of 0.06, confirming that they are not distinct populations; the ID number has no bearing on grade earned.

Table 3. Chi-square tests for the distribution of letter grades for independent category variables, ordered by Chi-square value.

Variable	Chi-Square	p-Value
instructor	2648	$<10^{-300}$
ethnicity	840	10^{-168}
modality (with hybrid)	217	10^{-42}
modality (without hybrid)	206	10^{-43}
course	156	10^{-27}
gender	135	10^{-28}
major (STEM or not)	91	10^{-18}
ID number	8.9	0.06

In contrast to the results of the numerical variables, most of the categorical variables showed statistically meaningful differences between populations, including differences in grade distributions between course titles (Geol 101, 102, 104, 105), instructors, gender, ethnicity, and major (STEM or not). By far, the largest difference was found between instructors. This result led to additional attention to the distribution of grades assigned by each instructor. Of the 15 instructors, two groupings were discovered. One group consistently assigned grades with percentages in the order (highest to lowest) of A, B, C, D, F. A second group assigned grades with percentages in the order of B, C, A, D, F. The six instructors responsible for 90% of the records were evenly divided between the two groups. This division accounts for the large Chi-square value, and likely accounts for the statistically significant difference in grade distributions between course titles, as course title and instructor are not independent of each other.

Of the remaining categorical variables, a higher proportion of A grades were earned by females over males (gender), Asian over white over other minority identities (ethnicity), and STEM students over non-STEM students (major). The gender difference is consistent with what others have reported [14,19,43,49–52]. Differences for ethnicity and major may or may not be meaningful here, as the total number of records for minority and STEM students in this dataset is small.

4.4. Linear Regression Trendlines of GPA vs. Grade, Pre- and Post-COVID-19

Figure 3 plots GPA vs. grade earned for in-person and online courses, with separate graphs for pre- and post-COVID-19 years. Boxplots depict the mean and spread of the data using letter grades, with a clear offset between the two groups in the pre-COVID-19 data (Figure 3a). Trendlines for GPA vs. earned grade (numerical values; Figure 3b) quantify the offset depicted visually by the boxplots. The data shown include all the hybrid in-person data from Fall 2020–Spring 2021. When the data are excluded, the plots have the same general appearance, with maximum trendline shifts of only 0.03 for slope and 0.1 for y-intercept.

For the trendlines, a perfect alignment of GPA and grade earned would yield a slope of 1 and y-intercept of 0. A slope of 1 and negative y-intercept (not observed) would suggest that GPA overpredicts grades for all students. A slope greater than 1 and negative y-intercept (observed) indicates generally lower grades than predicted by GPA, with a disproportionate impact on lower GPA students.

The pre-COVID-19 trendlines (Figure 3b, left) show a clear difference between the GPA-predicted grades of in-person and online courses. For in-person classes, the slope and y-intercept are 0.99 and 0.13, respectively, indicating a roughly 1 to 1 correspondence between GPA and predicted grade (r = 0.64). The slope for the online courses is nearly 20% higher (1.17) with a y-intercept of −0.91, indicating predicted grades lower than a student's GPA, with a larger discrepancy between GPA and predicted grade for lower-GPA students (r = 0.58).

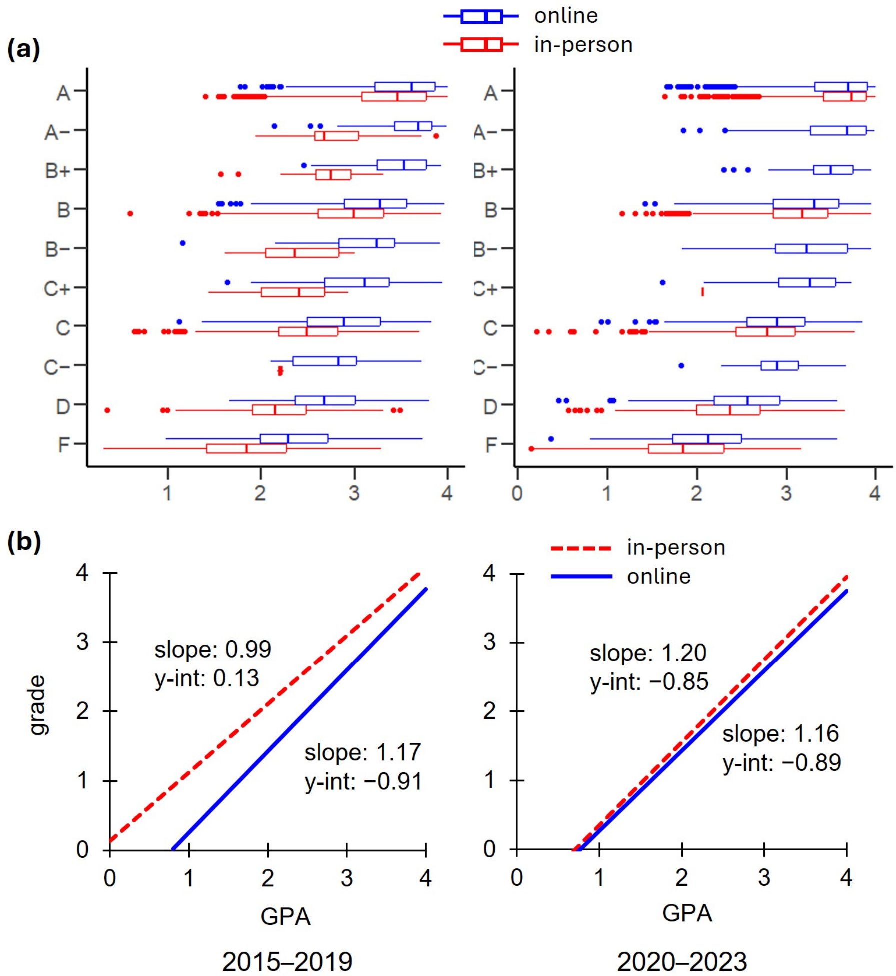

Figure 3. GPA vs. grade earned for online and in-person courses pre-COVID-19 (left column) and post-COVID-19 (right column): (**a**) boxplots of the distribution of letter grades for online (blue) and in-person (red), and (**b**) linear regression trendlines with slope and y-intercept values for online (solid blue) and in-person (dashed red) courses. Note, with only one exception, no +/− grades were assigned for in-person classes from 2020–2023.

For the post-COVID-19 trendlines (Figure 3b, right), the difference between in-person and online classes disappears. The regression line for online classes is largely unchanged relative to the pre-COVID-19 data. The change is due almost entirely to a shift in the in-person instruction line, nearly merging with the online instruction regression line. When separating student records by year in school (freshman through senior based on credit hours earned), a similar shift is observed within each group (Figure 4), with the exception of seniors, where a small difference between in-person and online persisted.

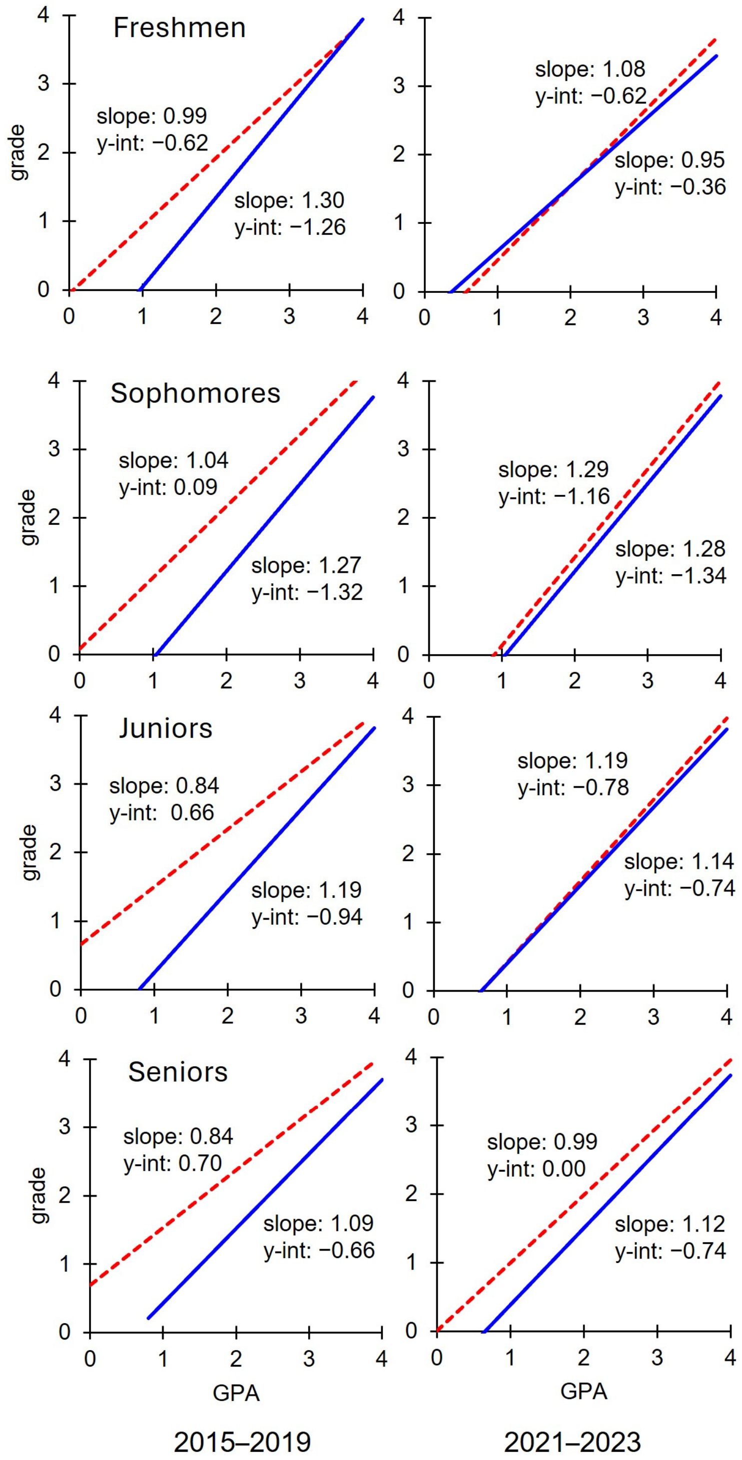

Figure 4. Linear regression trendlines for GPA vs. grade earned with slope and y-intercept for online (solid blue) and in-person (dashed red) courses broken down by academic classification (freshman-senior) for 2015–2019 (pre-COVID-19, **left column**) and for 2021–2023 (post-COVID-19, **right column**).

4.5. Post-COVID-19 Performance Comparisons

In seeking an understanding of the post-COVID-19 merging of trendlines, we introduced a flag, impacted, to identify students who had been in high school during the COVID-19 shutdowns. The year of high school graduation was available for 84% of the student records from 2020 to 2023 and for 81% of records overall. For this analysis, records with missing graduation dates were culled. Students with a graduation date of 2020 or later were flagged as impacted, with records removed for those who were still in high school, as dual-enrolled when taking the course (graduation year later than the course year). The percentage of impacted students during each Fall/Spring semester from 2019 is illustrated in Figure 5.

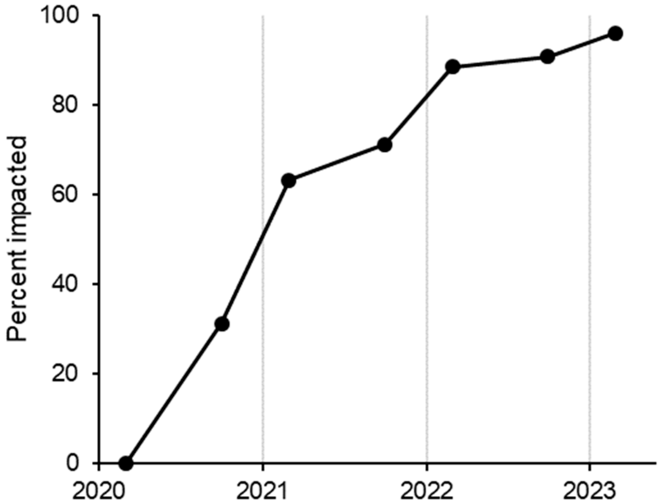

Figure 5. Percentage of students in each Fall and Spring semester who were in high school during the COVID-19 shutdowns (impacted). Vertical gridlines represent the start of each calendar year.

After separating the online and in-person sample populations into COVID-19-impacted and non-impacted, we calculated *t*-tests for the various combinations of groups (Table 4). Considering the number of missing graduation records, the same analysis was performed using student age as a proxy for high school graduation date, with consistent results. The experiment highlights the progressive impact of COVID-19 on the student population as a whole. The most significant results in Table 4 are (1) for in-person courses, and there is a strong statistical difference between non-impacted and impacted students; (2) the impacted in-person group is not statistically distinguishable from the non-impacted online group ($p > 0.05$). Together, these provide additional statistical confirmation that the normal benefit of the structure provided by in-person classes did not translate into improved performance for students who had experienced the pandemic while still in high school.

Table 4. The t-statistics and the *p*-values (in parenthesis) for the two-sample tests between pairs of groups drawn from the four non-overlapping groups of students: impacted—online, impacted—in-person, non-impacted—online, non-impacted—in-person. For *p*-values that are less than 0.05, the null hypothesis that the two groups belong to the same population is rejected.

	Non-Impacted and In-Person	Non-Impacted and Online	Impacted and In-Person	Impacted and Online
Non-Impacted and in-person	-	8.8 (10^{-18})	10.6 (10^{-26})	12.9 (10^{-37})
Non-Impacted and online		-	1.0 (0.32)	4.7 (10^{-6})
Impacted and in-person			-	4.2 (10^{-5})
Impacted and online				-

4.6. Direct Measures of Performance

Results for Physical Geology (Geol 101) online, taught by the same instructor since 2014, are shown in Figure 6. In Spring 2020, the Geography test and Exam 1 predated the COVID-19 emergency measures. The anomalously high score for Exam 2, after abruptly shifting to remote instruction, is suspected to be from cheating. In Fall 2020 and Spring

2021, Exams 1 and 2 were each split into two exams, which were averaged together to plot. A significant increase in scores occurred only for Exam 1.

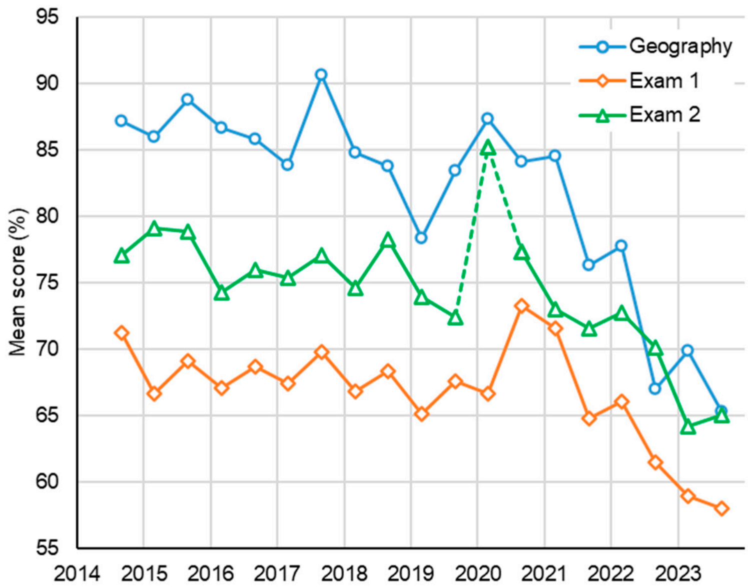

Figure 6. Mean scores for three exams for Physical Geology (Geol 101) online, all taught by the same instructor for ten years, and each year drawing from the same question pool. Vertical gridlines represent the start of each calendar year. In Fall 2020 and Spring 2021, four exams were given, with the first two and second two averaged to plot (points on either side of 2021 line). The anomalous high score for exam 2 in Spring 2020 (dashed lines) is suspected to be linked to cheating.

For all exams, the mean scores remained relatively stable from Fall 2014 to Spring 2019, followed by a striking decline beginning in 2021 and continuing through the end of 2023. Overall performance, as measured by raw scores on these exams, declined every year since COVID-19, with the most recent averages ~20% lower on the Geography test and ~10% lower on the term exams.

These results are not reflected in the final distribution of grades, as grade assignments were made each semester based on the mean and range of scores. The percentage of A and B scores did not change between pre- and post-COVID-19 semesters. The diminished learning has been masked by a form of grade creep, which accounts for the appearance of minimal change in the post-COVID-19 GPA vs. grade trendlines for online classes in Figures 3 and 4.

Raw scores were available for in-person and online classes taught by five other instructors, although breaks in teaching history for the same course and modality, adjustments made to raw test scores with extra credit options, or changes in the way an instructor taught or assessed a class limited the ability to meaningfully compare pre- and post-COVID-19 student performance. Figure 7 shows the results for two of these courses as examples (Geol 104 and 105; in-person), both taught by the same instructor. Scores for all exams after 2019 declined in Geol 104, and for 3 out of 4 exams in Geol 105, with some declines appearing to start even before COVID-19.

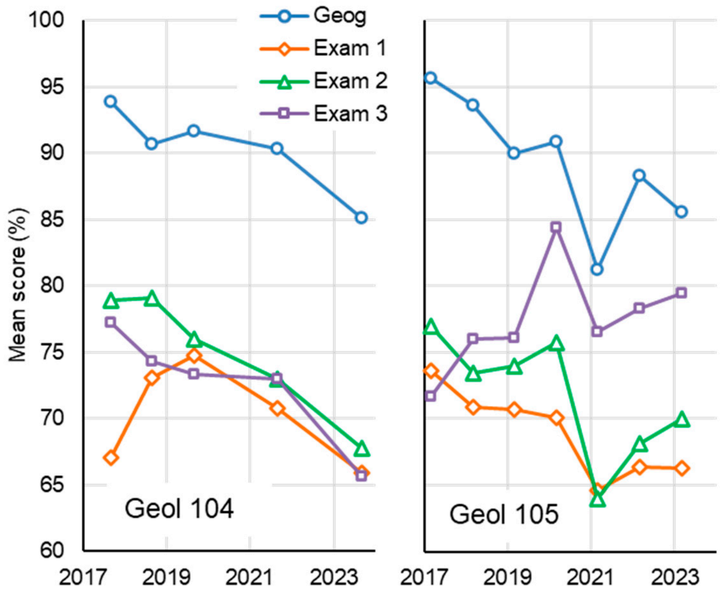

Figure 7. Example raw scores for exams from two in-person courses (Geol 104 and 105) taught by the same instructor but over a shorter span of years relative to Geol 101 online (Figure 6), taught with less frequency (not every Fall and Spring), and with greater variability in instruction or assessment. Vertical gridlines represent the start of each calendar year.

5. Discussion

The most significant finding of this study is the disappearance of a meaningful difference in the performance of students in online versus in-person courses. Pre-COVID-19, observed differences are consistent with what others have reported, where high-performing students tend to do equally well in both modalities (equal to their GPA) but lower-performing students tend to perform worse, on average, in online courses (Figure 3). The slope of the online trendline indicates a disproportionate impact with lower GPA. The most likely explanation, as others have noted, is the built-in structure provided by in-person courses (e.g., set meeting times, consistent pace, reduced external distractions) that online students must supply for themselves. High-performing students typically have a greater ability to self-structure [26–31].

That difference disappears in the post-COVID-19 data (Figures 3 and 4). Of note, the collapse of a separation in GPA-based prediction of outcome is primarily a result of changes in the in-person data, not the online data. Post COVID-19, the in-person trendline drops to essentially merge with the online trendline. The implication is that the advantages provided by the built-in structure of in-person courses went unrealized in the post-COVID-19 years, particularly for lower-GPA students. Something was lost in student preparation that disconnected the "structure advantage" from translating into improved performance.

Considered alone, the trendline data may appear to suggest that performance in online courses was unaffected by COVID-19, as the trendline does not significantly shift post-COVID-19. This can be demonstrated to be false by considering direct measures of scores on exams over the same time period and recalling the use of sliding grading scales employed by most of the instructors. Figures 6 and 7 show clear evidence of a post-COVID-19 decline in actual student learning in online as well as in-person courses.

The steady decline in exam scores after 2020 is better understood by considering the number of enrolled students who were still in high school during COVID-19, and the fraction of high-school impacted students reaching college in each successive year. Non-major geology courses at the University of Mississippi are taken by a mix of freshmen to seniors to satisfy general education science requirements. In the first year following the pandemic, the percentage of students in these courses who had been impacted by COVID-19 while still in high school was low but increased in each subsequent semester

(Figure 5). This is consistent with the steady decline in average exam scores observed in each post-COVID-19 academic year (Figure 6), rather than a single dip and stabilization or later recovery.

This assessment is further supported when considering plots of GPA vs. grade broken down by academic classification (freshman-senior) (Figure 4). For the post-COVID-19 years, only seniors in this study preserved a remnant of the separation between the in-person and online trendlines. This is the only group where most were already in college at the start of the pandemic.

Taken as a whole, this represents evidence of a loss in student preparedness for college that goes beyond missed material e.g., [77], or short-term mental health e.g., [74], during high school shutdowns. Based on the groundbreaking work of Jonathan Haidt in his 2024 book The Anxious Generation, it is likely that COVID-19 exacerbated an already existing decline in the mental development and maturation of teenagers caused by a shift from a real-world "play-based childhood" to a digital-world "phone-based childhood" [82]. The resulting decline in student preparation for college may be linked to diminished focus (ability to minimize distractions), critical thinking skills (e.g., connecting two related observations presented at different times or in different context), communication skills (ability to communicate understanding or ability to communicate struggles), social interaction (e.g., building study groups), and personal accountability (taking responsibility for one's own decisions and opportunities).

6. Conclusions

The pre-COVID-19 data from this study are consistent with the majority of published findings comparing online and in-person courses, where grade distributions tended to be lower for online courses, and with a disproportionate impact on lower-performing students. The post-COVID-19 data shifted significantly. (1) The separation in the GPA-based prediction of performance for online and in-person courses collapsed. (2) The advantage historically provided by the built-in structure of in-person courses stopped producing the improved grades (relative to online) observed pre-COVID-19. (3) Student performance on direct measures (exams) that were stable over many years pre-COVID19 began a sustained decline as a higher percentage of high school-COVID-19-impacted students were enrolled. (4) At the time of completion of this study at the end of 2023, direct assessments did not show signs of recovery. (5) Explanations for these observations are likely linked to losses in student preparation related to focus, critical thinking, communication skills, and social development in their formative K12 years. Students already in college at the time of shutdowns were also affected, but not to the same degree.

These findings are ripe with potential for future work. Is a similar post-COVID-19 merger of online and in-person performance replicated at other institutions with similar and with dissimilar student populations? Are there regional differences in college readiness that may be linked to differences in school closure or distancing policies? For the current study, COVID-19-impacted K12 students included only those who were in high school during COVID-19. As time moves forward, will students who were in junior high and elementary school during COVID-19 share the same struggles or demonstrate more resiliency? Finally, we made suggestions regarding the underlying causes of poor college readiness. Much room lies here for studies probing these possibilities.

We live in an age of global interconnection, where infectious diseases can spread halfway around the world on a plane in a matter of hours. As national and global leaders prepare for future outbreaks, our results indicate that school shutdowns do not simply place a pause on instruction. There are serious and lasting consequences not only with respect to the transfer of information to K12 students, but also on their ability to thrive.

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