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Apropos Students Temporal Exam Effort and Performance

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Apropos Students Temporal Exam Effort and Performance

Abstract

When looking at a student's performance on an exam, the question arises whether there is a relationship between the time a student used and their resulting grades. The topic investigated throughout this study analyzes a student's test performance when compared to the time given to complete the assignment. This study will also examine the relationship between different test types and how long they take students to complete. Some types of exams might lead to a greater amount of time. This study will investigate which types of exams improve student success while still measuring their obtained knowledge. The study investigates this question further through different engineering courses from multiple disciplines such as mechanical, industrial, and electrical.

1. Introduction

Tests and examinations are a stressful part of college life necessary to reinforce and evaluate the knowledge a student received in a course, and invariably some students perform better than others at test-taking. However, in engineering, there has been little study about the interrelationships between test designs, the time required for test completion, and student performance outcomes. Therefore, this study proposes to examine the relationships between the time students used to complete an exam and their performance outcome, and the type of exam questions administered to students and their performance outcome. The study examines these relationships using data from multiple engineering courses and exam formats by performing a statistical analysis approach. First, this analysis seeks to determine whether there is a correlation between the time a student takes from a time allotment and the student's resulting performance output. Second, this analysis seeks to determine whether there is a correlation between the type of questions presented on an exam and the student's resulting performance outcome.

In the literature, there is a plethora of papers written on various studies related to test and examination taking. Many of these studies address standardized test administration often at the secondary level. At the post-secondary level or higher-education level, studies investigate research questions related to examination structure, mainly in arts and sciences, and often with coursework in the areas of social sciences or psychology. Findings from this accumulated body of work are often extrapolated and applied to other fields, sometimes without due diligence to understand the context. Mudge [1] found that on untimed tests a student's pace might not validly reflect their performance. It was found that "some students work quickly but perform poorly, other students work slowly but perform well, and all variations exist in-between". Longstaff and Porter [2] demonstrated over several exams in a psychology course that "very little, if any, the relationship between the times required and the scores made". In psychology courses, several conducted variants of this experiment, all reach similar conclusions [3-7]. More recently, the prediction of a relationship between test-taking pace and performance fails not only in psychology courses but also in the fields of chemistry, engineering, agriculture, business, English

and literature, statistics, and mathematics. Experts have concluded that the prediction often fails because “putting time limits on power tests introduces irrelevant variance” [8].

Although much has been studied and written about the failings in predicting student performance based on the student test-taking pace, there are still many questions that still require addressing. In this study, the authors attempt to take a unique look at the problem by considering the importance of the test design and the influence that has on both student test-taking pace and performance. A better understanding of this relationship may help instructors develop better tests and examinations that will more fairly assess student knowledge from a course and help students more confidently reveal their command of the material.

2. Methodology

This study uses statistical analysis to examine the relationship between the time a student used to complete a test and student performance, and test design. A top-tier research university completed this study using data from an undergraduate engineering program. The obtained data for this analysis is from six undergraduate engineering courses: One 100-level (freshman) course, two 200-level (sophomore) courses, and three 300-level (junior) courses. The class size ranged from 11 to 54 students, with a lecture frequency of two 75-minute lectures per week or three 50-minute lectures per week. The data obtained from these six courses included 14 exams with associated information about (1) the amount of time each student spent solving their exam, (2) the grade earned by each student, and (3) the instructor’s solution for each exam. This information enabled the development of the dataset for statistical analysis.

Time and Performance Data

Across the 14 exam sets, 350 data points were organized. The exam sets consist of both midterm and final exams. The amount of time each student had to complete their exam was limited to 50 minutes, 75 minutes, or 110 minutes in the case of final exams. A few students had learning accommodations that allowed them up to two times the allotted exam time. To standardize all times, we converted the actual recorded time it took each student to complete their exam (in minutes) to the proportion of allowed time each student used (i.e., Proportion Time Used = Amount of time student spent taking the exam / Amount of time available to the student to take the exam). The authors excluded all data points that were missing either time data, exam grade, or both. The authors also excluded data points with proportions of allowable time that were greater than 1.4 because it was assumed that those points were associated with errors in data collection. One data point had a low exam grade that the authors classified as an extreme outlier (≈ 3IQR from the first quartile). The authors assumed the low grade was likely due to issues beyond the intent of this research and excluded it from the analysis. The authors excluded 25 data points in total, leaving 325 data points for analysis. Figure 1 shows the descriptive statistics about time and performance.

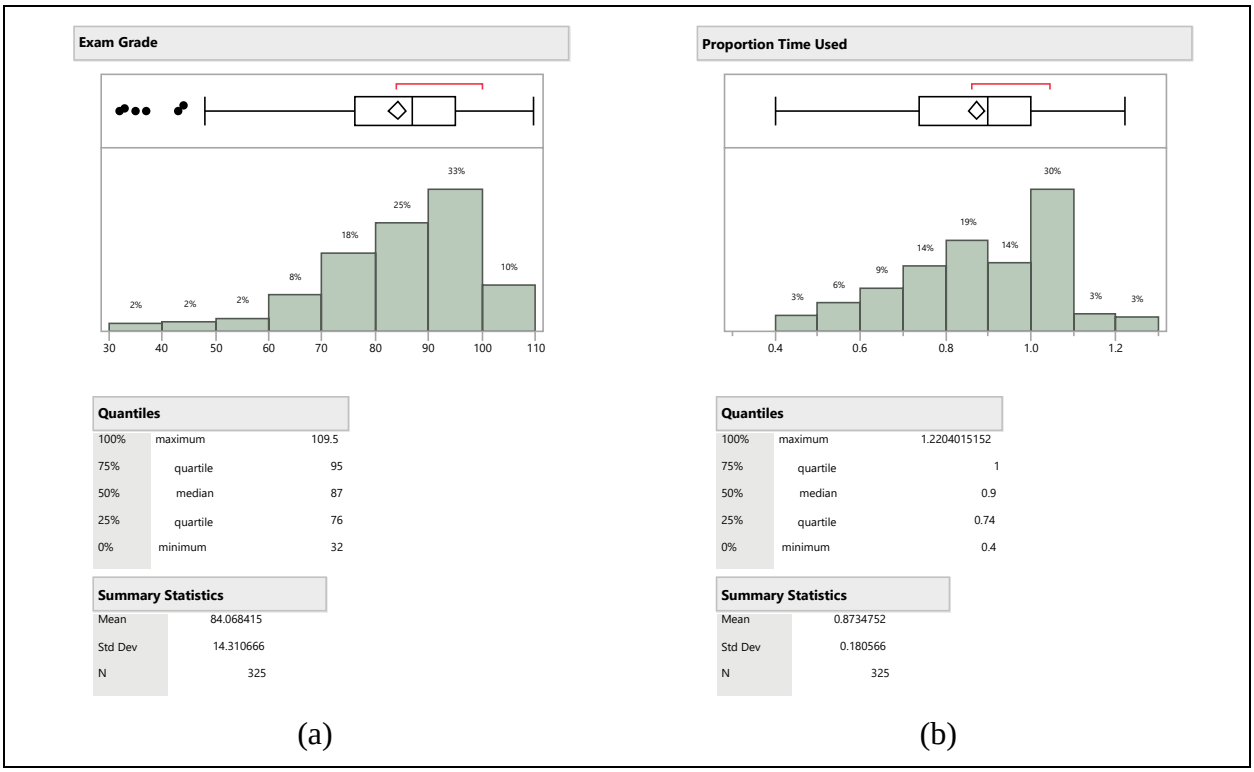


Figure 1: Descriptive statistics for (a) student exam grades and (b) the proportion of time each student used on their exams. Note that 10% of exam grades earned extra credit (>100%) and 36% of exam times exceeded the allowed time (>1.0).

Exam Questions and Effort Measure

This study investigates how different question types influenced both time to complete an exam and exam performance by classifying each problem on every exam according to the following five question types.

- Calculation – questions that require the student to calculate a value as the solution to the problem.
- Multiple Choice & True/False – questions that offer the student the ability to select the correct answer(s) from a defined list.
- Short Answer – questions that require the student to explain a concept, describe a scenario, or set up a problem without solving it.
- Software – questions that require the student to solve a problem using software taught as part of the course. For this analysis, the software used in exams was Microsoft Excel.
- Drawing & Graphing – questions that require the student to create a drawing of a system or scenario or graph lines and angles as the primary solution. Some calculations may be needed in order correctly create the graph or drawing.

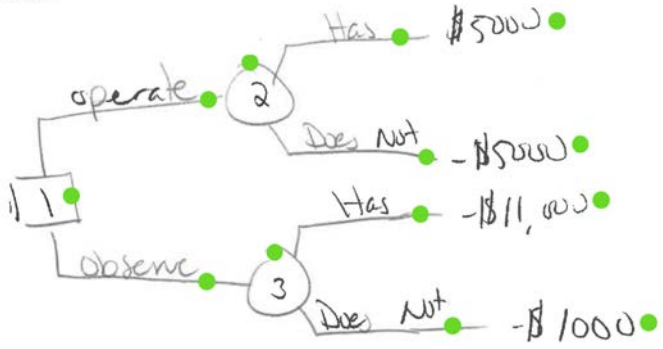
	Example of Question Type	Count
(a)	(1 points) What is the probability that a randomly selected skittle is dark green? $P(DkG) = \frac{24+14}{175} = \frac{38}{175} = 0.217$	4
(b)	(1 point) What is the recommended decision using the optimistic approach? **Circe the best answer**. *You must show work to receive partial credit.* i. a_1 ii. a_2 iii. a_3 iv. a_1 & a_2 v. a_1 & a_3 vi. a_2 & a_3 Best of Best	6
(c)	(1 point) **Define the ER doctor's decision alternatives.** operate or observe	3
(d)	Calculate the moment of inertia and Centroid using excel for the following shape:  area y_i A_i*y_i I_i d_i I_part part 1 400 38 15200 533.3333 11.80328 56260.29 part 2 144 18 2592 15552 -8.19672 25226.82 part 3 144 18 2592 15552 -8.19672 25226.82 part 4 144 18 2592 15552 -8.19672 25226.82 part 5 144 18 2592 15552 -8.19672 25226.82 Centroid 26.19672 Moment of Inertia 157167.6	32
(e)	(3 points) **Draw the decision tree that represents this problem.** *You do not need to solve this problem.* 	13

Figure 2: Example of each question type: (a) calculations, (b) multiple-choice, (c) short answer, (d) Excel, and (e) drawing. The green dots in each example show which counted elements determine the effort associated with each problem.

Table 1 summarizes each exam in terms of length (number of pages, number of problems, and total number of subproblems) and effort (total count and density). The total effort count was determined for each exam by aggregating the individual problem counts. The methodology utilized these total counts to calculate a density score for each exam (Table 2). Effort density ranged from 5.9 to 38. Using the midpoint of this range, the authors classified each exam in terms of high density (>21.95) or low density (<21.95) to gauge the complexity of the exam. The

authors assumed that easier exams would be ones with smaller densities, indicating fewer elements per problem on average (i.e., shorter answers with less effort).

Table 1: Summary of exam details

Summary / Exam	1	2	3	4	5	6	7	8	9	10	11	12	13	14
No. of Pages	8	8	6	5	6	8	7	7	6	10	6	7	5	6
No. of Problems	4	3	6	4	4	6	14	20	10	12	7	7	5	4
Total No. of Subproblems	4	3	6	8	8	7	17	22	18	24	15	31	7	9
Total Effort Count	111	114	152	146	151	184	173	252	177	205	206	182	99	95
Density (Count per Subproblem)	27.8	38.0	25.3	18.3	18.9	26.3	10.2	11.5	9.8	8.5	13.7	5.9	14.1	10.6

Table 2: Proportion of effort attributed to each type of question for each exam.

Question Type / Exam	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Calculation	1.00	1.00	1.00	0.58	0.30	0.28	0	0	0.38	0.49	0.20	0.48	0.71	0.91
Multiple Choice & T/F	0	0	0	0	0	0	0.02	0.06	0	0	0	0.19	0	0
Short Answer	0	0	0	0	0	0	0.91	0.94	0.62	0.40	0.65	0.19	0.17	0
Software	0	0	0	0	0.34	0	0	0	0	0	0.05	0	0	0
Drawing & Graphing	0	0	0	0.42	0.36	0.72	0.07	0	0	0.11	0.10	0.14	0.12	0.09
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Total counts were also used to determine what proportion of effort was spent on each type of question (Table 2). To analyze the effect the type of exam (or more accurately, the composition of the exam) had on student test time and performance, the authors assigned each exam a rating of none, low, or high with respect to each question type. A rating of low was assigned to each exam's question type if it composed < 0.5 of the effort count and a rating of high was assigned when the exam's question type was ≥ 0.5 of the exam's effort count.

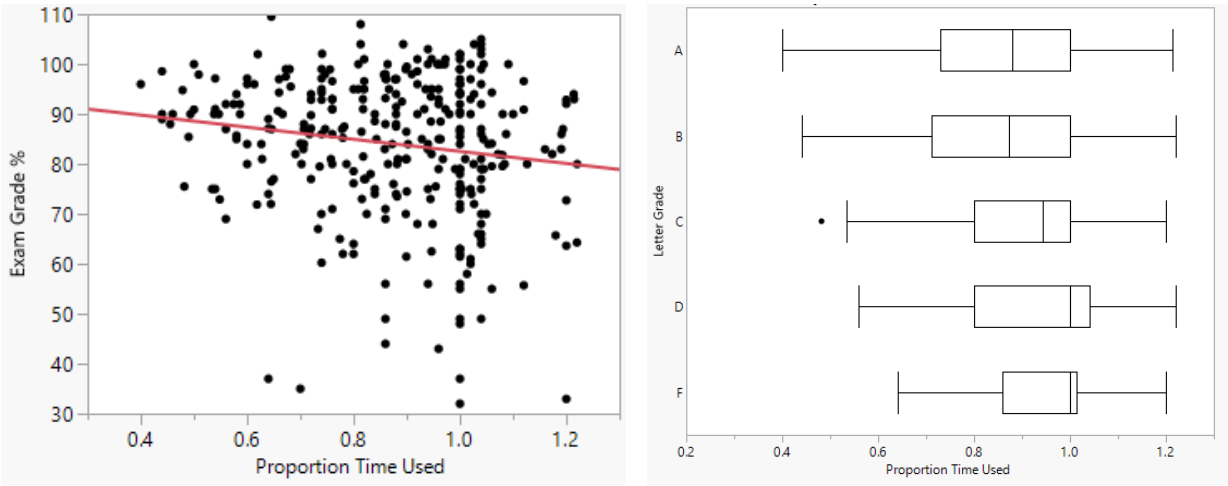
3. Analysis and Results

Our analysis explores the relationship between exam performance, completion time, and exam type to provide insights that instructors can use to create exams that encourage better performance.

Can time predict exam performance?

The authors first address the question; can you predict exam performance based on how long it takes a student to complete the exam? Figure 3a shows a scatter plot of performance vs. time. The authors can see that there does appear to be a negative relationship between performance and time, where the average exam grade decreases as the time to complete the exam increases.

Fitting a linear regression line confirms the negative relationship (Exam Grade = 94.642019 - 12.105213*Proportion Time Used; *p*-value = 0.0058). A low R^2 value of 0.023 and an analysis of residuals confirms what the plot suggests, which is that a simple linear relationship is not appropriate to predict exam grade, most likely because additional factors influence exam performance. The authors can see from Figure 3 that a range of completion times was associated with all levels of exam performance. This leads the authors to conclude that while a correlation may exist between the amount of time a student takes to complete an exam and exam performance, it cannot predict exam performance.



(a) (b)

Figure 3: Relationship between exam time and performance.

Do prepared students take less time to complete exams?

The authors next address the question, does exam performance (a surrogate for student knowledge and exam preparedness) influence the amount of time a student spends on an exam? Figure 3b shows the distribution of time used by letter grade. An analysis of variance (ANOVA) test was performed to see if exam performance affected the proportion of available able time used to complete an exam. The ANOVA test resulted in a *p*-value of 0.0196, confirming that performance (preparedness) does affect completion time. Further, testing using Student t's comparison of means test shows that A and B students spend significantly less time completing an exam than D and F students (Figure 4).

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
F	A	0.1091630	0.0435995	0.023385	0.1949409	0.0128 *
F	B	0.1024559	0.0454767	0.012985	0.1919270	0.0249 *
D	A	0.0944814	0.0380776	0.019567	0.1693955	0.0136 *
D	B	0.0877743	0.0402134	0.008658	0.1668904	0.0298 *
F	C	0.0737239	0.0471588	-0.019057	0.1665043	0.1190
D	C	0.0590423	0.0421063	-0.023798	0.1418824	0.1618
C	A	0.0354391	0.0278299	-0.019314	0.0901917	0.2038
C	B	0.0287320	0.0306873	-0.031642	0.0891064	0.3498
F	D	0.0146816	0.0538457	-0.091255	0.1206179	0.7853
B	A	0.0067070	0.0248732	-0.042229	0.0556428	0.7876

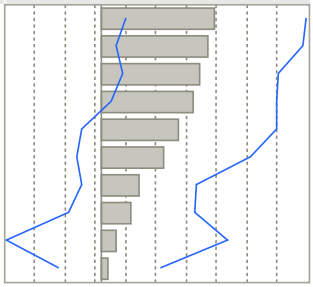
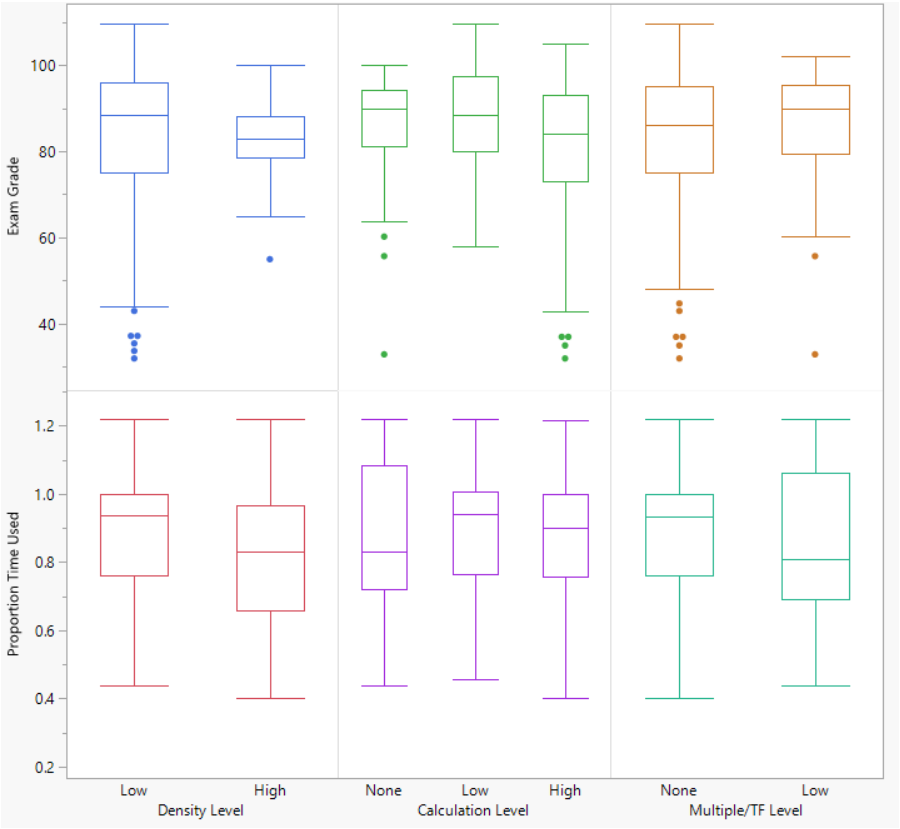


Figure 4: Student t’s comparison of means test for exam performance

Do different types of exam questions affect completion time or exam performance?

The last question the authors address investigates was how different types of exam questions affect the amount of time it takes a student to complete their exam or their exam performance. Figure 5 and Figure 6 use comparative boxplots to show the distribution of time and exam grades for each level of effort density and question type.



(a) (b) (c)

Figure 5: Boxplots showing the distribution of time and exam grade for (a) exam effort density, (b) exam proportion of calculation problems, and (c) exam proportion of multiple-choice and true/false questions.

The authors first investigate how exam complexity affects time and grades. While there are many ways to measure the complexity of an exam, the authors measured it in terms of effort. The authors assumed that complex questions required many steps (i.e., counts of answer elements) to solve. To make a problem easier, an instructor might break a big problem into subparts, helping to guide student's through the problem. The interpretation of the density measure shown in Table 1 consisted of the average number of solution elements (effort count) per subpart in an exam. Large densities imply exams are more complex. Having categorized each exam as high density (n = 65 data points) or low density (n = 260 data points), the authors tested the following hypothesis with respect to first time and then performance.

- H_0: High-*density* exams and low-*density* exams require students to use the same proportion of available time to complete their exams.
- H_A: High-*density* exams and low-*density* exams require students to use different proportions of available time to complete their exam.

Analysis: The authors performed a two-sample hypothesis test for difference in means assuming unequal variances. With a *p*-value of 0.0228, the authors rejected H_0 and concluded that the two densities did result in significant differences in time usage. Further analysis concludes that high densities result in a lower proportion of time used than low-density exams (*p*-value = 0.0114).

- H_0: High-*density* exams and low-*density* exams result in the same average grade.
- H_A: High-*density* exams result in a different average grade than low-*density* exams.

Analysis: The authors performed a two-sample hypothesis test for difference in means assuming unequal variances. With a *p*-value of 0.1622, the authors failed to reject H_0 and concluded that the two density levels did not result in significant differences in grades.

Our analysis reveals that effort density affects the proportion of time students take to complete an exam but not the exam performance. Counterintuitively, high-density exams result in less time than low-density exams. A possible reason for this result could be that more students "give up" on the high-density exams and turn their exams in early. Another reason could be that high-density exams had fewer questions and by default required less time to complete.

Table 3: Number of data points for each question type rating.

Question Type	None	Low	High
Calculation	50	108	167
Multiple Choice & True/False	259	66	0
Short Answer	131	100	94
Excel	301	24	0
Drawing & Graphing	107	208	10

The authors next looked at each question type to analyze its effect on time and performance. The authors rated each exam's question type as none, low, or high to indicate what proportion of the exam's effort was dedicated to the respective question type. A rating of low was assigned if < 0.5 of the exam's effort was attributed to the question type; a rating of high was assigned if the question type was responsible for ≥ 0.5 of the exam's effort. Table 3 shows how many data points resulted for each question type rating. The authors tested the following hypothesis with respect to first time and then performance.

- H_0: *Calculation* type questions affect the proportion of time used to complete an exam.
- H_A: *Calculation* type questions do not affect the proportion of time used to complete an exam.

Analysis: The authors performed a one-way ANOVA to test the effect calculation type questions have on the proportion of time. With a *p*-value of 0.7118, the authors failed to reject H_0 and concluded that calculation type questions do not affect time.

- H_0: *Calculation* type questions affect the exam grade.
- H_A: *Calculation* type questions do not affect the exam grade.

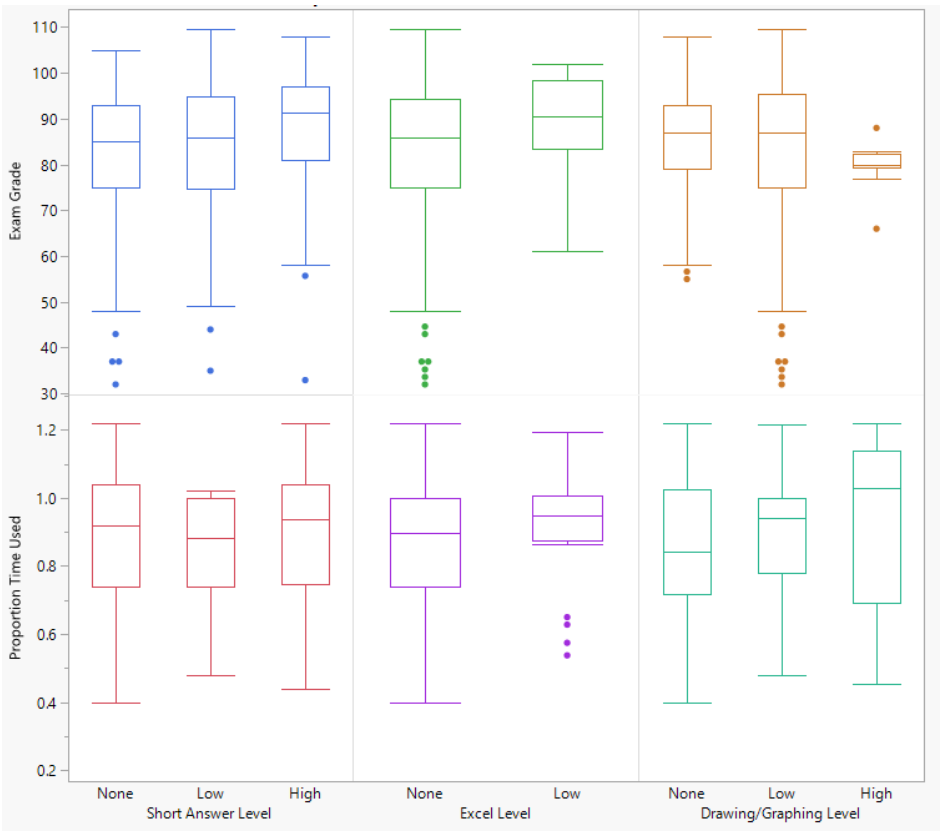
Analysis: The authors performed a one-way ANOVA to test the effect calculation type questions have on exam grades. With a *p*-value of 0.0011, the authors rejected H_0 and concluded that calculation type questions do affect grades. Using Student t's comparison of means test, the authors found that exams with high levels of calculation questions resulted in grades that were significantly lower than exams with low or none levels (*p*-value = 0.0004 and 0.0401 respectively).

- H_0: Exams with *multiple choice and true/false* type questions require the same proportion of time to complete an exam as compared to exams without multiple choice and true/false type questions.
- H_A: Exams with *multiple choice and true/false* type questions require a smaller proportion of time to complete an exam as compared to exams without multiple choice and true/false type questions.

Analysis: The authors performed a two-sample hypothesis test for difference in means assuming unequal variances. With a *p*-value of 0.0633, the authors rejected H_0 and concluded that multiple-choice and true/false type questions significantly reduce the proportion of time spent completing exams.

- H_0: Exams with *multiple choice and true/false* type questions result in the same grade as exams without multiple choice and true/false type questions.
- H_A: Exams with *multiple choice and true/false* type questions result in better grades than exams without multiple choice and true/false type questions.

Analysis: The authors performed a two-sample hypothesis test for difference in means assuming unequal variances. With a *p*-value of 0.2751, the authors failed to reject H_0 and concluded that exams with multiple choice and true/false type questions do not increase exam performance.



(a) (b) (c)

Figure 6: Boxplots showing the distribution of time and exam grade for (a) exam proportion of short answer questions, (b) exam proportion of Excel problems, and (c) exam proportion of drawing and graphing questions.

- H_0: *Short Answer* type questions affect the proportion of time used to complete an exam.
- H_A: *Short Answer* type questions do not affect the proportion of time used to complete an exam.

Analysis: The authors performed a one-way ANOVA to test the effect short answer type questions have on the proportion of time. With a *p*-value of 0.1276, we failed to reject H_0 and concluded that short answer type questions do not affect time.

- H_0: *Short Answer* type questions affect the exam grade.
- H_A: *Short Answer* type questions do not affect the exam grade.

Analysis: The authors performed a one-way ANOVA to test the effect short answer type questions have on exam grades. With a *p*-value of 0.0212, the authors rejected H_0 and concluded that short answer type questions do affect grades. Using Student t's comparison of means test, the authors found that exams with high levels of short answer questions resulted in grades that were significantly larger than exams with low or none levels (*p*-value = 0.0218 and 0.0102 respectively).

- H_0: Exams with *Excel* questions require the same proportion of time to complete an exam as compared to exams without Excel questions.
- H_A: Exams with *Excel* questions require a greater proportion of time to complete an exam as compared to exams without Excel questions.

Analysis: The authors performed a two-sample hypothesis test for difference in means assuming unequal variances. With a *p*-value of 0.2569, the authors failed to reject H_0 and concluded that Excel questions do not affect the proportion of time spent completing exams.

- H_0: Exams with *Excel* questions result in the same grade as exams without Excel questions.
- H_A: Exams with *Excel* questions result in better grades than exams without Excel questions.

Analysis: The authors performed a two-sample hypothesis test for difference in means assuming unequal variances. With a *p*-value of 0.0373, the authors rejected H_0 and concluded that exams with Excel questions do result in better grades.

- H_0: *Drawing and graphing* type questions affect the proportion of time used to complete an exam.
- H_A: *Drawing and graphing* type questions do not affect the proportion of time used to complete an exam.

Analysis: The authors performed a one-way ANOVA to test the effect drawing and graphing type questions have on proportion of time. With a *p*-value of 0.0405, the authors rejected H_0 and concluded that drawing and graphing type questions do affect time. Using Student t's comparison of means test, the authors found that exams with drawing and graphing questions used larger proportions of time than exams without drawing and graphing questions (Low-None *p*-value = 0.0220). The small amount of exams with high proportions of drawing and graphing questions did not result in a statistically significant increase in time (High-None *p*-value 0.1105), though the authors can see that the average time is larger in the boxplots.

- H_0: *Drawing and graphing* type questions affect the exam grade.
- H_A: *Drawing and graphing* type questions do not affect the exam grade.

Analysis: The authors performed a one-way ANOVA to test the effect drawing and graphing type questions have on exam grades. With a *p*-value of 0.2224, the authors failed to reject H_0 and concluded that drawing and graphing type questions do not significantly affect grades.

4. Conclusion

This paper presents the results of a statistical analysis investigating relationships between the time students used to complete an exam, their performance, and the type of exam questions administered to students. The authors identified a weak negative relationship between time used

and exam performance. While time was not found to be a reliable predictor of performance, the authors were able to confirm that higher-performing students who earned an A or B, on average, used statistically less time to complete their exam than lower-performing students who earned a D or F. The authors introduced a new measure to assess the amount of effort each problem and each requires. Using this measure, the authors identified the following insights.

- Higher exam performance is associated with high levels of short answer problems and Excel problems.
- Lower exam performance is associated with exams with high levels of calculation problems.
- Larger exam completion times are associated with drawing and graphing problems.
- Smaller exam completion times are associated with multiple choice and true/false questions.
- Exams that require, on average, high levels of effort per question result in lower completion times. Further investigation is required to determine if this phenomenon is a negative result attributed to students becoming frustrated and turning their exam in early or a positive result related to shorter exams.

While this study provides insightful findings, further research analyzing extreme time and performance values may lead to deeper insights. Future research should also consider investigating student preparedness and test-taking strategy as predictors of exam performance.

Resources

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