Engineering Educators Bringing the World Together
2025 ASEE Annual Conference & Exposition
Palais des congrès de Montréal, Montréal, QC • June 22–25, 2025 ASEE
Paper ID #45708

Do Centralized Testing Centers Influence Test Anxiety for Engineering Students?

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Do Centralized Testing Centers Influence Test Anxiety for Engineering Students?

Abstract

In this full, empirical research paper, we investigated whether the use of a computer-based testing center (CBTC) impacts students' test anxiety. Increasing student enrollment and the desire to test computational skills are leading some large universities to adopt computer-based testing centers. In a CBTC, students are able to take their exams asynchronously (i.e., at different times of their choosing) using institutional computers secured by a firewall to prevent unauthorized Internet access. We compared a CBTC setup to a second potential method of administering exams at scale for engineering students. Under the second method, students complete their tests in class synchronously (i.e., at the same time) using their own computers, which are not secured by a firewall. This method of administering exams has previously been described as Bring Your Own Device (BYOD).

We ran a crossover experiment in a large engineering course, varying the testing modality used by students for each exam. Each student took three of their six exams in the CBTC and the other three exams under the BYOD format. We administered a validated instrument on test anxiety after each exam and collected data on students' exam scores. Overall, 149 students participated in the study and completed all the surveys.

We found that there was no difference in test anxiety or performance when modality was changed. However, the timing of exams, i.e., whether a student took an exam "early" or "late" relative to other students, impacted performance. We explain this phenomenon in detail and provide recommendations for effectively administering large-scale computing exams.

Introduction

Computer-based testing can provide several benefits for instructors and students alike. For instructors, administering automatically graded computer-based tests reduces the amount of manual grading work that they have to complete, freeing up time that can be spent with students or on refining course content. For students, computer-based tests may allow them to receive immediate feedback that can be used for improvement.

To facilitate computer-based testing, several institutions have deployed computer-based testing centers (CBTC) to handle exam administration. CBTCs reduce the cost of testing for faculty because they offload many of the logistics associated with administering quizzes and exams: (1) proctoring is handled by dedicated CBTC staff, freeing up course instructors and other course

staff to focus on teaching and supporting student learning; (2) students individually choose the time of their exams using a web-based scheduler, alleviating the need and administrative challenges of conflict exams; (3) space is provided for testing hundreds of students. CBTCs are designed to provide flexibility for both instructors and students.

Nonetheless, despite the benefits of computer-based testing in a CBTC, students have raised concerns of test anxiety in that environment. Test anxiety refers to anxiety in cases where someone is being evaluated[1,2]. Test anxiety can hamper students' testing experiences and may adversely impact their performance on assessments[3,4,5]. A significant number of students have reported feeling anxious in a CBTC.

In this work, we compare test anxiety in a computer-based testing center to anxiety surrounding computer-based tests in the classroom (we characterize this second configuration as Bring Your Own Device or BYOD). Both methods of administering exams involve the use of computers to provide students with immediate feedback. Still, the specific properties of the testing environments, as explained in the Definitions and Related Work section, may impact students' test anxiety and testing experiences broadly.

Our work is related to recent research that compared CBTC and BYOD testing setups for computer science students[6]. The prior work may have limited generalizability because it considered only computer science students, who may be a distinct group. In this paper, we investigated test anxiety for engineering students across a range of majors. It is important to include students from a diverse range of majors to ensure that potential findings are not due to any potentially unique characteristics of students in a specific sub-discipline.

Our research questions are as follows:

- Does test modality (CBTC vs BYOD) influence students' test anxiety in an engineering course?
- Does test modality (CBTC vs BYOD) influence students' performance in an engineering course?

Definitions and Related Work

Test Anxiety

Test anxiety is anxiety in evaluative situations[2]. Test anxiety has been widely studied as a point of concern for educators. Researchers have found that students with higher levels of cognitive test anxiety scored significantly lower on examinations[3]. With cognitive worry, a component of test anxiety, students' ability to concentrate on the exam at hand may be diminished due to extraneous thoughts, such as worrying about the consequences of failing. In several cases, women have reported higher levels of test anxiety, which may contribute to some observed disparities in performance[7,8].

In the literature, researchers differentiate between two types of anxiety: state anxiety and trait anxiety. State anxiety is a temporary reaction in response to a stressful situation[9]. Trait anxiety represents a person's tendency to be impacted by an anxiety-inducing event[9]. In academic

settings, a person's trait anxiety and the situation at hand (for instance, a high-stakes exam) influence state anxiety.

Configurations for Exams

There are several possible configurations for examinations. We discuss a set of them here.

Device Used for Exams: Instructors may choose to administer either paper-based exams or computer-based exams. Going further, for computer-based exams, instructors may allow students to use their own laptops or other device or require them to take examinations on institutional computers. On institutional computers, instructors have the ability to restrict access to unauthorized materials and typically do so by having a firewall and clean file system. It can be more difficult to restrict access to unauthorized materials on students' computers because it may be considered invasive to require software or a firewall on personal devices.

Synchronous vs Asynchronous Exams: Exams may be administered synchronously or asynchronously. Synchronous exams mean that students take the exam at the same time. For asynchronous exams, students take a given exam at different times. In our context, a window of time (typically a three-day window) is provided to students during which they can choose when to take an asynchronous exam.

Question Randomization and Question Pools: Students taking an exam may be given different questions on that exam. Question randomization and question pools may be used to minimize prospects of cheating.

Exam Location: Exams may be administered in a variety of locations, including in the classroom, computer labs, or remotely. The literature indicates that testing in the classroom may be beneficial because of memory retrieval cues[10]. Separately, if an environment is typically associated with a challenging event or otherwise has cues that have elicited anxiety, that environment may subsequently aggravate anxiety[11].

The aforementioned properties of exams may influence students' test anxiety and their experiences more broadly. We discuss how these various factors are combined in the testing setups used in our research study.

Computer-Based Testing Center: A computer-based testing center is a dedicated lab that manages most of the logistics associated with testing. Exams are administered asynchronously on institutional computers and proctoring is handled by the lab staff. CBTCs have been used for regular course testing at a number of institutions, such as the University of British Columbia, the University of Illinois Urbana Champaign, the University of California Riverside, the University of California San Diego and the University of Central Florida.

Bring Your Own Device: Under a Bring Your Own Device (BYOD) setup, students take exams synchronously in class using their own devices. In this setting, proctoring is typically conducted by the course staff because the exam is offered during the regular course time, in the classroom ordinarily used for instruction for the given course. However, in our case, due to personnel constraints, proctoring was conducted by the same pool of trained proctors who work at the CBTC. A BYOD configuration has lower startup costs for instructors and institutions than a

CBTC because the BYOD format does not require a dedicated space and administration support.

The impact of various computer-based testing setups on students' test anxiety is not well understood. Different features of these environments and the types of assessments they support (e.g., synchronous vs. asynchronous) may influence students differently. Additionally, students' preferences for specific devices or the environmental cues associated with a testing setup could also affect their levels of test anxiety.

Prior work has focused primarily on comparisons for paper-based vs computer-based tests, rather than comparing different kinds of computerized tests. Researchers have found similar levels of test anxiety for paper-based and computer-based tests[11,12]. Our focus is different in that we compare methods for testing at-scale via computer-based testing, which provides students with immediate feedback to promote learning.

In other work, researchers explored whether computer anxiety and test anxiety influenced performance. Computer anxiety has been defined as the "fear associated with interfacing with a computer that is incommensurate to the true intimidation given by the computer"[13,14]. In one study, researchers recruited 72 introductory psychology majors, all of whom had taken a placement test in math, reading or writing via a computer. The researchers administered three measures: the Test Anxiety Inventory (for test anxiety)[1], the Computer Anxiety Rating Scale (a measure of computer anxiety)[15], and the Myer-Briggs Type Indicator[16] (for personality assessment) to gather information about specific symptoms before, during and after exams. The researchers found mixed results. There was no significant relationship between test anxiety and computer anxiety. However, following a discriminant function analysis, test anxiety appeared to affect math performance; computer anxiety influenced reading performance; and neither variable influenced performance on the English assessment. The researchers conclude by discussing perceptions of control as a factor that potentially influences general anxiety in students. More perceived control in computer testing has been associated with lower anxiety. For instance, when individuals were allowed to choose the order of tests, they experienced less anxiety than subjects expected to take tests in a fixed order[17].

The research study most similar to ours sought to determine how the CBTC and BYOD configurations impacted computer science students[6]. The students were in their second to fourth year of college. That study followed a crossover design and both test anxiety and performance data were collected. In that study, no differences were found in test anxiety or performance for students when the test modality was changed. However, a possible confounder there was that CS students in their second or later years of university studies may already be comfortable with computerized testing. In this work, we look at a larger and different population of engineering students to determine if the prior findings hold for a group that may or may not be as adept with technology.

Data and Methods

This study was conducted at a large public university in the United States. It involved a large course on applied mechanics taken primarily by sophomore (second year) engineering students across a range of engineering majors. We refer to the course as Mechanical Engineering 2xx (ME

2xx). We received approval from our Institutional Review Board before proceeding with the study.

The research employed a cross-over experimental study design, allowing for control of intra-subject variability, as each student acted as his or her own control[18]. At the beginning of the term, we collected data on students' trait anxiety (i.e., baseline anxiety) through a survey, the Revised Test Anxiety Online (RTA-O) scale[19]. The RTA-O has been validated, further refines the ubiquitous Test Anxiety Inventory[1], and captures information about the multiple dimensions of test anxiety. Afterwards, students were randomly split into two groups, groups A and B. Group A took their first exam in the classroom, while group B took their first exam in the CBTC. Thereafter, the modalities were alternated for each group for each exam. The course had six exams, meaning that students took three exams in the CBTC and the other three exams under a BYOD setup. The exams were 50 minutes long and consisted mainly of numeric fill-in-the-blank questions.

After each exam, students were sent a survey to collect information regarding their test anxiety (i.e., state anxiety). The survey was adopted from a validated instrument, the Revised Test Anxiety Online Short Form (RTA-O-SF)[20] and it included questions to capture information about both physical and psychological manifestations of test anxiety[19,20]. Students were given a time period of 48 hours to fill out the survey after they were done with each exam to ensure recollections were accurate. A small amount of extra credit was provided as an incentive for completing surveys.

There were 149 students who completed all six exams in the prescribed modalities, completed all of the surveys and provided consent for us to use their anonymized data for research. This corresponds to a participation rate of 40.4%. Among the students who reported gender information, 81 (70.4%) were men and 34 (29.6%) were women, which is in line with the broader course population.

Analysis and Results

No difference in test anxiety based on modality

We found no statistically significant difference in test anxiety when we compared a CBTC to a BYOD setup after controlling for exam ordering.

Before discussing the results in detail, we note that there were two possible confounders in the study: exam ordering and question randomization, which are related. "Exam ordering" refers to when in the testing window a student completed an exam relative to the majority of other students. We observed that for five out of the six exams, students in the BYOD setup typically took their exams earlier than those in the CBTC condition (see Table 1). Figure 1 shows a representative distribution of when exams were completed by students. As the figure shows, most students slated for CBTC exams completed them later in the testing window, after the BYOD half of the class had already taken the exam. Exam 5 was different due to scheduling constraints; for that exam only, students slated for CBTC testing completed their exam before the synchronous BYOD exam was held. Figure 2 shows a peculiar reversal in performance trends that we believe may be tied to exam ordering. For most exams, students in the CBTC setup scored higher than

	Thursday	Friday (before 11am)	Friday (after 11am)	Saturday
CBTC	👤👤		👤👤👤👤👤👤	👤👤👤👤👤👤👤👤👤👤👤👤
BYOD		👤👤👤👤👤👤👤👤👤👤👤👤👤👤👤👤👤👤👤👤		

Figure 1: Timing for an exam for the entire class (reflective of all exams other than exam 5). Each icon represents 10 students, rounded to the nearest 10. Students in the CBTC took their tests later in the asynchronous exam windows. In other words, students in the CBTC could choose when to complete their exams within a three-day window provided by the instructor, and most chose to take it later in the second or third day of the window. At that point, most students slated for a BYOD exam had already completed the same exam.

those testing under BYOD; however, the opposite was true for Exam 5, for which the BYOD students took the exam later and scored higher than those who tested in the CBTC setup.

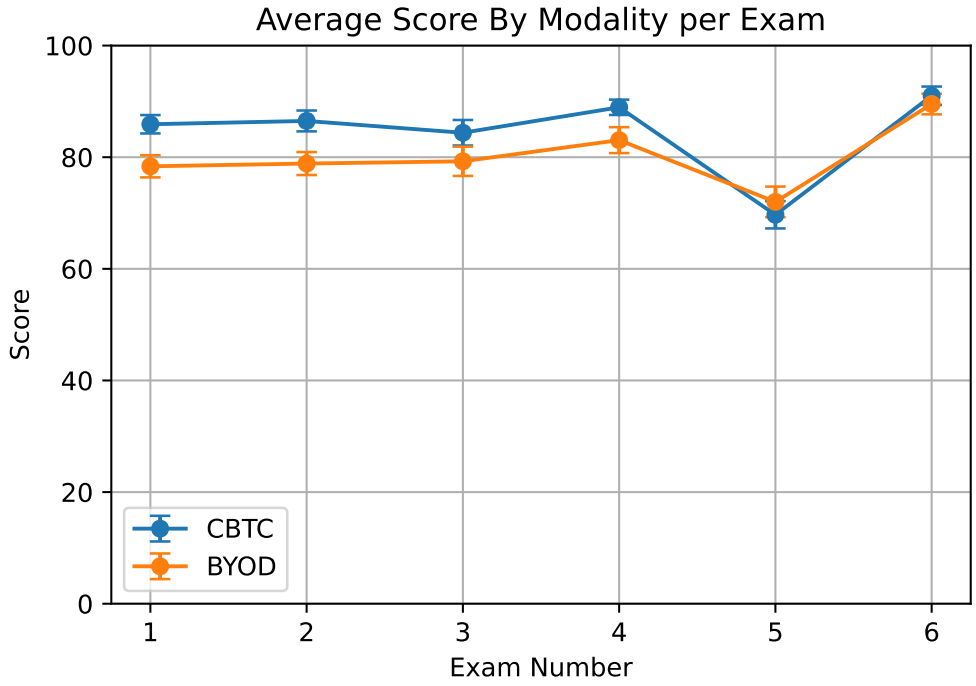

Figure 2: Performance by modality for each exam. Exam 5 had a reversal from the general trend where students in the CBTC performed better than those under BYOD.

The second confounder was question randomization. The instructors for the ME 2xx course had the same or very similar questions for all students. Best practice suggests using question pools and variable randomization on asynchronous exams to mitigate early test takers sharing information with later test takers, i.e. "collaborative cheating"[21,22]. In prior work, researchers found that using question pools with 3-4 question versions significantly reduced the benefits of collaborative cheating[22].

Given the two confounders, students in the CBTC may have had more opportunities to benefit from their classmates who completed the exams in the BYOD setup. The students testing in the CBTC could have gotten information about exam content, even though that was not authorized by

Table 1: Exam ordering for each exam.

Exam	Ordering
Exam 1	BYOD before CBTC
Exam 2	BYOD before CBTC
Exam 3	BYOD before CBTC
Exam 4	BYOD before CBTC
Exam 5	CBTC before BYOD
Exam 6	BYOD before CBTC

the instructors. These confounders were partially accounted for by the inclusion of exam ordering as a factor in our analysis.

We ran an ordinary least squares (OLS) regression to determine the impact of modality (i.e. CBTC vs BYOD) on test anxiety, as shown in Equation 1.

$$\mathrm{za}_{ij} = \beta_1 \,\mathrm{Mode}_{ij} + \alpha_1 \,\mathrm{zTraitAnxiety}_i + \gamma_1 \,\mathrm{examTakenEarly}_{ij} + \epsilon_{ij}. \tag{1}$$

The terms in the regression are as follows:

- za_{ij} represents the standardized (z-scored) test anxiety reported by student i for exam j. Test anxiety is operationalized as the average of the nine Likert items from the survey. Test anxiety is then standardized on a per-exam basis.
- Mode_{ij} is an indicator variable that is 1 if student i took exam j in BYOD mode and 0 if taken in CBTC mode.
- $\mathrm{zTraitAnxiety}_i$ is the standardized (z-scored) trait anxiety of student i. We operationalize trait anxiety as the average of the Likert items on the trait anxiety survey which was administered at the beginning of the semester.
- $\mathrm{examTakenEarly}_{ij}$ represents "exam ordering." It indicates whether an exam was taken early. $\mathrm{examTakenEarly}_{ij}$ is a binary variable set to 1 if a student took their exam in the BYOD condition before most students in the CBTC. The variable is also set to 1 if a student in the CBTC took their exam before the start of the BYOD exam period. In all other cases, the binary variable has a value of zero.
- ϵ_{ij} represents an error term for student i on exam j.

This model estimates:

- β_1, which can be interpreted as how much higher students' reported test anxiety is for BYOD exams.
- α_1, which indicates how much a student's standardized test anxiety is influenced by their standardized trait anxiety.
- γ_1 represents the increase in anxiety from taking the exam early.

The results of this regression are shown in Table 2. The residuals were normally distributed, which indicates that we can make valid statistical inferences from the model. There was no

Table 2: Regression Results for Equation 1 (Test Anxiety)

Variable	Coeff.	t-stat	p-value	95% CI
β_1	0.14	1.72	0.086	$[-0.020, 0.30]$
α_1	0.47	14.50	< 0.001***	[0.41, 0.53]
γ_1	0.047	0.58	0.57	$[-0.11, 0.21]$

Note: *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

significant difference in test anxiety based on modality. Additionally, exam ordering did not have a significant impact on test anxiety. However, trait anxiety (i.e., baseline anxiety) had a statistically significant positive relationship with test anxiety. As trait anxiety increased by 1 standard deviation, state anxiety increased by 0.47 standard deviations ($p < 0.001$).

No difference in performance based on modality

We explored performance to gain a better understanding of test anxiety in the two testing modalities (CBTC vs BYOD). Test anxiety and performance are closely linked[2,3]. There was no significant difference in performance between the two modalities after controlling for exam ordering.

We ran a regression model with performance as a function of modality, trait anxiety, and exam ordering, as shown in Equation 2.

$$\text{Performance}_{ij} = \mu_j + \beta_2 \,\text{Mode}_{ij} + \alpha_2 \,\text{zTraitAnxiety}_i + \gamma_2 \,\text{examTakenEarly}_{ij}. \tag{2}$$

The terms in the model have similar meanings as those described for Equation 1. The only different terms are Performance_{ij} (the predicted score out of 100 for student i for exam j) and μ_j (the estimated mean score for exam j).

In this model, we estimate:

- μ_j, the mean score for exam j.
- β_2, which can be interpreted as how much higher students' test scores are for BYOD exams.
- α_2, which indicates how much a student's performance is influenced by their standardized trait anxiety.
- γ_2 which indicates the score advantage (or disadvantage) from taking the exam early.

Results for this model are shown in Table 3. The μ_j terms are not reported in the paper because they do not relate to the overarching research questions. The results indicate that trait anxiety and exam ordering have a statistically significant impact on students' performance. As trait anxiety increased by 1 unit, performance fell by almost 4 points ($\alpha_1 = -3.91$ specifically). This result was statistically significant at the $p < 0.001$ level. Notably, exam ordering also had a statistically significant negative relationship with performance. Those who took the exam early (examTakenEarly $= 1$) scored roughly 4 points lower on average. We believe this negative relationship exists because students who took the exam later in the testing window had the opportunity to communicate with students who took the exams early in the exam window. Such

Table 3: Regression Results for Equation 2 (Performance)

Variable	Coeff.	t-stat	p-value	95% CI
β_2	-2.07	-1.27	0.21	$[-5.27, 1.13]$
α_2	-3.91	-6.01	< 0.001***	$[-5.19, -2.64]$
γ_2	-3.66	-2.23	0.026*	$[-6.89, -0.44]$

Note: *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

communications were unauthorized, but this prohibition was virtually impossible to enforce.

Negative correlation between test anxiety and performance

Similar to prior work, we found that there was a negative correlation between performance and (state) test anxiety. In our case, Pearson's correlation coefficient for the two variables was $r = -0.37$. Higher test anxiety was associated with lower performance, and low test anxiety was associated with higher performance.

Discussion

The analysis showed that students in the CBTC and BYOD conditions have similar levels of test anxiety after accounting for when exams are taken in the exam window. Additionally, students in both conditions perform comparably. These findings were consistent with prior work that investigated the two modalities for only computer science students[6] and found no differences in either test anxiety or performance. Furthermore, we observed a negative correlation between test anxiety and performance, a finding which has recurred in the literature. The main novel takeaway from our work is that both configurations (CBTC and BYOD) appear to be equally effective methods for computer-based testing at scale, based on considerations of anxiety and performance. This expands prior work which has virtually focused on comparisons between paper-based and computer-based testing, despite the limitations of paper-based testing (e.g. grading bottlenecks and the difficulty associated with giving instant feedback for a variety of problem types on paper-based tests).

This study therefore suggests that a CBTC can indeed be an effective method for delivering assessments at scale for engineering students. Nonetheless, the initial observed differences in test anxiety and performance based on exam ordering are problematic. A CBTC may unintentionally create opportunities for academic misconduct. This reinforces the need to have more variance in questions to maintain exam integrity for asynchronous exams.

Limitations and Future Work

The work did not include freshmen engineering students. Most of the students in our study indicated that they had already taken several courses which had used a CBTC. Findings may have different if they had included students not experienced with testing in such an environment.

Additionally, our current work does not investigate the specific properties of the testing

environments that may influence anxiety. Even if there are no significant differences in test anxiety for the two modalities, certain properties of the testing setups may aggravate or mitigate anxiety. We are currently conducting qualitative research, in the form of interviews with students, to address this gap.

Finally, there may be issues with carryover effects, i.e. the effect of one treatment (e.g. test anxiety resulting from taking an exam in a CBTC) may persist into the next period. We mitigated this by having a gap between each period of measurement. We also specifically asked students to focus only on their most recent testing experiences.

Conclusion

There was no difference in students' test anxiety or performance when the testing modality was changed. The data shows that both the CBTC and BYOD setups may be appropriate for computer-based testing at scale, but further studies can strengthen this claim. Still, the CBTC has some ancillary benefits because it handles logistics associated with exam administration.

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