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Proctoring and Apps in College Algebra

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PROCTORING AND APPS IN COLLEGE ALGEBRA

DISSERTATION

A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the College of Education at the University of Kentucky

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ABSTRACT OF DISSERTATION

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The pandemic forced more instructors and students to move to online learning. For the first time, many experienced a loosening of the reigns and were forced to allow students to submit non-proctored work. Many may have questioned what students really learned in the year 2020. Many college math course competencies emphasize procedures. Now that apps can do that for students, where does that leave math instructors? Additionally, online instruction has exploded over the last decade and has challenged the teaching of college mathematics. While online instruction opens the door to access, it does beg the question of whether students complete their own work and thus whether proctoring is necessary. These thoughts were heavy on my mind as I conducted this research.

This research sought to answer questions pertaining to the use of apps and proctoring in College Algebra. These two seemed inter-related as a deeper question behind proctoring is whether students use cell phone apps to solve problems and if so, does this circumvent the purpose of the course. The review of literature demonstrated limited work on the two topics individually but appeared to be totally missing the interaction of the two.

Additionally, much of the review of literature found a theme of conceptual versus procedural assessments. This study further addressed this topic in the assessment instrument provided. This study included the analysis of fourteen common College Algebra questions across four semesters. Results showed that proctoring and apps do make a significant difference in outcomes.

KEYWORDS: Proctoring, Apps in College Algebra, Proctoring in College Algebra, Exam Design, Course Design

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DEDICATION

I would like to dedicate this work to my mother, Bernice Fern Miller Holbrook. My mom is currently 88 years young. She is a unique woman in her love for information. Her modus operandi/pattern of procedure is in her intellect. She has always had a curiosity and loves to read. One of my distant memories is that of her receiving an unassembled motor to put together as a present. She has always loved puzzles and games. No one can beat her at a game of cards. I never even really tried. I just learned to laugh and socialize during games.

That is why I dedicate this work to her. She is so very deserving of recognition in the academic world. She, as well as my father, encouraged their children to learn as way of independence in this world. They both dedicated their lives to ensuring that their children would have opportunities through education that they could not imagine. That is just what happened. All children were expected to do well in school and to go to college. Our tobacco crop earnings were dedicated to college funding, and we were all aware of this fact. We worked as a family and experienced a good time at this work in retrospect.

My mom was somewhat of a brainy kid and received some negative attention as such. She graduated high school at a young age and entered business school. I believe my mother would have been a CEO of a successful company somewhere if she had not met my father and fell in love. She married, left her job, and lived her life on the farm raising six children. She then dedicated her time to this endeavor and never looked back. She did fill her time with reading and learning. She oddly kept up with the tax code and could do taxes on the side. This I believe was to fill her need for knowing things as well as to maximize the farm life earnings and expenses. It is my interpretation that she never received the recognition that she deserved.

Therefore, I dedicate this work to my academically inclined deserving mother.

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John, my husband, encouraged me every step of the way even though there was nothing in this for him. Not even a raise at my work. He simply wanted it for me if that what I wanted. He experienced the lion's share of this journey. He experienced my tears, ramblings, and continuous questioning of "why am I doing this". Additionally, I thank my children, Derrick, Ashley, and Zachary who make my life so full and complete.

Friend Linda reminded me to pray. Friend Melissa and others walked with me countless miles, this I considered my therapy and unwinding from the process. Mia was the instigator of the idea to enter the doctoral program. We took many classes together, commuting between Ashland and Lexington. I would not have taken this journey had it not been for Mia, and I appreciate her for that.

Ashland Community and Technical College supported my endeavors. I would like to thank the Foundation as well as my college president, Larry Ferguson, for their full support of my pursuits. Additionally, my wonderful colleagues for all the encouragement. Lastly, but not least, my students who I love and make my days new and fun every day.

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CHAPTER 1. INTRODUCTION

The topic of proctored versus non-proctored assessments is not necessarily a comfortable one. The underlying question is that of whether we believe students may cheat in unsupervised environments. Teachers are heroes, dedicated to changing lives, and may prefer to focus on the positive. This research may weigh to the opposing side. Additionally, efforts may be better spent looking for strategies to improve students' engagement, retention, and success through innovative course design. This, too, is a most important topic and will be addressed in this review. The review will show that the topic of proctored exams is an important one and addresses an integral part of the teacher's role. We will view this topic through the lens of Bandura's (Bandura, 1986) Social Cognitive Theory (SCT), Usher’s Appalachian research on student’s self-efficacy in math and science (Usher et al., 2019), and more specifically on work of Burnett et al. (2016) on how it relates to academic honesty.

This study will focus on the course, College Algebra. This course meets the general education, quantitative reasoning requirement for many college programs. College Algebra is one of the most failed general education courses. About 50 percent of students do not pass College Algebra with a grade of C or above, as noted in a recent report, “Common Vision,” from the Mathematical Association of America (MAA). The report called Americans’ struggle with math the most significant barrier to finishing a degree in both STEM and non-STEM fields (Saxe & Braddy, 2015).

Additionally, College Algebra, as well as math in general, is included in the STEM pipeline. Nationally, growth in STEM jobs has been three times faster than non-STEM jobs (Langdon et al., 2011), and in the next decade, almost all of the 30 fastest-growing jobs will require some STEM skills. However, not enough students are entering STEM fields, and fewer than 40% of students who enter college intending to major in STEM actually persist to graduate with a STEM degree (ACT, 2011). "The need to prepare young students for STEM careers is urgent" (Peterson, 2017, p 28). Peterson (2017) estimated that 45,000 STEM-related jobs in Washington would go unfilled in 2017. Critical to meeting this goal is placing a higher priority on improving the undergraduate and graduate talent pool for science and engineering by improving pre-college science and mathematics education (Miller & Solberg, 2012).

Therefore, this topic addresses a critical issue for students and instructors alike. This gatekeeper course is of vital importance and can be key in determining students' pathways. This, plus the rise of online offerings, students' academic honesty, and student's self-efficacy makes for an important topic. Institutions of higher learning and instructors need to get this right to help students find a pathway to success. The online environment, as well as the face-to-face learning environment, must provide the best possible product to assist these students in their studies.

Quantitative research will seek to answer questions related to College Algebra course design by comparing proctored vs. non-proctored online College Algebra exam results. Additionally, we will look at the use of apps and the impact thereof. This study seeks to determine whether proctored exams are necessary in online College Algebra courses to maintain rigor and consistency. Algebra is known for statements from students such as, "Where will I ever use this?" and "I have never been good at math". Is it possible that some students opt for the online version to avoid math lectures and find help within their circle of friends to avoid the pain of a course they so despise? Moreover, what if none of the exams are proctored? Can we expect a struggling student that may be most desperate to obtain a particular grade to enter a program to not reach out to a friend or online app? Online math products regenerate algorithmically based math problems. Whereas this is a fabulous tool, it can lead to some unintended consequences.

The invent of online algorithmically generated math platforms, such as Pearson's MyLabsplus, Wiley's Wileyplus, and Cengage's Webassign, have provided ample resources for instructors to design high-quality courses. As always, technology comes with pros and cons. Many courses are based on course-specific readings that would prevent most cheating, but math classes are typically skill-based courses with algorithmic type of assessments. The obvious pro here is the convenience it provides educators and students alike, but less obvious may be the con. For every technological advance, there is an app or program that can aid in cheating the system. A smartphone app, Photomath, will take a picture of basically any algorithmically designed problem and answer it instantaneously.

In a study by Ladyshewsky (2015), he found when comparing proctored vs. non-proctored exams, there to be no significant difference in scores. In this study, as in many others, prevention security measures were taken such as lockdown browsers, that prevent students from surfing the web or printing the screen, asking one question per page, no backtracking, limiting the testing time, providing emphasis on academic integrity expectations, randomization of a deep test bank, and asking higher order thinking questions (Lee-Post & Hapke, 2017). While these measures provide great suggestions for all online instructors, they may not be sufficient for the specific College Algebra situation.

Websites and phone apps exist that can crack the code of these algorithmically based problems. Many of the security measures mentioned above simply do not apply to this unique situation as students using the app can receive instantaneous feedback. The alternative is to redesign the online course to reflect higher-order application problems not so easily found on the internet. Whereas higher-order thinking questions are great, they can make the class much more difficult for these students (Sun-Lin & Chiou, 2019).

Additionally, College Algebra serves to prepare students entering the Calculus sequence. Instructors may struggle to determine whether the ultimate goal of this course is to apply a few things well or acquire a vast skill set necessary to proceed to higher mathematics. As traditionally defined, College Algebra contains a long list of course competencies with a specific skill set. It can be a tough course to teach, as instructors must race the clock to meet all goals. This is the challenge; to provide the best experience to the students, producing a strong appreciation for the subject, deep understanding of at least some of the applications, and a skill set that will allow students to be successful in the Calculus series if they so desire.

The review will show that much attention has been focused on ensuring that results of online math, as well as other subjects, are comparable to traditional face to face (f2f) courses when proctoring is in place for both groups. This comparing of proctoring to proctoring, showed time and again that online can be as successful, if not more so, than traditional f2f. For example, Graham and Lazari (2018) compared College Algebra midterm and final exam results in an online and traditional section finding no significant difference in test results. The review will also show that of the many studies available comparing proctoring and non-proctoring, there are none specific to College Algebra. This lack of research brings up whether proctoring is, therefore, inferred for this course and courses similar in nature. In the quest for research on proctoring versus non-proctoring, twenty-two research articles were found and included in this review. One intermediate algebra study is included, the remainder of the disciplines being that of medical terminology, economics, psychology, statistics, business, criminal justice, computer science, and physics. Four of these studies are purely qualitative and ask students to self-report cheating, and three are of mixed design.

Is all this fuss even necessary? Do students cheat on exams? The review of the literature shows mixed results for cheating as a general topic. However, as discussed earlier, the algorithmic-based nature of College Algebra is a unique factor in online learning. Lanier (2006) found that there is evidence that the incidence of overall cheating in online classes is up to four times greater than that in traditional classes. Additional studies also found cheating to be expected and common. Students given the right opportunities would cheat (Moten et al., 2013). One out of every four-college student admitted to cheating with a smartphone during tests (Srikanth & Asmatulu, 2014). Sivula and Robson (2015) found that graduate students performed 34% better on online un-proctored exam without any security mechanisms. On the other end of the spectrum, Grijalva et al. (2006) estimated that 3% of students cheated in a single online class and that this rate is not quantitatively different than instances of cheating in a traditional classroom. Stack (2015) supported the theory that students do not cheat. Finding that once the demographics are controlled, there is no significant difference in online versus in person exams scores.

A sad, but too common, internet search will reveal companies that exist to help students cheat in online classes. Ads stating, "Without having to miss out on the fun, just outsource your test to us, an expert will take it, and you will get the awesome grade that you deserve. All at prices you will not believe. How does that sound?" (Berkley & Halfond, 2015, p.1). An additional point to consider foundational to this discussion is, "What's harder, and what's more important, than deterring and detecting cheating in online education? Certainly, designing interesting course formats that catch and hold the attention of students halfway around the world through all hours of the day and night" (Berkley & Halfond, 2015, p.1). This comment leads to a later point of instructional design. The opposing views of proctoring versus non-proctoring is complicated by the subject matter and course design, as we will see in the following sections.

Additionally, institutions may avoid the provision of proctoring services due to expense and unpopularity with students. Lee-Post and Hapke (2017) provide a thorough look at strategies to ensure academic integrity and the related expenses noting that there is significant cost involved in proctoring. Costs and ensuring security issues in proctor validation, student and instructor inconveniences, and money spent on the time and space adds up (Owens, 2015). Additionally, students state that the proctoring requirement would influence their decision in choosing an online course (Milone et al., 2017). Therefore, institutions may not wish to lose enrollment numbers due to unpopular proctoring requirements.

On the other hand, public perceptions may be of influence on this topic. A 2013 Gallup poll found that 45% of Americans thought online education provided less rigorous testing and grading that could be trusted than the traditional classroom-based counterpart (Saad et al., 2013). Therefore, the question of whether proctoring is necessary is of utmost importance. Fask et al. (2014) makes a powerful point in that the existence of student cheating on online exams should not only be viewed in the context of the moral failings of the students but should impose a moral burden on the professors and institutions to assure students, potential employers, graduate admissions departments and other consumers of grade information the grades are genuinely reflective of the learning. Therefore, as educators, it is our duty to all involved to get this right. If we can ensure academic integrity and equivalent assessment results in non-proctored environments, we should certainly lift this requirement. Otherwise, the practice may need to be encouraged and supported by institutions.

Integral to the topic of proctored exams is the idea that students may use technology outside of the proctored environment to circumvent the learning of content. This research design will fully engage the use of technology to study its impact. This research will look at the use of technology and its effect on final exam results. We will look at proctored versus non-proctored results, with and without the aid of technology. The review will show that technology has been successfully infused to the math classroom, but that technology must be merged with pedagogy for full positive impact.

The graphing calculator came on the scene to the mathematics world in the 1980s. Since then, it has been incorporated to the classroom in varying degrees. At times this technology has been a learning tool used for good, and at other times, it has been a box that students beg for answers. The former as a route to a greater understanding of mathematics. The latter as a route around the understanding of mathematics. Additionally, while the cost value ratio may be reasonable for a serious student of mathematics, those taking the one required quantitative reasoning course of College Algebra may find the $150 price tag inhibitive. With the innovation of smartphone apps, the graphing calculator has gained new and fresh attention. Students have more information than ever imagined right in front of them, and it is mostly free.

One of the smartphones apps available is a replica of the Texas Instrument TI-84 graphing calculator. This app can be downloaded for free and readily available for use in the classroom. Research shows that students typically have smartphones on them at all times and thus making this a viable option in replacing the older handheld options (Kassarnig et al., 2017). Additionally, there are many other apps available to students. This review looks to explore the technological options for college algebra and the related successes or lack thereof. Most specifically, this research seeks to discover any data related to the emergence of smartphone apps in college algebra. Many apps are available such as Mathway, Photomath, WolframAlpha, and Calculate84. Some of these apps give step by step solutions to help students learn procedures, and others only give the final answer. Are students gaining insights and achieving the desired outcomes? Are students bypassing the procedure to gain credit in online college algebra courses where assessments may not be observed or proctored?

Should an instructor even mention Photomath? Is this dangerous territory that instructors hope students do not discover? If the current trend continues, instructors must embrace the technology and design instruction to match. As long as assessment techniques require algorithmically designed outputs, the apps and the teacher may be at a standoff.
This review will demonstrate the complexity of the issue. Does the proctoring environment provide a sterile, positive environment that promotes learning and success, or one of anxiety-ridden lower results? Also, does the type of exam or discipline make a difference? This research raises many questions. This review hopes to answer at least some of these

questions. Issues such as testing environment, use of technology, test anxiety, self-efficacy, academic dishonesty, security measures, web-based proctoring, and course design are addressed. The research will show that math is best taught using real-life applications and higher-order conceptualizations. While this may be true, this idealized classroom may not be the common reality (Mesa et al., 2014).

This study will help in determining the effect of proctored exams on online College Algebra students' final exam scores. Additionally, looking at the use of apps in a proctored verses non-proctored environment. Current literature appears to be missing both of the topics individually. The intersection of these two topics creates an even greater uniqueness. This situation is certainly not unique in the real world of academics. It is what is happening currently in classrooms around our world. College Algebra competencies, online non-proctored exams, and apps have all converged and raise questions that require answers.

A two-way factorial ANOVA will help answer the following research questions:

1. In what ways does the presence or lack of a proctor significantly affect exam performance?

2. How does the treatment of the instruction of, and use of, apps affect exam performance?

3. How does the treatment of apps and proctoring interact with regard to exam performance?

CHAPTER 2. REVIEW OF LITEATURE

2.1 Framework

The study will be framed through the lens of Bandura's Social Cognitive Theory (SCT) (Bandura, 1986). Bandura's SCT attributes an important causal role to humans as agents in their own development. That is, "environmental forces are not sole determinants of human behavior; people, by virtue of their own cognitive and self-reflective capacities, are ‘partial architects’ of their life courses" (Bandura, 1997, p.8). Bandura’s theory merges behaviorism and environmentalism to include cognition in a triadic reciprocal causation relationship. Bandura’s theory interjects the mind’s cognition as a powerful element in determining one’s behavior. Personal cognition or thought, one's environment, and one's behaviors work together to create an active and continually regenerating cycle, determining one’s destiny. Some of these thought patterns may include faulty data but nonetheless affect decision making (Bandura, 1986). Students, through their actions, create as well as select environments. By constructing their own circumstances, they achieve some regularity in behavior (Bandura, 1986). Furthermore, self-referent thought mediates the relationship between knowledge and action (Bandura, 1986).

2.1.1 *Math Self-Efficacy*

“Perceived self-efficacy is defined as people's judgments of their capabilities to organize and execute courses of action required to attain designated types of performances” (Bandura, 1986, p. 391). We can think of this self-efficacy as the belief that one can succeed. Unless one believes that they can produce desired results by their actions, they have little incentive to act (Bandura et al., 1996).

Judgments of efficacy determine how much effort people will expend and how long they will persist when facing obstacles (Bandura, 1986). Students with strong perceived self-efficacy will persist more vigorously than those who judge themselves as inefficacious. Obstacles spur persons possessing a strong sense of efficacy to greater effort. Therefore, competent functioning requires both skills and self-beliefs of efficacy to use them effectively (Bandura, 1986).

Those who believe themselves to be inefficacious constrain their options and fearfully avoid activities, even though they are within their capabilities (Bandura, 1986). Faulty data may be involved in these inefficacious beliefs. Appraisal of personal capabilities and potential are not always accurate or rational (Bandura, 1986). These erroneous beliefs prompt actions causing a student to behave in ways, such as lack of belief in math abilities, that confirm the original misbelief. Success requires not only skills but also a strong self-belief in one's capabilities to master problems (Bandura, 1986).

Bandura (1986) hypothesized that beliefs about one's capabilities derive from four primary sources: 1) Direct experiences of success and failure as indicators of what they can do (and cannot) do, 2) the actions of others as vicarious evidence of their own capabilities, 3) evaluative messages from students' social environment, 4) students' interpretation of their physiological and affective arousal in ways that inform their perceived efficacy.

First, we look at self-efficacy derived from direct experiences of success and failure as indicators of what they can do (and cannot) do. For college mathematics students, it can be the successes experienced that makes one believe they are good at math. On the other hand, if one has experienced negative outcomes in math, they may not believe themselves capable of success. As defined by Usher and Pajares (2008), self-efficacy for self-regulated learning is a metacognitive process where students examine and evaluate their thought processes and discover pathways to success. In addition to knowing self-regulatory strategies, students must believe that they can apply them effectively. The environment may send a message to the student's alerting them to believe themselves inefficacious in an activity based on past experiences. An algebra student who has not experienced success may not believe themselves capable and constrain their action out of fear of failure. In Usher and Pajares' (2008) extensive review of self-efficacy research, they found mastery experiences to make up the lion's share of the four sources in developing self-efficacy, the correlations range from .29 to .67 (median r= .58). Unlike with any other source, correlations between mastery experience and self-efficacy were significant in every investigation within their review.

Second, we look at the actions of others as vicarious evidence of our own capabilities. Students compare themselves with others, mainly peers. Students want to know how their score compares with others. Vicarious information gained from others perceived to be similar in ability yields the most influential comparative information. The experiences of those perceived as having similar attributes (e.g., gender, ethnicity) often creates the most powerful source (Usher & Pajares, 2008). When a student is surrounded by peers achieving positive results, this can increase said students' self-efficacy. On the other hand, if said student is surrounded by peers who are not achieving success, this may damage efficacy.

Third, we look at evaluative messages from students' social environment. Verbal and social persuasions are powerful contributors to self-efficacy. Encouragement from teachers, parents, peers whom students trust can make a powerful difference. Effective mentors encourage individuals to measure success in terms of personal growth rather than triumphs over others (Usher & Pajares, 2008). Evaluative messages from their social environments, such as messages questioning the usefulness of a skill, such as algebra, to their real life may also weigh on a student's mind.

Fourth, we look at students' interpretation of their physiological and affective arousal in ways that inform their perceived efficacy. Ones' emotional and physiological states, such as anxiety, stress, fatigue, and mood, affect self-efficacy. Strong emotional reactions to school-related tasks can provide cues to expected success or failure. High anxiety can undermine self-efficacy. Students who experience dread when going to a particular class likely interpret this apprehension as evidence of a lack of skill in that area (Usher & Pajares, 2008). Bandura (1997) suggested that people tend to function optimally when their physiological arousal is neither too high nor too low. In general, increasing students' physical and emotional well-being and reducing negative emotional states strengthens self-efficacy (Usher & Pajares, 2008).

2.1.1.1 Math Anxiety

Math anxiety is a feeling of tension and anxiety that interferes with manipulating numbers and solving mathematical problems in a wide variety of ordinary life and academic situations (Richardson & Suinn, 1972). As related to the fourth category of primary sources for deriving self-efficacy, students who receive a physiological message such as anxiety in response to algebra may take that to mean they are unable to complete the task. On the other hand, if positive feelings have been experienced in the past, the student may receive the message to power through an activity.

The heightened arousal experienced by some in relation to math signals a potential threat and can result in negative emotions associated with the stimuli. Math anxiety can lead to avoidance of anything perceived math-related (Palestro & Jameson, 2020; Pizzie, et al, 2020). This could include avoidance of the following: math problems, math classes, careers in STEM, and entrance to higher education (Palestro & Jameson, 2020).

Math anxiety is a real problem for many students (Jamieson et al., 2016; Pizzie et al., 2020). Much research speaks to the need to reframe student's thinking by infusing course design strategies to offset the anxiety response (Jamieson et al., 2016; Palestro & Jameson, 2020; Pizzie et al., 2020). Cognitive reappraisal is one such emotion regulation strategy that has been shown to decrease negative affect and amygdala responsivity (as noted by neuroimaging of the brain) to stimuli that elicit negative emotion (Pizzie, et al., 2020). Prizzie et al. (2020) describe cognitive reappraisal as reframing a potentially emotion-eliciting situation in a way that changes the emotional impact before the emotional response has become fully activated. Research has shown that individuals with high math anxiety displayed hyperactivity in the right amygdala when exposed to math, even when they did not have to perform the calculations (Pizzie & Kraemer, 2017).

2.1.1.2 Persistence in Problem-Solving and SCT

In a mixed-method study by Cifarelli et al. (2010), interviews were conducted that provide support for the hypotheses that students exhibiting high levels of self-efficacy beliefs will be more persistent in problem-solving and will apply more complex and sophisticated strategies than students exhibiting fragile self-efficacy beliefs. This study consisted of 139 students enrolled in College Algebra and incorporated a large and diverse sample. Participants who identified as having positive attitudes about mathematics used more complex solution strategies. These participants regularly demonstrated persistence in their problem solving when difficulties arose. In contrast, participants who identified as having negative attitudes about mathematics struggled whenever difficulties arose in the course of their problem-solving.

2.1.1.3 Math Self-Efficacy and Academic Honesty

This research seeks to address the question of proctoring in College Algebra, asking whether proctoring is a main effect on the outcomes on a final exam. Finn and Frone's (2004) research connect the two concepts of SCT and proctoring by looking at math self-efficacy and academic honesty. Finn and Frone's research reveal that identification with school and academic self-efficacy were significantly and negatively related to cheating. That is, cheating was higher for students with lower levels of self-efficacy and lower levels of school identification. Cheating increased by 0.26 standard deviation for every standard deviation decrease in school identification and increased by 0.15 standard deviation for every standard deviation decrease in self-efficacy.

Additionally, cheating is inversely related to achievement; that is, cheating occurs most often among students with low achievement. Gender and age were significantly related to cheating. Specifically, male and younger students reported cheating more frequently than did female and older students, respectively. Additional results show students who were low achievers were more likely to cheat than were students who were high achievers. Cheating increased by one-third of a standard deviation for every one standard deviation decrease in performance.

In light of this finding, Finn and Frone (2004) recommend that future research needs to consider situational characteristics of the school and classroom that may facilitate or impede cheating. For example, the inverse relation between academic performance and cheating may be stronger when the classroom environment's situational characteristics make cheating less risky. An example of this would be when the threat of detection is low, as is the case in a proctored environment.

2.1.2 *Challenges Specific to the Population under Study*

2.1.2.1 Poverty in Appalachia

As defined by ARC (Appalachian Regional Commission), Central Appalachia includes West Virginia's nine southernmost counties, as well as eastern Kentucky, Virginia's southwestern tip, and parts of Tennessee. Appalachia has been compared to the Third World (Lohman, 1990) and Central Appalachia called the other America (Sarnoff, 2003). Poverty and educational disadvantages are at an extreme in Appalachia and most notably so in Central Appalachia. The college in which this study will occur is situated on the border of Central Appalachia and serves students from those counties, which are especially affected by socioeconomic inequality. In an age where college degrees are essential for determining success in life, only 9% of low-income children will obtain those degrees (Bailey & Dynarski, 2011). Poverty adversely affects education. In the schools with the most impoverished students in America, those where over 75% of the student body is eligible for free and reduced lunch, their PISA (Program for International Student Assessment) scores in reading are below every participating OECD

(Organization for Economic Co-operation and Development) country except for Mexico (Berliner, 2013). There can be no question that Central Appalachian students experience considerable obstacles to their education.

2.1.2.2 Lack of Degree Attainment in Kentucky

Spalding (2012), in writing *Overcoming Barriers to Community College Degree and Credential Attainment in Kentucky*, noted that less than a third of those who enroll in community colleges graduate within three years and that in a 2004 survey of 1600 former KCTCS students who did not earn a degree, the second most common reason given for leaving school was because of the need to work and earn money while attending class. Spalding also noted that 31 percent of adults 25-54 in Kentucky have an associate degree or higher, ranking the state fifth from the bottom on this measure and that degree attainment rates are particularly low for those who are poor, African American, Hispanic or older. Therefore, these students are in a hurry to enter the workforce and improve their situation.

2.1.2.3 SCT Related to Appalachia

In a mixed-method study of 673 students, Usher et al. (2019) relate SCT themes to rural Appalachia. Findings show that failures, setbacks, or lower grades undermined students' math and science confidence in a similar proportion that successes raise it. Qualitative and quantitative approaches led to one clear conclusion: Appalachian students pay attention to their own past experiences when judging what they can do in math and science (Usher et al., 2019). According to Usher et al., “for most students, self-efficacy in math and science is built from a complex array of efficacy-relevant experiences that occur through enactive (e.g., grades, score), vicarious (e.g., social comparison, social modeling), and social (e.g., encouragement, help, scaffolded instruction) means" (p. 47).

They also note that diverse career choices, as modeled in their environment, may be lacking in rural settings. When living in a rural or poverty-stricken area, students may not experience role models working in STEM jobs (Peterson et al., 2015). Therefore, math may seem non-important for life choices. Evidence suggests that students in rural and urban areas differ in their educational aspirations, motivation, and college-degree attainment (Byun et al., 2012) despite being just as successful (in terms of high school graduation rates and ACT scores) as youth in other (e.g., suburban) areas (Kannapel & Flory, 2017).

Kannapel and Flory (2017) further highlight SCT's connection to role models and the absence of such necessary vicarious postsecondary identifiers in rural Appalachia. Many students in middle Appalachia lack familial role models and guidance for pursuing postsecondary education because of parents' lack of experience with higher education (Kannapel & Flory, 2017).

2.1.2.4 Lack of Equitable Educational Experiences

Furthermore, students might not receive the same quality or access to learning opportunities in math and science in rural compared to urban settings. The remote location and uncompetitive salaries of rural school districts can thwart the recruitment and retention of highly qualified teachers (Peterson, 2017). Students may have access to fewer educational role models or receive mixed messages about the value of higher education from their school and in the broader community, where many jobs do not require a college education (Byun et al., 2012; Peterson et al., 2015).

It can be debilitating when students hear negative math narratives from those they see as models. In such instances, judging efficacy by social comparison is self-limiting, especially if models have verbalized these self-doubts about their abilities (Bandura, 1986).

2.1.3 *Academic Honesty*

2.1.3.1 Perceived Usefulness of Algebra

According to Bandura (1986), modeling with guided mastery is ideal for creating new skills, but these skills are unlikely to be acquired unless they prove useful in everyday life. Students may question the belief that the math they learn will be necessary to the lives they will eventually lead. As noted above, this may be especially detrimental for students in rural areas. These students may receive mixed messages about the value of higher education from their school and in the broader community, where many jobs do not require a college education (Byun et al., 2012; Peterson et al., 2015). Others may lack access to educational information converted socially or through formal or informal learning opportunities. These factors may partly explain why rural students tend to be ambivalent about formal education (Demi et al., 2010; Hardre' et al., 2009).

In a comprehensive study of rural high school students, Hardre’ et al. (2009) found that the more rural students saw the usefulness and value of what they learn in school, the more likely they are to exhibit an interest in school, put forth effort, and exhibit intentions to graduate and go on to post-secondary opportunities. Furthermore, Hardre' et al. noted that algebra might be a hard sell. This study found that these rural students demonstrated a lower motivational profile for math than any other subject area and all other areas combined. As a result, some students may blame cheating on the following: irrelevant course materials, poor instructional quality, or a lack of connection between assignments and course materials (Srikanth & Asmatulu, 2014). College Algebra may present concepts that do not demonstrate immediate usefulness to perceived surroundings. In contrast, courses such as Statistics and Applied Math may offer more opportunities to connect to real-world surroundings. College Algebra may appear disconnected from everyday life.

2.1.3.2 Reciprocal Determination

According to Bandura (1986), not only does the environment influence the mind, but so does behavior. The environment influences how a person thinks and feels, which in turn influences behavior, which impacts the environment. Each of the three factors bounce back and forth affecting one another in a continual cycle. This triadic reciprocal causation relationship theorized by Bandura (1986) is also known as reciprocal determination. This term refers to the mind's cognition in connection to one's environment as well as behaviors. These three elements continually check in with each other as one makes decisions. These experiences can occur within the four primary sources as mentioned above. One's experiences, cognition, and behaviors work together to create an active and continually regenerating cycle, determining one's destiny.

Burnett et al. (2016) conducted a study relating the themes of reciprocal determination that connects Social Cognitive Theory (Bandura, 1986) to academic honesty. The purpose was to examine the perceptions related to ethics and cheating among a representative sample of primarily female undergraduate students compared to trends reported in the literature. Social Cognitive Theory guided the development of nine scripted questions utilized in focus group sessions. The focus groups' results were organized around four main themes: demographics of those who cheat, students' perceptions of cheating, the role of technology in cheating, and the consequences of cheating, including students' attitudes and behaviors related to reporting cheating incidents. Overall, students viewed cheating as something that happens everywhere, and people that cheat frequently write it off as not being that big of a problem (Burnett et al., 2016).

Additionally, Burnett et al.'s (2016) study found that freshman students were perceived to have a greater challenge with time management skills, and their academic schedules mainly focus on general education and large lecture courses. These two factors play a role in the perceptions of why students cheat. First-year freshman and second-year students tend to rationalize their cheating more in the large lecture classes that they are not as interested in but are required to take. Parents, peers, and professors' pressure to earn high grades was another commonly mentioned reason for cheating (Burnett et al., 2016).

Reciprocal determinist, as referred to in the SCT (Bandura, 1986), may illustrate that student behaviors, and their perceptions and expectations of the environment, may revolve around the frequently mentioned issue of getting good grades. The availability of technology and the potential for a non-proctored exam present an environment conducive to cheating. When students observe that no consequences are present for behaviors, they may reason that the means justify the end. Life experiences and observations may have taught them that some unpleasant steps must be experienced to get the desired result. When there are no consequences for cheating behaviors, this can encourage them even more (Lanier, 2006). Burnett et al. (2016) study results indicate that perceptions students have of the physical or virtual academic environment have a great impact on their decisions about cheating behaviors.

2.1.3.3 Lack of Consequences

Surprisingly, despite academic concerns about cheating in online assessments, there is ample evidence to suggest that faculty often do not take aggressive action to combat student cheating in online courses (Fask et al., 2014). This lack of consequences is noted by students and fits perfectly with the aforementioned Bandura concept, "environmental forces are not sole determinants of human behavior; people, by virtue of their own cognitive and self-reflective capacities, are ‘partial architects’ of their life courses" (Bandura, 1997, p.8). A self-reflective student may note the lack of consequences and justify cheating as an acceptable behavior.

The Social Cognitive Theory (Bandura, 1986) constructs of outcome expectations along with the perceived need to cheat, namely the desire to raise course grade, is readily applied to the outcome exceptions of being a competitive candidate to enter a desired program whether it be the nursing program, radiography, pharmacy, or graduate school. The College Algebra general education course may represent an unnecessary roadblock to this success.

2.1.3.4 Intrinsic Motivation

Ideally, students would be intrinsically motivated to learn College Algebra. However, as we have seen, this course may be a hard sell. Students may not see the immediate usefulness to their chosen field. Chen et. al (2012) note that teachers cannot rely on intrinsic motivation for all learning. Gagné and Deci (2005) back up this statement in further illustrations from Self-Determination Theory (SDT).

Gagné and Deci (2005) in studying SDT note that intrinsically motivated behavior is propelled by people's interest in the activity itself. Though the research focus here is related to the work world, it may readily apply to the classroom. Gagne' and Deci point out that activities that are not interesting, those that are not intrinsically motivating, require extrinsic motivation. When externally regulated, people act with the intention of obtaining a desired consequence or avoiding an undesired one, so they are energized into action only when the action is instrumental to those ends. Gagne' and Deci use the analogy of the work-place in their example of stating that one may work harder when the boss is watching. Here we can apply the same concept to, one may prepare and better perform when they know a proctor will be watching.

Additionally, Gagné and Deci (2005) explain that many of the tasks that must be completed in a work-day are not inherently interesting or enjoyable. The same may be said of the classroom, not every task that a student must complete will be inherently interesting or enjoyable. This review does not propose that math is uninteresting, as that is certainly not the case. Nevertheless, it may be seen as so by many students (Hardre' et al., 2009). When the subject is not perceived as useful nor enjoyable, and technology is available to circumvent, SCT makes a strong case for academic dishonesty as a natural consequence.

2.1.4 *Conclusion*

The research supporting Social Cognitive Theory (Bandura, 1986) was clear that students need access to role models, as well as encouragement fostered by incremental successes and application of math to their perceived real-world (Bandura et al., 1996; Byun et al., 2012; Peterson et al., 2015; Usher et al., 2019). Our school system provides a powerful tool for these opportunities. Haimorvitz and Dweck (2017) encourage teachers by noting they possess this power to make change and that teachers can help reframe challenges.

Encouraging strategies via course design and intervention measures were offered to increase math self-efficacy. Regardless, much research spoke to the connection between self-efficacy and academic honesty. The question was raised as to whether students will engage with College Algebra content if there is no accountability. Can one expect a student who struggles with math self-efficacy and sees no use of the subject to engage in content when tools are available to circumvent the need to learn College Algebra competencies? This research asks the question; “Is proctoring necessary?”. Does proctoring create an environment that encourages students to persevere towards the course goals?

In this framework, SCT explains why some cheating behaviors may be present in the classroom. This research should not be taken as a commentary on students' moral failings but as a natural consequence of human behavior as explained within the SCT framework. This research seeks to determine whether proctoring and apps affect final exam scores. Even though this study does not propose to engage in course design, much research points to the fact that course design is important to self-efficacy. This research encourages teachers to provide a course design that will address the issues raised. This research challenges teachers to understand the students they serve and provide supports that maximize their success.

This review reveals a potential crisis in connecting the lack of self-efficacy, math anxiety, and reciprocal determination that may prevent students from engaging in content. This review notes factors affecting the population under study that explains potential academic dishonesty. With tools available to circumvent a course that may not be seen as relevant to their chosen field, students may miss the intended course purpose. Is oversight required for at least one assessment along the journey? This review reveals an important question about whether students will engage in the algebra content if not monitored. Thus, the question of proctoring is of great importance.

2.2 Proctoring

A non-proctored exam may be equated to a take-home exam. Bengtsson (2019) work looks at this subject in higher education. Bengtsson concludes that take-home exams may be the preferred choice of assessment method on the higher taxonomy levels because they promote higher-order thinking skills and allow time for reflection.

Bengtsson cautions that take-home exams are not recommended for students on Bloom's (1956) lowest taxonomy level. This research speaks to an underlying issue in this proposed study. A conceptualized, higher-order thinking exam may alleviate the problem of proctoring but create a problem-solving dilemma for those who struggle most with the subject. As noted by Cifarelli et al. (2010), problem-solving is the area of most concern for those who lack self-efficacy. Additionally, many of the competencies for College Algebra ask students to solve procedural problems. One such College Algebra competency asked students to solve linear, quadratic, exponential, and logarithmic equations. Additionally, students are asked to graph such equations. These operations present no small feat for students, even though one may consider these lower-level taxonomy content. These procedural problems present complicated processes.

Additionally, these lower-level problems may be solvable with an app. This conundrum leaves the instructor wondering how much of the exam should be conceptualized to higher-order questions and how much should address the lower-level competencies that may require proctoring.

2.2.1 *Academic Dishonesty*

2.2.1.1 Online versus f2f Cheating

While plagiarism has been the focus of many online programs, there has been much less attention paid to other problems related to dishonesty in online assessment (Rowe, 2004). It should be noted that writing-intensive fields do express concerns of cheating in their utilization of plagiarism software (Rowe, 2004). Lanier (2006) found cheating to be much more prevalent in online classes compared to traditional lecture courses. In studying 1262 criminal justice and legal studies students, Rowe noted the following: nearly 80% of the students never cheat in lecture classes, 41.1% admitted to cheating in an online class, males cheat more often than females, students having a 2.0 were most likely to cheat, single students cheat more often than married students, nearly 40% admit to helping others with online exams. Additional studies also found cheating to be expected and common and that students given the right opportunities would cheat (Moten et al., 2013). One out of every four college students admitted to cheating with a smartphone during tests (Srikanth & Asmatulu, 2014). Wachenheim (2009) found that students in an online class taking a non-proctored final exam online scored more than one full letter grade higher than those taking the proctored final. Surprisingly, Srikanth and Asmatulu (2014) noted that of those who cheat, almost 25% do not even realize what they are doing is considered a form of academic dishonesty.

2.2.1.2 Online Students not clear on what Constitutes Cheating

What an instructor considers cheating may not be the same as what a student considers cheating (Burgason et al., 2019: Srikanth & Asmatulu, 2014). Ladyshewsky (2015) noted that what constitutes cheating may be changing. Conventional views of cheating in universities may not be keeping up with the digital era of learning, which involves greater and greater use of open-source collaboration and ready sharing of ideas, knowledge, and information (Harkins & Kubik, 2010).

Cole et al. (2014) indicated that some students felt that the nature of online courses implied consent to share collaboration and access resources. Additionally, 27% of these students surveyed stated that googling or accessing resources during online testing was considered appropriate. Burgason et al. (2019) further demonstrate that students are not clear on what constitutes cheating in online classes. In a qualitative study of criminal justice students, 46% of face-to-face students stated that using existing notes or PowerPoints during an online test was not cheating at all or trivial cheating compared to 71% of the distance education students (Burgason et al., 2019). The data revealed that collaboration is understood quite differently between the two groups. Only 61% of face-to-face students believed collaboration is moderate or serious cheating compared to 94% of the distance education students (Burgason et al., 2019). These findings suggest that online students view academic integrity differently than do their instructors and the university. Additionally, this study is unique in that it examined cheating behaviors by career professionals taking courses entirely online.

The literature review is clear that instructors need to make an effort to provide clear expectations, spell out precisely what is considered cheating, and state the related consequences. For example, Moten et al. (2013) noted that since some students do not read the academy honesty policies, there should be a requirement to click a confirmation button before entering the online course room. Prior studies have shown that having a clearly articulated policy against cheating decreases the behavior (Moten et al., 2013).

2.2.1.3 Instructor's Response to Suspected Cheating

Instructor's may be lax in their enforcement of academic honesty policies. Rogers' (2006) work supports this hypothesis as he found that faculty members using online tests were concerned about cheating but were not proactively implementing measures to combat the behavior. In addition, faculty members did not devote time to communicate to students the importance of academic integrity and what behaviors constitute cheating. Burrus et al. (2007) found that students who believed punishment for cheating at an institution would be less severe were more likely to cheat.

This situation ties in with our SCT framework. We can see that students and professors are not on the same page with expectations. Furthermore, if instructors nor institutions enforce policy, students may be naturally inclined to act in their own best interests. Shuey (2002) suggested that institutions should insist that persons taking distance education or online courses need to take exams on campus in a proctored setting. However, Shuey (2002) also noted that this method is inconvenient and sometimes infeasible, as well as contradictory to the primary rationale for taking online courses.

Owens (2015) conducted a qualitative study comparing cheating behavior in proctored and non-proctored environments. Owens (2015) based her findings on the cost-benefit ratio framework for her research. Hutton (2006) suggested that college students cheat because the cost-benefit ratio slanted in favor of cheating. In particular, taking non-proctored, online exams lowers a student's chance of being caught cheating, with the ultimate payoff for cheating frequently resulting in higher grades. This framework is somewhat similar to Burnett et al. (2016) study relating the themes of reciprocal determination to academic cheating. Coalter et al. (2007) found that 57.5% of faculty reported not taking any action when they suspected dishonesty, with 82.9% indicating a lack of evidence as a primary reason for not pursuing these incidences. Rogers (2006) found that 52% of faculty surveyed stated that they were concerned about cheating in online exams, yet 82% gave online exams for face-to-face courses through non-proctored environments. Cluskey et al. (2011) note that instructors often proctor one high stakes exam, typically the final exam, per course as a good faith effort to ensure academic integrity. Rowe (2004) suggests that all major assessments should be proctored. Miller and Young-Jones (2012) found that cheating occurred more frequently in online courses but noted that students who took only online courses, instead of a mixture, cheated less than those taking online and face-to-face mixture.

2.2.1.4 Students May not Cheat in Online Classes

On the other end of the spectrum, Grijalva et al. (2006) estimated that 3% of students cheated in a single online class and that this rate is not quantitatively different than instances of cheating in a traditional classroom. Other sources supported the theory that students do not cheat at any higher rates online (Harmon & Lambrinos, 2006; Hayes & Embretson, 2013; Ladyshewsky, 2015). Grijalva et al. speculated that cheating might occur due to panic during an exam. Because the online setting is less conducive to panic cheating- there are simply fewer or no opportunities for panic cheating- it is conceivable that panic cheating is limited to traditional class testing situations (Grijalva et al., 2006).

Additionally, Hayes and Embertson (2013) suggest that proctored scores are better due to the sterile environment provided. Non-proctored environments have greater noise levels, temperature, light, and cognitive distractions compared to standardized proctored settings (Hayes & Embertson, 2013). Fask et al. (2014) believe that the pluses and minuses of non-proctored exams may cancel each other out. The plus of inflated grades and the minus of lack of controlled environment may explain some studies showing no difference in exam outcomes.

2.2.2 *Proctored versus Non-proctored Findings*

2.2.2.1 Pro-proctoring

INTERMEDIATE ALGEBRA. In an argument for proctoring, Flesch and Ostler (2010) noted that institutions must attest to the value of the products they offer. Furthermore, they stress that courses transfer to many four-year institutions and are prerequisites to many specialized programs such as nursing. We need to be confident that we are assigning grades that genuinely reflect students' learning (Flesch & Ostler, 2010). In line with this thinking, Flesch and Ostler studied the effect of proctored versus non-proctored tests in an online intermediate algebra course. Using four sections of students enrolled in the online course offering of Intermediate Algebra, students were randomly assigned to the proctoring versus non-proctoring groups. Group one took two tests and one final exam in a proctored setting with no books nor notes; additionally, they took three non-proctored tests. Group two took five non-proctored tests as well as a proctored final exam. Results showed that proctoring affected the learning outcomes. The main finding was that students working at home with all their resources available did significantly better than students who had to take at least two proctored exams. Non-proctoring inflated their overall average and assigned a significant number of students with a grade of C, or better, who would have otherwise earned no better than a D (Flesch & Ostler, 2010). This study confirms that there is a benefit to the proctored testing model in producing learning outcomes and final grades that are consistent. Flesh and Oster believe that for the immediate future, proctoring is needed in math and fact-based courses. Additionally, Flesch and Ostler noted that accurate assessment methods help to ensure the survival of educational institutions.

ECONOMICS. In studying a school of economics, Arnold (2016) agrees that the non-proctored online test environment may be more conducive to cheating. Wachenheim (2009) agrees. In studying final exam scores in introductory economics courses, Wachenheim (2009) found students in an online class taking a non-proctored final exam online scored more than one full letter grade higher than those taking the proctored final. Recommendations based on this study are to continue to tell students early and often and in a variety of ways that the course may be time-consuming relative to their expectations, regularly engage students in the class, retain the proctored final exam and continue to announce this early, often, and broadly. Hence, students are ever conscious that they will be responsible for the material in an unaided environment. Instructors need to ensure computer exam questions concentrate on application and train students early to read, understand, and practice (Wachenheim, 2009). Even if using security measures, as we will discuss in another section, instructors may find that the birthday fallacy is active and that test bank questions are more similar than they may think (Wachenheim, 2009). The birthday fallacy is that of believing Ones' birthday is unique and unlikely to be replicated within a small group. It may surprise one to know that mathematically, even in a group of 23, there is a 50% chance that two people will share the same birthday.

Psychology. In another pro-proctoring study, Daffin and Jones (2018) compared student performance on proctored and non-proctored exams in online psychology courses. They found that in a sample of 1700 students, 10-20% performed better and took about twice as long on non-proctored versus proctored exams. The twice as long results lead them to believe that students may have spent this time opening up browsers, reading textbooks, phoning a friend, and so forth (Daffin & Jones, 2018). Another explanation could be related to test anxiety, or possibly the students were in a relaxed environment and made use of the extra time. However, Daffin and Jones noted, if the students were as prepared as the in-person counterparts, the timing should have been comparable. Studies have shown that students achieve comparable results online and in-person when both tests are proctored (Graham & Lazari, 2018; Lorenzetti, 2006; Stack, 2015).

Medical Terminology. Alessio et al. (2017) examined the effect of proctoring on medical terminology exams. On average, students scored 17 points lower and spent significantly less time on online tests that used proctoring software versus non-proctored tests. Average test scores for proctored tests were 74.3% compared to 89.4% on non-proctored tests. Students took approximately half the amount of time taking proctored tests even though a lockdown browser was in place with no video monitor. These results infer that the lockdown browser was not sufficient to control cheating. This result confirms the earlier finding that proctoring may be needed in math and fact-based courses (Flesch & Ostler, 2010). These courses can be unique in that competencies are such that learner outcomes require students to use an algorithm to find one final numerical answer

(Carstairs & Myors, 2009). These algorithmic problems are often searchable on the internet or can be computed with an App.

Non-conceptualized Exam Questions. Carstairs and Myors (2009) looked at results from a fifty-five multiple-choice question exam consisting of knowledge-based/cognitive items. When comparing proctored versus non-proctored results, they found impactful differences occurred due to the questions being of lower order thinking type. These non-conceptualized questions lead to lower exam security (Ladyshewsky, 2015). In 1956, with collaborators, Benjamin Bloom published a framework for categorizing educational goals familiarly known as Bloom's Taxonomy; this framework has been applied by generations of K-12 teachers and college instructors in their teaching. The framework elaborated by Bloom and his collaborators consisted of six major categories: knowledge, comprehension, application, analysis, synthesis, and evaluation. The categories after knowledge were presented as skills and abilities, with the understanding that knowledge was the necessary precondition for putting these skills and abilities into practice. While each category contained subcategories, all lying along a continuum from simple to complex and concrete to abstract, the taxonomy is popularly remembered according to the six main categories (Mcdaniel, 2020).

Accounting. Goedl and Malla (2020) provide another strong piece of evidence that proctoring matters. In eight well-controlled accounting exam comparisons, each of the exams demonstrated an inflated non-proctored result. Additionally, longer testing times were observed in each of the experiments for those unsupervised. The most profound finding in this study was that, of course grades. In course one, there were 28% more A grades for those non-proctored (63% compared to 35%). Additionally, 21%

fewer F grades were assigned in the non-proctored environment (27% compared to 7%). Thus, making the point that the extremes are most impacted by proctoring. For course two, there were 24% more A grades for those non-proctored (36% compared to 12%). Additionally, 31% less F grades were assigned in the non-proctored environment (50% compared to 19%).

ENGINEERING. Ardid et al. (2015) found a significant difference in engineering students' test results in the proctored environment. In studying three groups, 117 training homework, 217 proctored exams, and 159 non-proctored, they found noticeable differences between assessments in proctored and non-proctored environments. Furthermore, Ardid et al.'s study demonstrated that the online exams' weight did not affect the student's performance and marks.

MARKETING. Reisenwitz (2020) investigated the differences between non-proctored and proctored online exam scores. Exam scores of marketing students in the same class from two consecutive semesters were compared. Exam averages were compared to assess if there were significant differences between the two sections, controlling for student GPA. Results support the necessity for proctored exams. However, Reisenwitz noted possible limitations of this research. First, students in the proctored section may have scored lower exam scores due to an increase of anxiety of knowing that they were being proctored versus the minimization or elimination of cheating due to proctoring. Second, there may have been other variables for which controls were needed.

2.2.2.2 Cheating on Tests: How to Do It, Detect It, Prevent It

Civek (1999) details all one could want to know about academic cheating in his book *Cheating on Tests: How to Do It, Detect It, and Prevent It*. Of most interest to our purpose here, chapter nine outlines prevention measures and speaks highly of proctoring. Not only does this writing emphasize the effectiveness of conscientious proctoring in providing an atmosphere that deters the behavior, but also makes the point that it conveys to the student an expectation that academic integrity is highly valued. Chivek recommends that the test giver remain attentive during the testing by actually observing students, staying in and walking around the room, and keeping an eye out for behaviors that would arouse suspicion. The teacher should additionally announce that he or she will be circulating and will be available to answer questions about test directions, ambiguous test questions, and so on. This practice can ease student anxiety in knowing that the teacher is engaged and available. On the other hand, Chivek notes that it is possible for a proctor to be "excessively vigilant," creating an environment of suspicion, mistrust, and anxiety for test-takers. Chivek recommends that proctoring be approached in a nonthreatening way, as a normal part of the learning environment as proctoring should be a natural part of the overall classroom environment a teacher creates.

2.2.2.3 Does Proctoring Support Learning?

Some propose that the presence of and emphasis on proctoring facilitates learning (Goedl & Malla, 2020; Lanier, 2006; Lorenzetti, 2006). Lorenzetti (2006) compared 120 pharmacy students taking Medical Terminology as part of their program. The mastery of the subject matter came from the group that studied online and took proctored quizzes—suggesting that the knowledge that assessments would be proctored somehow encouraged them to undertake their course study more effectively. The researcher concluded that the course content's online delivery was as effective as f2f delivery when paired with proctored testing. Proctored testing proved to be a better facilitator of learning (Lorenzetti, 2006).

Additionally, Lorenzetti (2006) showed that students expecting a proctored quiz increase their use of practice quizzes almost twice as frequently as students in a non-proctored quiz. This type of thinking is born of the concept that students who believe they are expected to produce independent results will rise to the challenge and be more on point throughout the course. This thinking suggests that students feel encouraged to study harder and learn more if they know a proctored exam is part of the course. As a result of the proctored exams, these students may take the learning of course materials more seriously (Lorenzetti, 2006).

Online learning, in general, may increase learning regardless of proctoring. Hannay and Newvine (2006) found that over 90% of online students in a criminal justice class reported that they had read the required text compared to less than 60% of their classroom counterparts who apparently were waiting on their instructors to feed the information to them. Overall, the authors found that students in their sample earned higher grades, believed they learned more, thought exams were easier, spent more time on classes, found the text more useful, and perceived classes to be of higher quality. Also, they saw classes as harder in the online learning environment.

2.2.2.4 No Significant Difference

SECURITY MEASURES/BLOOMS. Gold (2013) infused Bloom's Taxonomy (Mcdaniel, 2020) in researching proctored versus non-proctored test results. The University in study had implemented required interventions such as including 30% essay questions in undergraduate courses. Intervention seemed to work to make outcomes equivalent in proctored vs. non-proctored settings. The results of an analysis of over 100 online courses and 1800 students indicated that it is possible to establish processes and procedures that allow students' results on their final exam to be comparable irrespective of whether the final exam is proctored or is a fully online examination (Gold, 2013). All final exams included a wide range of questions, covering both lower and higher-level cognitive skills defined in Bloom's taxonomy (Mcdaniel, 2020).

Demographics Matter. In an interesting twist, Dendir (2019) compared the exam results of students enrolled in an economics class. This study included 72 proctored f2f and 128 non-proctored online results. Initial findings showed inflated exam scores for the non-proctored online students. This mixed design study also analyzed a great deal of demographic information. Upon further review, considering the demographics, online non-proctored students underperformed (Dendir, 2019). Findings suggest that the non-proctored inflated exam scores were due to the self-selection bias of students who sign up for online classes that makes them appear to have a higher level of success on exams. Some studies show that the non-proctored online students have better results because they self-select to take online classes and therefore may be better students (Allen & Seaman, 2013; Salvo et al., 2017).

Reisenwitz (2020) raises a concern in that as more instructors conclude that proctored exams are necessary for their online classes, the surge in popularity for online classes may plateau or even decline as a result. Students may be attracted to online classes because of the increased opportunity for academic dishonesty in instructors who do not proctor their exams. It will be interesting for future research to note how this dynamic plays out.

In general, most of the review supported the belief that exam scores are inflated in the non-proctored environment, and that non-proctored tests should be considered open-book, open–resource testing (Allessio et al., 2017; Ardid et al., 2015; Arnold, 2016; Carstairs & Myors, 2009; Daffin & Jones, 2018; Goedl & Malla, 2020; Flesh & Ostler, 2010; Michael & Williams, 2013; Moten et al., 2013; Staats et al., 2009; Trenholm, 2007; Wachenheim, 2009). Regardless, there are opposing findings (Dendir, 2019; Feinman, 2018; Gold, 2013; Grijalva et al., 2006; Harman & Lambrinos, 2006; Ladyshewsky, 2015). Some opposing findings rely on the use of security mechanisms and course design as interventions to create equivalent results regardless of the environment. Therefore, this review will additionally look at security measures and course design.

2.2.3 *Security Measures*

In analyzing online integrity approaches, Lee-Post and Hapke (2017) posit that the knowledge of academic integrity will compel an individual to act accordingly. Therefore, prevention strategies should be firmly in place in the course design. Feinman (2018) presents one such finding on cheating through that of security mechanisms. This study supports the idea that measures such as synchronous testing, restricted time, randomization, one question per page, blocked backtracking, deferred feedback, and higher-order thinking test items can eliminate the need for proctored exams.

2.2.3.1 Bloom's Taxonomy in Statistics Class

Cressey (1953) identified three major factors needed to commit fraud: opportunity, need, and rationalization. These factors can be partially eliminated with security mechanisms in place. In his study of introductory statistics courses, Feinman (2018) worked with instructors to align each exam item with needed cognitive processes.

Feinman noted that instructors used a revised Bloom's taxonomy and a more detailed taxonomy classification done by Darwazeh and Branch (2015) to create higher-order thinking questions. It was found that in all the groups, none of the statistical tests revealed significantly higher scores on non-proctored exams. Thus, on average, the student's scores were either equivalent or lower on the non-proctored exams. These students took the test in a proctored environment and again in a non-proctored environment or vice versa. The majority of the students, regardless of the course delivery mode, had a score difference less than or equal to 5% or performed better on the proctored exams. This result suggests that the combination of the security mechanisms was effective.

2.2.3.2 Multiple Security Measures in Post-Graduate Class

Ladyshewsky (2015) gave post-graduate business assessments with short-case scenarios, including four options that required students to demonstrate critical thinking. These online students had security measures in place, such as no backtracking and a lockdown browser. This research found no significant difference in test results for online/non-proctored versus face-to-face/proctored. Ladyshewsky's work adds to our previous list of security measures to prevent online cheating. This study suggests using a lockdown browser that prevents printing and other capture devices, copying and pasting, screen sharing, and right-click options. Additionally, Ladyshewsky suggests including institutional statements and guidelines describing academic integrity and the consequences of cheating, assigning online assessments worth 25% as opposed to 50% for less high stakes testing, using a large pool of questions that are randomly drawn, and randomizing the order of questions to avoid collusion.

2.2.3.3 Study of Current Security Measures Practices

Michael and Williams (2013) conducted a literature review of current practices to discourage cheating in online courses. Their work focused on academic integrity, plagiarism, and other cheating issues. They believe that cheating is expected, and proctoring is the only sure way to prevent it. Additionally, Michael and Williams note that in quantitative fields such as finance and accounting, it is common to rely on high-stakes assessments of skills at some basic level. Regardless, based on their findings, they offer a list of strategies that may be used when proctoring is not feasible. They repeat many of the practices as mentioned above and add the following to our growing list; software control of the environment such as Respondus, algorithmic test banks, adding a syllabus quiz, scaffolding, tying the assignments to the class experience, prosecuting those who are caught cheating, giving students enough resources such as reviews, so they are not tempted to cheat, and building confidence throughout the semester.

2.2.3.4 Institution-Wide Implementation

Gold (2013), in a study of 1800 college wide exams, determined no significant difference in proctored versus non-proctored when security measures were in place. In what may be considered a progressive action, the university implemented the following guidelines for all testing: the length of the exam must be at most 3 hours and set to automatically closed after the allotted time, each exam had to include a number of both objective and essay questions, undergraduate exams must include a minimum of 30% essay and graduate no more than 20% objective, each exam must be peer-reviewed to ensure that final exams assessed the mastery course objectives. Instructors were encouraged to include questions that addressed each level of Bloom's taxonomy (Mcdaniel, 2020).

2.2.3.5 Additional Strategies

Burgason et al. (2019), as a result of their study, recommends proctored exams as the most secure measure but adds to our list of strategies in that of requiring frequent brief and time-intensive exams, assigning writing based and collaborative assignments, incorporating case studies, creating online debates, and repeating academic expectation of honesty throughout the semester.

Lanier (2006) uses an innovative strategy to deter cheating in that students are rewarded for reporting students who cheat, and those who are found guilty receive a zero. He says he rarely has to make good on the strategy, but it does appear to prevent the need. Additionally, he utilized a discussion board topic on the review of ethics, plagiarism, and cheating to serve as information and as a deterrent.

McCabe et al. (2001) found that honor codes were correlated with lower rates of cheating. Gurung et al. (2012) found that honor codes containing formal language and direct statements of consequences of academic misconduct were perceived by students as promoting less cheating.

In what may be considered a security measure, Arnold (2016) says that you can detect a rhythm to cheating behaviors in proctored versus non-proctored environments. In a study of 400 first-time freshman students enrolled in economics, he looked at their exam scores' rhythm. For example, in non-proctored environments, some students were found to have extremely high scores on formative assessments with extremely low scores on summative assessments; there were no such rhythms found in proctored environments.

This strategy can be employed by those who worry about proctored versus non-proctored testing discrepancies by bringing these students in for further examination. Questions remain. Did students do better on the formative assessment due to lack of anxiety and time to complete the work effectively? Do students lose their knowledge due to test anxiety when placed in a proctored environment? All of these answers seem to be maybe and appear to depend on the individual.

Nevertheless, are security measures enough to ensure exam security in highly algorithmic math courses? Trenholm (2007) is not buying it as he states in his study,” At this time, in math e-learning, it appears only some form of significant proctored summative assessment instrument will ensure that educational standards and integrity are preserved” (Trenholm, 2007, p.53).

2.2.4 *Web-based Proctoring*

An emerging technology is proctoring via computer software, for example, Proctorio, ProctorCam, Examity, and ProctorU. Studies such as Milone et al. (2015) and Woldeab and Brothen (2019) compare exam scores obtained f2f to those utilizing one’s computer proctoring via this technology. With such technologies, students may be required to purchase a device to install on a computer. Additionally, software is available to analyze students’ eye movements and the like to detect what one may consider cheating behaviors. After completing the exam, a report is sent to the instructor, and at that time, they can review footage and decide as to whether to allow the exam result. Lee-Post and Hapke (2017) express a concern that such technology may give too much sensitive information. In their review of options, such as computer software and biometrics (fingerprints, face, iris, voice, signature, and keystroke), Lee-Post and Hapke provide a detailed table of security measure options and related cost-effectiveness.

2.2.4.1 Comparing Web-based Proctoring to f2f Proctoring

NO DIFFERENCE FOUND. Hylton et al. (2016) studied the effectiveness of webcam-based proctoring to deter misconduct in online exams. A web-based proctor monitored one group while the other was not monitored. The results indicated no statistically significant difference between the two groups' scores, although the non-proctored group had slightly higher scores. There was a statistically significant difference found on the time taken to complete the online exams where the proctored group used significantly less time to complete their exams. The results of a post-experiment survey indicated that those who were not proctored perceived to have experienced greater levels of opportunity.

Lee (2020) hypothesized that there is a mean difference of test scores between online proctored, such as ProctorU and offline proctored, f2f, and was hoping to validate that the more comfortable at home setting would lead to higher scores. Lee found that students scored similarly on proctored exams, whether in person or at home, via a webcam. In studying 1762 Master's degree students on a combination of multiple-choice, true-false, and open-ended questions on a final exam counting as 30-40% of their final grade online proctored exam scores were not significantly different.

QUALITATIVE STUDY OF STUDENT'S EXPERIENCES WITH PROCTORU. Milone et al. (2015) speaks to the impact of proctored online exams on students' educational experience. Many instructors may feel compelled to utilize multiple choice exams with high enrollments, reducing and making manageable workloads (Milone et al., 2015).

Multiple-choice exams offer standardized responses but may increase the possibility of cheating (Milone et al., 2015). In this study, students had the option of testing in person or using ProctorU. Seventy-nine percent of the students used ProctorU for a total of 501 exams taken. After each exam, students were directed to take a post-exam survey. This process led to a gold mine of interesting qualitative data. Milone et al. summarized the results with the following themes emerging; proctoring helps students learn the material, proctoring helps prevent cheating, and proctoring is not necessary at this level.

Additionally, 70.43% stated that the use of proctoring reduces cheating and is fairer by keeping all students on a level playing field. Forty-four percent said that the use of proctoring makes the course a more legitimate learning experience. Regardless of students' praising of proctoring's benefits, only 13.98% said they would choose a course that used proctoring over one that did not. Results demonstrated that online proctoring does influence the educational experience in ways that must be considered when determining the balance of proctored and non-proctored assessments.

Highly Anxious Students and ProctorU. Woldeab and Brothen (2019) compared testing center proctoring to online proctoring. They believe that the negative effects of online proctoring may generally be hidden. In what could be seen as a surprising finding, anxious students were more anxious utilizing online proctoring such as ProctorU. In comparing f2f proctoring to online proctoring, of 631 undergraduate students taking introductory psychology, students testing conditions compared ProctorU to an in-person testing center with peers. For those highly anxious students, ProctorU had a significant impact on the outcomes. A total of 44 of these students took their final exam monitored by ProctorU and served as the experimental group. The remaining 587 took their exams in the computerized testing center and thus served as the control group. Woldeab and Brothen assessed their scores on five variables relevant to their studies: Westside Anxiety scale, final exam performance, ACT scores, GPA, and total credits completed. This study showed that high trait test anxiety results in lower exam scores and that this is especially true for those students with high test anxiety taking exams in an online proctored setting.

2.2.5 *Proctored Scores May Be Better Due to the Sterile Environment Provided*

2.2.5.1 Pluses and Minuses May Equal Each Other Out

Fask et al. (2014) believe that the pluses and minuses of non-proctored exams may cancel each other out. The plus of inflated grades and the minus of lack of controlled environment may explain some studies showing no difference in exam outcomes. Fask et al.'s study sought to determine whether the cheating or the environment makes the difference. Fask et al. studied two identical elementary statistics classes. These students were not aware of the study and were randomly assigned to proctored versus non-proctored final exam settings near the course's end. They had all attended face-to-face and had received equivalent educational experiences. The online non-proctored class scored 10.13 percentage points higher on the final exam than the in-class group.

Additionally, students taking the practice exam online performed an average of just over 14 points lower than the students taking the exam in a proctored environment. This finding evidenced that the difference in the testing environment created a disadvantage to students taking the online exam, which somewhat offset the advantage that the non-proctored students gained from greater opportunities to cheat.

2.2.5.2 Most Notably in Math

Hayes and Embertson (2013) conducted a study with science, and engineering students enrolled in a psychology course to determine the impact of environmental and cognitive distractions and personality on performance on computerized, mathematical problem-solving tests. According to Hayes and Embertson (2013), proctored scores are better due to the sterile environment provided. Non-proctored environments have greater levels of noise, temperature, light, and cognitive distractions in comparison to standardized proctored settings. Additionally, Hayes and Embertson suggests this finding is particularly true for mathematics. They propose that solving mathematical reasoning problems requires extensive cognitive demands, which suggests a greater susceptibility to the negative effects of distraction on outcomes. Additionally, they noted that highly distractible and anxious students do better in a standardized, controlled classroom than left to their own environment.

2.2.5.3 More Variability in Non-Proctored

Hollister and Berenson (2009) have much to say about the environment in their study of computer science students' exam results. In comparing f2f proctoring to non-proctoring, they found that there is no significant difference in central tendency of performance when controlling for GPA. The study did reveal that the group taking the exams in the non-proctored environment did have more variation in their performance results. They believe that familiarity with an environment creates potential differences in variability of performance. Explaining that typically, students are used to a more structured learning and testing environment, and this familiar environment for f2f students may have impacted their overall course buy in and potentially resulted in greater performance variability in the non-proctored group. Additionally, Hollister and Berenson

(2009) noted that these findings might not be applicable to all forms of assessments. These exams were hands-on, activity-based exams where students were asked to perform in a simulated computer environment.

2.2.6 *Summary of Proctoring and Security Measures*

In the review of proctored versus non-proctored exams, variability has been demonstrated. Extreme high and low exam results evidence that the non-proctored environment may have aided some but been detrimental to others. Studies that only look at the overall mean scores of exams may find there to be no difference.

In general, the literature tends to support the idea that non-proctored exams will inflate grades. The big "if" in this discussion is if the exams use higher-order exam questions, the results may be equivalent in online and f2f exams. Ladyshewdky (2015) suggests that lower-order thinking questions may depress the exams' security, whereas higher-order thinking items may increase the security of exams. Research supports the idea that higher-order/application problems are difficult for students (Cook, 2006; Sun-Lin & Chiou, 2019). So, the question remains, for College Algebra, is it better to redesign a course that may be more difficult, or is it preferable to assess the students with algorithmically designed items via proctoring?

The review of the literature demonstrates that this topic is complicated. The research was mixed on whether students cheat. In general, it seemed that non-proctored, algorithmically-created, textbook-publisher exams lead to cheating. Cressey (1953) identified three major factors needed to commit fraud: opportunity, need, and rationalization. The non-proctored, algorithmically-created, textbook-publisher exams provide this perfect environment.

An additional complication to this topic is the fact that online students may vary from traditional in-person students. Online students typically self-select to an online course. Salvo et al. (2017) noted that in general, college students who enrolled and completed online courses were older students with higher enrollment status and superior academic performance, were more autonomous and self-regulated, and had future career aspirations. Also, of note, is that online education may not have achieved equality. Students living in rural areas and of lower socioeconomic status often do not have access to quality internet connection nor computers. So, it is challenging to analyze the results of populations that are not random and representative of the entire population.

Regardless, careful instructional design can be a step in the right direction. Courses that challenge students to want to learn should be the goal. As stated by Berkley and Halfond (2012), "What's harder, and even more important, than deterring and detecting cheating in online education? Certainly, designing interesting course formats that catch and hold the attention of students halfway around the world through all hours of the day and night" (p.1). This need to catch the students' attention leads us to the topic of course design.

2.2.7 *Course Design*

2.2.7.1 Teacher Presence

Course design is an excellent strategy for diminishing the gap of proctored versus non-proctored results (Feinman, 2018; Gold, 2013; Ladyshewsky, 2015). The most prominent topic in the literature review of online course design was that of the teacher's presence (Darabi et al., 2013; Hegeman, 2015; Martin et al., 2018; Reisetter & Boris, 2004; Stone & Chapman, 2006). According to Reisetter and Boris (2004), it was evident that the teacher's voice in the course design is critical. The more often students can sense teachers' personalities in the course materials, the more connected they feel to the class. Posted information such as teacher-created unit introduction that made use of conversational style, personal examples, and responses to frequently asked questions, FAQs, in personal language is highly valued. Extensive and personalized feedback on assignments is critical and also contributes to connections with instructors (Reisetter & Boris, 2004).

Instructor Created Videos. Hegeman (2015) studied the effect of instructor-generated video lectures compared to publisher-generated resources. She found that instructor-generated video lectures and coordinated note-taking sheets organized within modules increased success among mathematically unprepared students enrolled in online freshman-level mathematics courses. The instructor's design of an online course should ensure that the instructor is placed prominently in the role of content provider (Hegeman, 2015).

Frequent and Specific Feedback. According to Stone and Chapman (2006), being silent in an online classroom is equivalent to being invisible, and presence requires action. Frequent and specific feedback, addressing students by name, praise, and use of a supporting tone were all of importance in the online classroom (Darabi et al., 2013). The research on distance learning suggests that students need more support and feedback from their instructor than would be required in a face-to-face course since time and space separate them from the instructor and their classmates (Stone & Chapman, 2006). In reference to cheating on exams, Moten et al. (2013) note the following:

> Online students do not necessarily have the same respect for their online teachers because they never meet them face-to-face. That is why personalizing the online learning environment is so important. Instructors need to call students, let them hear their voices, upload photos, personalize class and activities to make them "real" to students. (p.140)

Course's Structure and Coherence. Reisetter and Boris (2004) present the results of a survey administered to students in seven School of Education graduate courses at the University of South Dakota. They found that course coherence, clear goals, teacher voice, and extensive teacher feedback were the most essential elements for learner success. Ninety-five percent believed that the course's structure and coherence was very or somewhat important and that exceptions had to be explicit. Clear course procedures were equally important to 91% of the learners, and 89% indicate that the selected text needed to be understandable (Reisetter & Boris, 2004).

2.2.7.2 Learner Supports

Backward Design and Learner Supports. An intervention strategy is that of backward design. In this design, an instructor utilizes state and local mandatory objectives and works backward to scaffold lessons to ultimately produce the desired student learning (Mireles et al., 2014). Additionally, Mireles et al. (2014) used learning supports (real-world problems, hot topics, and Q & A session) to contextualize math concepts using the CRA (Concrete to Representational) model in an intervention they call FOCUS (Fundamentals of Conceptual Understanding and Success).

Self-Efficacy. In examining the effects of teaching strategies on self-efficacy and course climate, Fencl and Scheel (2005) bring us back to SCT (Bandura, 1986).

They, again, emphasize that the teacher and the instructional design make the difference. The relationship found for non-physics majors between physics self-efficacy and outcome variables, including expected course grade and future science-related plans, indicates self-efficacy is an important attribute for understanding students' performances in introductory physics. The teaching strategy made a difference in students' self-efficacy. Teaching strategies that were found to be especially beneficial to self-efficacy include: question and answer, collaborative learning, electronic applications, and conceptualized problem assignments. Question and answer, inquiry labs, and conceptual problem assignments were found to have unique and significant positive effects on classroom climate (Fencl & Scheel, 2005).

Time and again, the literature review emphasized the success of providing supports as well as teacher presence in the online and face-to-face courses. Particularly for online courses, supports such as online office hours, instructor video, timely feedback, participation in discussions, encouragement, and constructive criticism were instrumental in a positive experience that leads to success (Hosler & Arend, 2012).

Hosler and Arend (2012) found that their qualitative results mirrored the statistical findings in that students appeared to sense specific aspects of teaching presence to influence their levels of critical thinking. Findings support the hypothesis that cognitive presence can be increased or decreased through the instructor's specific teaching actions. Facilitated discourse made the most significant contribution to the relationship between teaching presence and cognitive presence, which was supported in the qualitative data (Hosler & Arend, 2012). Additionally, Hosler and Arend found three emerging themes that students felt encouraged critical thinking: an organized course, clarity of assignment goals, and course assignments' relevance.

Growth Mind Set and Encouragement. Haimovitz and Dweck (2017) conducted a study in which college students were asked to imagine a scenario in which they receive a low grade on their first writing assignment in a required course. Students were either told that they had not mastered the topic or had not mastered the topic "yet" before they were directed to comments on how to improve. Those who heard the word "yet" in this critical feedback endorsed a growth mindset and felt more encouraged and motivated. They were also more likely to perceive their teacher as holding a growth mindset and a 'failure is enhancing' mindset, and to be more invested in their success (Haimovitz & Dweck, 2017). This finding suggests that teachers can frame instruction to impact the students' beliefs and, therefore, motivate them to learn course material. In the study of math, showing and highlighting struggles, especially as something normal and positive in the learning process, may help students understand how their own intelligence and abilities can grow (Haimovitz & Dweck, 2017).

2.2.8 *Conclusion*

Much research in this review spoke to proctored versus proctored exam results to establish whether online students could be as successful as traditional in-person students. Overwhelming, the answer was yes (Graham & Lazari, 2018; Lee 2020; Milone et al., 2015; Werhner, 2010). Some results demonstrated the online students fared better. Thus, leading to the question of whether online students are just better. Students who choose the online format may be self-starters who can efficiently manage their time (Salvo et al., 2017). When comparing proctored versus non-proctored results, much of this review supported the belief that exam scores are inflated in the non-proctored environment (Allessio et al., 2017; Ardid et al., 2015; Arnold, 2016; Carstairs & Myors, 2009; Daffin & Jones, 2018; Goedl & Malla, 2020; Flesh & Ostler, 2010; Michael & Williams, 2013; Moten et al., 2013; Staats et al., 2009; Trenholm, 2007; Wachenheim, 2009).

We have seen that proctoring can be beneficial to some students in providing a sterile, quiet environment (Hayes & Embertson, 2013). Additionally, proctored exams can increase learning by motivating students (Lorenzetti, 2006). Students expecting a proctored exam tend to engage in learning throughout the semester as they are expecting a big event that requires synthesis of knowledge, and thus good note-taking and attention to detail is maintained throughout (Lorenzetti, 2006). Fask et al. (2014), in studying the pluses and minuses of the non-proctored and proctored environments, believe the two environments equal each other out. Berkley and Halfond (2012) state that it is all about course design and creating an interesting format that will catch and hold the attention of students.

Course design was found to have a major impact on outcomes (Feinman, 2018; Gold, 2013; Ladyshewsky, 2015). Students who utilized higher order thinking questions and conceptualizations equalized proctored versus non-proctored results (Ladyshewsky, 2015). Relevance of course content may also be a factor in exam results. According to Bandura (1986), modeling with guided mastery is ideal for creating new skills, but these skills are unlikely to be acquired unless they prove useful in everyday life.

Additionally, the SCT framework informs us that students cognitively figure out their futures by experiences and observations (Bandura, 1986). Those who see no consequences to cheating and do not see the relevance of college algebra in their surroundings are especially at risk for cheating (Burnett et al., 2016). According to Bandura (1986, 1997), there are four sources of self-efficacy: interpreted result of one's previous attainments/mastery experiences, vicarious experiences, verbal and social persuasions, and emotional and physiological states. The most powerful of the sources is the interpreted result of one's own previous attainments or mastery experiences (Usher et al., 2019). The Social Cognitive Theory (Bandura, 1986) constructs of outcome expectations along with the perceived need to cheat, namely the desire to raise course grade, is readily applied to the outcome exceptions of being a competitive candidate to enter a desired program whether it be the nursing program, radiography, pharmacy, or graduate school (Burnett et al., 2016). The College Algebra general education course may represent an unnecessary roadblock to this success.

Additionally, students with high anxiety may skew results (Woldeab & Brothen, 2019). Some arousal can be helpful by heightening students' attention and focus, whereas too much arousal may be counterproductive (Bandura, 1986). "As a general rule, moderate levels of arousal facilitate deployment of skills, whereas high arousal disrupts it" (Bandura, 1986, p. 407).

This review finds that the perfect testing environment would be one with no distractions where students felt compelled to academic honesty without the need for observation. One where students were optimally comfortable and familiar with surroundings and engaged in the content. One where students felt the optimal amount of arousal so as not to become overly anxious. One where students felt self-efficacious about their abilities and could apply relevant course content to their surroundings and experiences.

2.3 Technology

Technology in education is commonly defined as a technical device or tool used to enhance instruction (Okojie et al., 2006). This may take many forms, such as handheld devices, smartphone apps, Ipads and apps, computers, and media such as videos. Many may think of the graphing calculator as the standard technology in math class. In 1985 Casio introduced the first commercial graphing calculator, the fx-700G. Sharp produced its first graphing calculator in 1986, HP in 1988, Texas Instrument in 1990. According to a recent google search, the current best overall graphing calculator is the TI-84 Plus CE. For a more advanced option, such as for engineering students, Nspire CS CAS was recommended.

Currently, the buzz appears around the startup company Desmos, who is taking on Texas Instruments with its free, web-based calculator, which is attracting the attention of teachers and test providers (Loewus, 2017). Loewus (2017) explains that the Desmos business model is a relatively novel one. The general public can use the online calculator and all its associate features for free. The company charges textbook publishers, such as Pearson and The College Board, to embed its tools. According to Wikipedia, "Desmos is an advanced graphing calculator implemented as a web application and a mobile application written in JavaScript. It was founded by Eli Luberoff, a math and physics double major from Yale University, and was launched as a startup at TechCrunch's Disrupt New York conference in 2011".

What else is out there? Ronau et al. (2014) examined 480 dissertations on the use of technology in mathematics education from 1968 to 2009 and developed a framework that provided structure to define and measure quality. Four broad categories of technology and the related number of dissertations were found to be that of calculators (175), computer software (268), internet technologies (112), and other (148). A total of 703 technologies were utilized in the various studies, as many dissertations had multiple technologies within the 480 dissertations. Sample technologies were Sketchpad, Geogebra, applet, and podcast. Since this study, mobile technologies have exploded on the scene, and the statistics may look much different. This study gives us a starting point to look at the data of technologies.

Sultana (2015) expanded the categories from those addressed in the Ronau et al. (2014) research. This research added categories such as Computer Assisted Instruction (CAI), interactive geometry applications such Geogebra, spreadsheet applications such as Microsoft Excel, computer graphing software such as Desmos, Video production such as Youtube and Echo360, general internet usage such as for projects, graphic applications such as virtual manipulatives, and apps such as Calculate84.

2.3.1 *Technological Tools by Category*

2.3.1.1 CAI

The bulk of the research for mathematical technology landed on computer assisted instruction (CAI). A revolution of sorts happened in the 2000s in the invent of algorithmically designed problem sets. The capability had been there for some time in computer programming but had not been utilized to the extent that has become the current reality. Textbook publishers took hold of this potential and rolled out elaborate platforms. Much research has been conducted showing CAI infused classrooms to be highly effective in raising exam results and pass rates in mathematics.

In a study to determine if online homework using MyMathLab (MML) would lead to an increase in academic performance compared with traditional paper-based, instructor-graded homework, Kodippili and Senaratne (2008) looked at 72 college algebra students. The students' success rate, the final grade of A, B or C, was 70% in the MML group, while the success rate was 49% in the traditional homework group.

Burch and Kuo (2010) compared traditional and online homework in College Algebra to determine whether online systems facilitate the understanding and retention of the material better than traditional paper-and-pencil homework. They compared 65 students enrolled one semester with paper homework to another semester of 61 students with online homework. Paper homework is typically graded for completeness and correctness and may take a few days to be returned. Online homework offers instant feedback and possible multiple attempts, as were present in this study. Results found that students using online homework performed better on the proctored exams at a statistically significant level (Burch & Kuo, 2010).

CAI has evolved and improved. Educators have been exploring computer-based technologies as an instructional tool since the mid-20th century (Glickman & Dixon, 2002). The education reforms of the 1990s called for a change from procedural to conceptual understanding. Situated-Learning is based on learning within a context, and thus came the Reform-Computer Assisted Instruction (R-CAI) (Glickman & Dixon, 2002). Currently, computer-based instruction is quite elaborate in design. Although many procedural problems are available, companies have evolved to provide better graphics and options that make conceptual based learning widely available.

2.3.1.2 Graphing Calculators

In a dissertation studying the use of graphing calculators in college algebra, Gerren (2008) reported on the positive implementation of the device. Additionally, Gerren noted that it was the instructors' proactive orchestration that was most impactful to the results. An interpretive case study design incorporating qualitative and quantitative research methods was used to explore the question of what happens when an exemplary teacher uses graphing calculators? The participants were the teacher and eleven students of a Texas community college algebra course. All 29 classes of the 14-week spring 2006 semester were observed in their entirety by the researcher. The three major findings were: (1) The instructor's proactive orchestration of specialized instruction, support materials, and designed activities contributed to the establishment of graphing calculator use as an essential part of classroom norms and promoted students' independent use of the tool; (2) The dynamic and interactive features of the TI-84 Plus graphing calculator facilitated the delivery of instruction at high cognitive levels during student interactive activities providing access to, exploration of, and use of multiple representations for some mathematical concepts and solutions not easily attainable using traditional methods; and (3) Although the majority of students had never used a graphing calculator before the course, all students used the tool at appropriate times during instructional activities, self-reporting that their use of the calculator was generally beneficial for enhancing their understanding of lessons and supporting class interactions. Additionally, all students independently chose to use the calculator during major assessments and reported knowledgeable use of the tool to facilitate improved test performance.

What this research most notable wants to learn, is whether technology improved learning of mathematical concepts. Was there a measured result that captured real learning, learning that demonstrated conceptualization of content? The most closely aligned, and only study found to do this specifically for College Algebra, is that of Shahriari (2019) entitled *The Effect of Using Technology on Students' Understanding in Calculus and College Algebra.* This research study included 315 College Algebra and 40 Calculus students at the University of Arkansas. The results evidenced that the use of technology, handheld graphing calculators, online graphing utility Desmos, and smartphone apps in teaching and learning increased college algebra students' understanding of several concepts such as domain, vertical and horizontal asymptotes, end behavior of a function, and logarithmic functions. Also, college algebra students' skills such as logical reasoning, use of graphs, organization, written order, and correct use of notation and symbols significantly increased when using technology. A survey of calculus students also evidenced increased learning. These results demonstrated how technology can aid in the conceptualization of core competencies in college algebra.

Ellis-Monaghan (2010) summarized her experiences in teaching college level mathematics blended with technologies. With an open mind set to the challenges and changes, Ellis-Monaghan reported a decade of positive results and strategies for infusing the graphing calculator as well as other technologies to the mathematics classroom. However, Beaudin and Picard (2010) find that CAS and graphing calculators are still under-utilized and that curriculum has not really changed that much. Additionally, Brown (2010) makes the point that many have not adjusted their assessments to align with graphing calculators. Many are still asking students to complete routine calculations. Brown (2010) is a proponent of the graphing calculator and believes that the student’s hands-on experience facilitates better understanding of the topics while using this technological tool.

However, there were conflicting findings on the use of the graphing calculator. King and Robinson (2012) in asking whether undergraduate students view calculator usage as a proxy for learning with understanding found that no, they did not. In this study, focusing on whether the inherent characteristics of the mathematics questions presented to students facilitate a deep or surface approach to learning, ten 2nd-year undergraduate students were asked a series of mathematics questions during structured interview sessions. Finding suggested that students used calculators as a way of circumventing the need to understand a mathematics problem.

Additionally, Rodriguez (2018) found no significant difference in studying College Algebra students at Miami Dade College. This quantitative, quasi-experimental approach compared preexisting groups of two algebra classes with the experimental group ($n = 33$) using graphing calculators to assist their understanding, and the control group ($n = 42$) not using graphing calculators. The researcher compared these students' final grades on a 0–100 scale, as well as their responses to two survey items to measure their satisfaction with the course and motivation to learn. The results indicated that graphic calculators did not improve students' test scores with the same teacher and other variables held constant.

2.3.1.3 Computer Graphing Software

An example of a computer graphing software is Desmos. As formerly mentioned, Desmos is an advanced graphing calculator implemented as a web application which has largely replaced the handheld graphing calculators. Ruthven et al. (2009) reported successful implementation of graphing software in the teaching of secondary-school mathematics. Ruthven's qualitative study highlighted the crucial part played by the teacher in the structuring and shaping of technology-and-task-mediated student activities. Here the graphing software was treated as a pedagogical aid and contributed to many positive results. Teachers were particularly drawn to use graphing technology to support classroom activity that involved investigation, exploration and discovery. Teachers reported that the software aided in procedures being carried out more rapidly and reliably and the ability for students to explore equations beyond the types in the textbook. Adding that students were able to grasp the spatial patterning of the graphs and its link to their equations.

2.3.1.4 Video

YouTube videos abound on the teaching of mathematics. YouTube is an internet-based company providing searchable video topics of most anything one could want to know. With the explosion of online learning, video learning has become critical. Teachers can make their own YouTube videos or search for others' work. Additionally, teachers can use other video processing services to create and upload videos. Dunn (2019) studied the reported effectiveness, efficiency, appeal, and satisfaction of YouTube and ECHO360 in a web-assisted college algebra course. Students reported that they found YouTube the most appealing.

2.3.1.5 Graphic Applications

Gningue et al. (2014) suggests the intervention of manipulatives based on Bruner's theory of representation to teach pre-algebra and algebra concepts. In teaching students with learning difficulties, it has been shown that the Concrete-to-

Representational (CRA) model can help students learn algebra (Witzel et al., 2003). Research shows that online models are widely available and prove useful for online education (Kolb, 2017).

2.3.1.6 Apps

Hernawati and Jailani (2019) report the current existence of more than 4000 mobile applications for mathematics education. This emerging technology raises lots of new questions in math education. So much so, that a new term has emerged due to the use of mobile technologies. The term m-learning refers to using portable devices to connect to the internet such as smartphones and iPads (Park, 2011). Apps can be purchased from smartphones, with many of these apps being free. A quick search of the iPhone app store will lead to popular math apps such as; Photomath, Mathway, Microsoft Math Solver, and SnapCalc. Many of these apps use the smartphone camera, taking a snapshot of the math problem and providing the solution. A search for graphing calculators nets the following: Graphing Calculator X, Calculate84, Taculator, NCalc Graphing Calculator, and Desmos Graphing Calculator. Both of these lists are just the tip of the iceberg as the lists go on and on.

An example of the implementation of apps to the college classroom is that of an algebra-based physics course. Vieyra et al. (2015) described five challenges that encouraged inquiry-based learning using smartphones' mobile-senor data capacity. Many of the apps involved the use of a smartphone's accelerometer, "a sensor particularly well suited for teaching concepts of force and motion and cause and effect" (Vieyra et al., 2015, p. 33).

The first activity involved acceleration due to gravity in the home. Dropping the smartphone on a couch while capturing the acceleration lead to questions such as, how should the mobile device be held upon dropping? Which axis measured acceleration due to gravity? The next activity studied net force and motion in an elevator. The third activity involved acceleration in the lab. Students selected a counterweight only slightly less or more massive than the mobile device itself-so that a descent acceleration could be measured, and so that the mobile device would not move so quickly that it might be damaged or injure a student. Students found that more massive systems with equal net forces have a smaller acceleration, and vice-versa. This activity showed students how to derive Newton's second law quantitatively through their inquiry experience. A fourth activity was centripetal acceleration while dancing. And lastly, locating the accelerometer with a turntable. These activities demonstrate what can happen when an innovative teacher merges technology with pedagogy.

So (2016) evaluated mobile instant messaging tools to support teaching and learning in higher education. This study included a total of 61 undergraduate students enrolled at a teacher-training institute in Hong Kong. Each student possessed a smartphone with WhatsApp and was assigned to experimental and control groups. Besides the traditional classroom learning for both groups, the experimental group was supported with bite-sized multimedia materials and teacher-student interaction via WhatsApp outside school hours. The participants of the control group used WhatsApp only for academic communication. The strength of the intervention was found to be medium to large. The participants showed positive perception and acceptance of the use of WhatsApp for teaching and learning. The participants slightly rejected the view that receiving instructional materials outside school hours interfered with their private lives.

Kassarnig et al. (2017) used smartphones for a fundamental implementation of technology. Step one, be there! This study investigated class attendance, peer similarity, and academic performance by using cell phones to verify class attendance via location services to correlate achievement with attendance. This finding demonstrates a commonly held belief of instructors that class attendance correlates with success.

Most specifically to this review is the use of the app, Photomath. This particular app instantaneously solves any algorithmically designed, solve this type of equation. The app works well whether the equation is given in handwritten or typewritten form. Solution steps are provided and can be utilized by students to aid in their understanding. Only one study was found that addressed this type of app specifically. Unfortunately, this study did not look at the students' outcomes with the app, but did give us insight into teachers' attitudes toward the app. Hamadneh (2015) found that factors influencing math teachers toward Photomath were high and positive. Additionally, there were no statistically significant differences in teachers' attitudes towards Photomath due to teachers' educational qualifications, years of teachings, and teaching experience. This study opened the door to the possibilities of such apps as welcomed technology.

2.3.2 *Issues and Concerns*

2.3.2.1 Smartphone Concerns

On the other side of the argument are those who cite the research of the dangers of Googling and smartphones that dumb down the population. Agbo-Egwu et al. (2018) conclude that the patterns of students' ability to recall basic mathematical facts, theorems, axioms, and formula indicated a negative influence of smartphone over-dependence on simple recall. They believe that the participants' over-reliance on the internet for simple recall poses a significant threat to the future of mathematics. Additionally, they believe that "the act of memorization in mathematics is a skill which must be developed and sustained for the very survival of mathematical prowess" (Agbo-Egwu et al., 2018, p 103). They recommend that at the university level, the teaching of mathematics should cultivate greater conceptual knowledge as well as emphasize procedural and factual knowledge. They believe that the two types of knowledge are not in opposition to one another but work in unity. Additionally, they warn that mathematics teachers at the university level should never assume students are already abreast of some vital mathematical concepts. They remind instructors that even at this level, depth matters the more. (Agbo-Egwu et al., 2018).

In the review, an overwhelming number of articles on the topic of smartphones dividing the attention of students, and therefore, lowering grades were found. Such as, *Checking phones in lectures can cost students half a grade in exams* (Staff, 2018). An additional example, Sparrow et al. (2011), speaks to the concerns over technology at your fingerprints. *Google Effects on Memory: Cognitive Consequences of Having Information at Our Fingertips* Sparrow et al. (2011) raises the question, do students need to be able to recall specific facts to think in higher-order ways (i.e. multiplication tables in order to factor). Do students need to have some formulas memorized in geometry to compute area and circumference or at least know how to think about it?

The mantra, "research is needed", was repeated over and again within the review. For example, the recent ambitious 1:1 iPad initiative in the Los Angeles Unified School

District quickly ran into problems and was criticized for lack of planning and vision (Rogers, 2013). Students hacked the iPads they received to use social media sites and play games rather than using study apps. “These problems call for research on what kind of technology use policy should be established to promote effective use of tablets” (Rogers, 2013, p. 99).

Cell phones have been banned in 69% of today's classrooms (commonsense, 2010). Potentially this banning is for good reasons. As noted above in the Rogers (2013) finding, students in the Los Angeles Unified School greatly misused the classroom's given technology. Thomas and McGee (2011) cited four common complaints of cell phone use: textese (misuse of the English language), cheating, cyberbullying, and sexting. Thomas and McGee (2011) turn these concerns into an argument for smartphone use. The authors cleverly summarize the positives using two Latin phrases,

> the first is cum hoc ergo propter hoc, or correlation does not imply causation. Although some students do misuse cell phones, cell phones are not the cause of these behaviors. Second, ex abusu non arguitur ad susm, the abuse of a thing is no argument against its use. Instead of banning cell phones in the classroom, teachers and administrators in schools should be modeling the moral and ethical use of cell phone technology while harnessing their computing power to support sound pedagogical instruction (Thomas & McGee, 2011, p. 28).

These powerful words speak to our topic in that the teacher and the technology must approach m-learning carefully. The teacher needs to be ahead of the newness and prepared to model, encourage, and enforce the desired behaviors.

2.3.2.2 Resistance to Implementation

The next obstacle is that of implementation. Beaudi and Picard (2010) note that much of the available technology has been underused dating back to the invent of the graphing calculator and computer algebra systems (CAS) and that traditional methods may be preferred by many.

Pape and Prosser (2018) conducted a 3-year study of college faculty using grounded theory. Eight math faculty engaged in training for the use of CCT (classroom connectivity technology) such as Texas Instruments (TI) Navigator over the course of three years. These community college faculty members engaged in a total of 27 full-day professional development (PD) sessions.

Results found that barriers to implementing classroom connectivity technology at the instructor level included: faculty beliefs about mathematics teaching and learning and students' abilities, lack of agency related to the college's quality enhancement plan, and the perception of misalignment between the activities and the state-mandated curriculum. They felt that the curriculum was to be delivered to students in discrete chunks. These chunks mandated by the state were too numerous to be delivered by exploring mathematical concepts and teaching toward big ideas (Pape & Prosser, 2018). Challenges expressed specific to the community college students included: underprepared and non-traditional students' reluctance to engage in navigating unfamiliar systems and institutional processes, student's lack of self-efficacy, and general non-comfort with technology.

This study found that the teacher must be the innovator. The teacher must be comfortable and willing to engage with the technology. Beliefs about teaching and learning and attitudes toward technology were the most common philosophical and pedagogical barriers. In the end, eight highly educated faculty members, over the course of three years, and 27 full-day trainings could not make peace with their job description, contract, and curriculum promises, to implement this technology.

In another interesting study, Mesa et al. (2014) looks at 14 community college mathematics faculty to provide insights into the behind closed lecture door's happenings. Researchers carefully coded behavior in the classroom to construct a detailed story of what is going on. An added level of interest was that the faculty had an average positivity rating from students of 4.2/5 and were therefore thought of as the "good instructors". What did they do that was good? The instructors, per their interview, felt that they provided mean-making or student-centered techniques. Researchers coded 401 strategies, 174 (45%) of which were traditional, 112 (29%) meaning-making, and 103 (26% student –support). These results demonstrate that even among those top college instructors, the traditional lecture method is still the standard. Faculty once again expressed the common complaint that there is too much content that needs to be covered, which imposes limits on the time available to teach in new and innovative ways. This again presents a barrier to implementing new technologies in the college classroom.

Additionally, implementation barriers may be present due to such findings as seen in the study of graphing calculators by Rodriguez (2018). This study found no significant difference in college algebra outcomes when comparing a section with and without graphing calculators. Additionally, King & Robinson (2012) found negative effects of graphing calculators in that of students' missing the point by using the technology to circumvent the understanding of mathematics.

2.3.3 *Pedagogy*

In reviewing the topic of technology in academics much focus was noted on the need to implement technology based on pedagogy. As defined by Wikipedia, pedagogy is most commonly understood as the approach to teaching. It is the theory and practice of learning and how this process influences and is influenced by learners' social, political, and psychological development. Heid and Blume (2008) make the point that the teacher must make decisions on how to use technology in math and be most prominent in the use thereof.

2.3.3.1 TPACK

One such framework to guide the practice of pedagogy is that of the Technological Pedagogical Content Knowledge (TPACK) model. This model was developed around 2005 by Punya Mishra and Matthew Koehler at Michigan State University (Mishra & Koehler, 2006). This framework asserts that the interaction of technological knowledge (TK), pedagogical knowledge (PK), and content knowledge (CK) allows for the ultimate integration of technology to the classroom. Those possessing knowledge of all three areas will best address the flexibility needed to guide their students in meeting classroom goals. This theory explains the need for those instructing in College Algebra to be not only be an expert in the discipline but also possess understanding of the pedagogy needed to properly add technology to the classroom. Additionally, the teacher needs to possess knowledge of the device in use. These three elements, each critical to the process, will result in the most success.

Additionally, the intersection of any two of the three elements creates subcategories within the framework. Pedagogical Content Knowledge (PCK) merges the two skills of teaching and subject matter specialist. One might consider this merging as the essence of traditional classroom teaching. For one to be good in this role, they must certainly know their subject matter but also know how to get it across to the learner. This intersection includes education, teaching, learning, assessment and evaluation and curriculum (Hernawati & Jailani, 2019).

Another subcategory would be Technological Content Knowledge (TCK). This would include the knowledge of how to integrate the technology to a specific area of concentration. One would need to be a content expert for example in math and also well versed in the most appropriate technology to help in the study of mathematics. This person should be aware of the options available and research strategies for the implementation of said options (Hernawati & Jailani, 2019).

Technological Pedagogical Knowledge (TPK) is a concept about the use of specific technologies and how they affect teaching and learning. This involves knowing how to merge pedagogy with technology. This art is one of not just knowing how to use a device or related technology, but also knowing how to teach with that technology to increase learning in the student (Hernawati & Jailani, 2019).

Considerable research exists demonstrating positive results when the TPACK framework is utilized. So much so that the AMTE (Association for Mathematics Teacher Educators) Technology Committee proposed the TPACK framework to create a list known as the TPACK Mathematics Teacher Standards (Hernawati & Jailani, 2019). The TPACK model instructs one to carefully consider the app of interest and formulate lessons that are integrated with the chosen technology. The teacher should apply the framework with a chosen mobile application that is in accordance with the math content and appropriate learning model and method, manage the class and adjust as necessary.

In examining how a community college teacher incorporated CAI in a College Algebra classroom, Sultana (2015) noted the Technological Pedagogical Content Knowledge (TPCK) framework was helpful in the infusion of technology to the classroom. Lee and Hollebrands (2008) also encouraged the use of TPCK and noted that teachers need to know how to capitalize on the power of technology to create lessons that assist students in developing understandings of mathematics.

2.3.3.2 Triple E Framework

While the TPCK framework builds a firm foundation for our topic, professor Liz Kolb later added more detailed "how to" to the theory, resulting in the Triple E Framework, developed in 2011 by Professor Liz Kolb at the University of Michigan, School of Education. This framework was created to address the desire for K-12 educators to bridge research on education technologies and teaching practices in the classroom (Triple E Framework). Kolb's (2017) method purports that successful merging of technology within the classroom will include engagement, enhancement, and extension. The triple E framework tool asks the instructor to decide if the technology integration brings increased engagement to the learning. Does the technology allow students to focus on an assignment with less distraction? Does it motivate students to start the learning process? Does it cause a shift in the behavior of the student from passive to active social learners? For enhancement, does the technology allow students to develop a more sophisticated understanding of the content? Does the technology support (scaffold) to make it easier to understand? Does the technology create paths for students to demonstrate their understanding of the learning goals in a way that traditional tools could not? For extension, does the technology create opportunities for students to learn outside of their typical school day? Does it create a bridge between school learning and everyday life? Does it allow students to develop skills they can use in their daily lives? These questions are powerful to our discussion. If the technology, i.e., smartphones, in our discussion, does not address at least some of these nine questions, then it is just noise, a distraction.

2.3.3.3 AIT

Hoang and Caverly (2013) present an additional framework: Algorithmic Instructional Technique (AIT) developed by Vasquez (2003). AIT, which is more directly applicable to our subject matter, includes four stages: modeling, practice, transition, and independence. The instructional goal with AIT is to help students develop algorithms to approach different math situations. AIT is a balance between behaviorist and constructivist instructional models. Instruction through AIT provides that balance because it allows students to see how an instructor develops an algorithm and how they give students opportunities to create, use, and refine the algorithm when encountering different situations. Since instructors using the AIT model expect students to be active in their learning, faculty can integrate technology into the four stages so that students can use mobile devices to collaborate and deepen learning.

Hoang and Caverly (2013) provide examples of each of these stages combined with technology. First, we look at modeling. After an instructor models a useful algorithm, students can share their notes via *Evernote* (Evernote Inc., 2013: Android, iOS) to compare the understanding of material with peers. Next, we look at the guided practice stage. An instructor can provide steps to an example problem with an error, asking students to locate it with a *YouTube* video of the problem type given. In the transition stage, students can practice with problems generated with *Algebra Tutor* or another online learning tool with built-in feedback such as Photomath, Mathway, or Pearson's Mylabs. In the independence stage, students can use Google Drive. Students can post questions about particular word problems that they do not understand and share information that can help in the creation and use of algorithms.

2.3.4 *Conclusion*

Research provided examples that evidenced smartphone apps can make a powerful difference in the college algebra classroom. First, Shahriari's (2019) Dissertation: *The Effect of Using Technology on Students' Understanding in Calculus and College Algebra* evidenced that the use of technology (handheld graphing calculators, online graphing utility Desmos, and smartphone apps) in teaching and learning increased college algebra students' understanding of several concepts such as domain, vertical and horizontal asymptotes, end behavior of a function, and logarithmic functions. In addition, college algebra students' skills such as logical reasoning, use of graph, organization including written order, and correct use of notation and symbols were significantly increased when they used technology.

Vieyra et al. (2015) provided detailed examples of how technology can be infused to algebra-based physics. Vieryra et al. step us through a real-time use of smartphone apps in a college classroom, revealing the creativity and openness necessary to achieve such results-results that may be hard to measure. Hoang and Caverly (2013) in a similar measuring of success attempt to explain the infusion of technology within a framework.

Again, demonstrating creative and potentially impactful strategies for college algebra. And lastly, Kassarnig et al. (2017) correlated class attendance to success by utilizing the smartphones location feature. Both usefulness and hindrances in the implementation of technology were noted within this review.

Certainly, more research is needed specific to the smartphone in College Algebra. Cited studies reveal great potential. The section reviewing pedagogical strategies speaks to the need to merge technology with educational practices. The heart of the issue seems to be that of capturing the faculty's attention and encouraging openness to change. Additionally, technology is advancing so quickly. Every day brings newness. It can be intimidating. New assessment techniques will be needed to address the app world. The newness of the technology, the potential for advancements, and the lack of college-level math studies reveal the need for study.

The review highlighted examples beaming with possibilities. In many ways, it is a great time to be in education. Opportunities abound but must be approached with pedagogy and creativity. Larkin and Calder (2016) believe that much more research is needed on this very important topic. As of this writing, they felt that little research had been conducted. They offer a paper in a special issue of *Mathematics Education Research Journal* (MERJ) on mathematics and education and mobile technologies. They highlight nine articles on the subject; all applicable articles were included in this review. They believe research should ensure the following concerns are addressed: pedagogy, what approaches might best optimize student engagement, and mathematical thinking? How might the notion of scaffolding be re-envisaged to include feedback from digital sources and a greater element of self-assessment? Equity issues? What comes first, the mathematics, the app, or the pedagogy? They felt the full scope of this topic was yet to be unraveled. Larkin and Calder (2016) note that these individual apps have both helping and hindering affordances. “To muddy the water even further, these affordances within the one app have varying effects for different students, dependent on the particular learning approach that best suits the individual students.” (Larkin & Calder, 2016, p. 3).

What is missing in this review are assessment results comparing proctored versus non-proctored exams, particularly when technologies are present. Also, what about exam difficulty? What are the results when an instructors’ exam includes solve this type/algorithm-based questions compared to conceptualized/reading problems questions? How can we measure such learning goals that address student conceptualization of a topic? Many college math course competencies emphasize procedures. Now that apps do that for the students, where does that leave math instructors? These are the questions that will lay heavy in my mind as I move forward in my research.

CHAPTER 3. METHODOLOGY

This study is that of a quantitative research design. The site for this research was Ashland Community and Technical College (ACTC). This college is located in North-Eastern Kentucky on the edge of the Ohio and Big Sandy rivers forming a Tri-State with Ohio and West Virginia. According to projections from the 2020 census, Ashland, Kentucky, has a population of 19,582. This area is located within Middle Appalachia.

In the fall of 2019, ACTC had an enrollment of 2,598 students. ACTC offers courses in a variety of fields. As of 2019, the top five most popular programs were: Associate in Arts / Associate in Science, Health Science Technology, Associate Degree Nursing, Business Administration, Medical Information Technology.

ACTC offered six sections of College Algebra during the Fall of 2019. Of these, three met face-to-face (*N=60*), two were offered online (*N=46),* and one met as high school dual credit *(N=20*). Also, for Spring 2020, six sections were offered. Of these, three met face-to-face *(N=46),* one was offered online *(N=38),* and two met as high school dual credit *(N=28).* I taught two in-person sections of these Spring 2020 total classes *(N=33)* and one online *(N=38).* Additionally, I typically teach one online summer section, with *(N=26)* enrolled in Summer 2019. This study compared final exam scores with various treatment designs for my Fall 2019, Spring 2020, Fall 2020, and Spring 2021. Looking at courses with the same instructor across cohorts was used in hopes of controlling for instructor bias.

General demographic data of those enrolled in the courses included in this research demonstrated that 260 students were originally included, with 190 of those students completing the final exam. The dependent variable for this study is the percentage on the final exam, and thus the study includes the 190 students who persisted to the final exam. To protect students' identity, the demographic data is not tied to any student exam score. Therefore, only the general demographic data of the larger population of the 260 initially enrolled students was available. More than triple the number of females enrolled each semester with a total ratio of female to male at 196:62, with two unidentified students. Ashland being a non-diverse population at 93% white, is reflected in this demographic data. For the 260 total students, there was one American Indian/Alaska Native, two Asian, three Black/African American, three Hispanic/Latino, and three identified with two or more races. The average Math ACT score was similar across the four cohorts. The fall 2019 cohort had the following ACT average per the three sections as follows: 21.1, 19.3, and 18.6, for Spring 2020, the averages were 19.8, 18.4, and 20.1, for Fall 2020, averages were 18.4, 20.8, 19.2, and for Spring 2021 averages were 20.2, 19.4, and 19.1. As for the previously completed math course, the data tells us that two students had taken MAT 100 (College Algebra Math Workshop), two had taken MAT 105 (Business Math), eleven had taken MAT 110 (Applied Mathematics), one had taken MAT 116 (Technical Math), seventy-five had taken MAT 126 (Technical Algebra and Trigonometry), twenty-one had taken MAT 146 (Contemporary College Mathematics), fifteen had taken a developmental math course, and 125 had taken no college-level math course prior to enrollment in College Algebra. In summary, we can see that the four cohorts were similar. Participants were typically white, female, with an average ACT math score around 20, and either enrolled in their first math course or coming from Technical Algebra and Trigonometry.

The dependent variable of the final exam score was measured with a fourteen-question assessment. Final exams were given to each of these cohorts. This final exam instrument included material considered the second half of College Algebra. This material included topics such as polynomial, rational, inverse, exponential, and logarithmic functions, as well as systems of equations. Upon analysis of the exam questions, it was discovered that there were fourteen equivalent exam questions throughout the cohorts. Therefore, students' final exam average was found by calculating the number of correct responses on these fourteen common questions and dividing that total by fourteen. This measure is referred to as the final exam score used in this design.

This study utilized a two-by-two factorial ANOVA design. The two treatments being that of proctoring and apps. The outcome is that of final exam score. This research seeks to understand whether students utilize apps effectively or as intended in College Algebra. This study will establish the nature of the questions on the final exam utilized in this research design.

3.1 Factors

3.1.1 *Apps*

The term m-learning refers to using portable devices to connect to the internet, such as smartphones and iPads (Park, 2011). Apps can be purchased from smartphones, with many of these apps being free. A quick search of the iPhone app store will lead to popular math apps such as; Photomath, Mathway, Microsoft Math Solver, and SnapCalc. Many of these apps use the smartphone camera, snapshot the math problem, and provide the solution. A search for graphing calculators nets the following; Graphing Calculator X, Calculate84, Taculator, NCalc Graphing Calculator, and Desmos Graphing Calculator.

Both of these lists are just the tip of the iceberg, as the lists go on and on. Some of these apps give step-by-step solutions to help students learn procedures, and others give only the final solution.

The final exam within this design contains questions assessing the following topics: polynomial, rational, inverse, logarithmic, and exponential functions, and the solving of systems of equations. This content is considered the second half of the College Algebra course. Photomath is an app that can solve short, x=[ans], math equations. When analyzing the final exam instrument in question, it was found that approximately 25% of the questions can be answered with the basic, free version of Photomath. Additionally, the smartphone app, Calculate84, is a replica of the Texas Instrument TI-84 graphing calculator. This app can be downloaded for free and is readily available for use in the classroom. One of the final exam questions was found to be directly answerable with a graphing calculator, and four questions were indirectly answerable with the graphing calculator. It can be argued that all questions are better understood/conceptualized and thus answerable with the aid of technology (Kolb, 2017).

3.1.2 *Proctoring*

Additionally, this research sought to understand the impact of proctoring on final exam scores. Some research supports the belief that exam scores are inflated in the non-proctored environment (Daffin & Jones, 2018; Flesh & Ostler, 2010; Goedl & Malla, 2020; Moten et al., 2013; Staats et al., 2009; Trenholm, 2007). Proctoring can be beneficial to some students in providing a sterile, quiet environment (Hayes & Embertson, 2013). Additionally, proctored exams can increase learning by motivating students (Lorenzetti, 2006). Students expecting a proctored exam tend to engage in learning throughout the semester as they expect a big event that requires synthesis of knowledge. Thus, good note-taking and attention to detail are maintained throughout (Lorenzetti, 2006). Fask et al. (2014), in studying the pluses and minuses of the non-proctored and proctored environments, believe the two environments equal each other out. Berkley and Halfond (2012) state that it is all about course design and creating an interesting format that will catch and hold the attention of students. This research sought to determine the treatment effect of proctoring and apps in this controlled experiment with the same instructor and the same measurement instrument over four semesters. Participants were divided into four cohorts: proctoring/no apps, proctoring/apps, no proctoring/apps, and no proctoring/no apps.

3.2 Data Collection

Before the Covid-19 Pandemic of 2020, all ACTC College Algebra final exams were proctored with no use of apps. The exam environment was that of a lockdown browser with no use of outside helps, such as a cell phone. Students were allowed one 3 by 5-inch notecard and a non-programmed graphing calculator. A college-approved proctor observed students in a sterile environment. Furthermore, there was no instructional use of, nor mention of, apps in the teaching of College Algebra before Fall 2020. Thus, the Fall 2019 cohort (*N=40)* provided data for the proctored/no apps group.

Due to the Covid-19 Pandemic, proctoring was disallowed at ACTC for the Spring 2020 final exam. Therefore, this group (*N*=50) is that of non-proctored/no apps. All Spring 2020 College Algebra students in this study were given an online version of the exam and required to complete it within a 2-hour time frame. Students could take the test at any time and place but were to complete the exam before a stated deadline.

In Fall 2020, apps were embraced in the course design of the College Algebra sections included in this study. Class time was spent downloading apps and demonstrating the use thereof. For online students, videos were provided of the in-person demonstrations. Students were encouraged to utilize any app deemed helpful in the learning of College Algebra. The most commonly mentioned app was that of Calculate84. This app is a near replica of a Texas Instrument (TI) 84 graphing calculator. Lessons were designed around the use of this app. The Fall 2020 cohort (*N*=50) is that of non-proctored/apps.

For the Spring 2021 cohort (*N*=50), all courses continued to be instructed on the use of apps such as Calculate84 and Photomath. The final exam instrument remained the same. To achieve the proctoring treatment, some students could not come to campus due to travel distance or pandemic restrictions and were observed via the Blackboard Collaborate online course system. Otherwise, students were proctored in person and on campus. Students continued to be required to complete the exam within a 2-hour time limit and be instructed to use cell phones to access apps as needed. Thus, this cohort is that of proctored/apps.

Table 1

Four Semester Cohorts within the Design

College Algebra final exams	Non-proctored	Proctored
No Apps	Spring 2020 *(N=50*) cohort 2	Fall 2019 *(N=40)* cohort 1
Apps	Fall 2020 *(N=50)* cohort 3	Spring 2021 (*N=50)* cohort 4

3.3 Research Questions

My research questions are as follows:

1. In what ways does the presence or lack of a proctor significantly affect exam performance?
2. How does the treatment of the instruction of, and use of, apps affect exam performance?
3. How does the treatment of apps and proctoring interact with regard to exam performance?

3.4 Design

3.4.1 *ANOVA*

A factorial ANOVA was used to compare the difference among the means of our four groups of data. ANOVA expands to the analysis of variance. It is described as a statistical technique used to determine the difference in the means of two or more populations by examining the amount of variation within the samples corresponding to the amount of variation between the samples. It analyzes the factors/independent variables (proctoring and apps) that are hypothesized to affect the dependent variable (final exam scores). It is of two types: one-way ANOVA, when one factor is used to investigate the difference amongst different categories, having many possible values, and two-way ANOVA, when two factors are investigated simultaneously to measure the interaction of the two factors influencing the values of a variable. This study will thus be a two-way ANOVA (Lane et al., 2003).

A factorial ANOVA is an efficient way of conducting a test. Instead of performing a series of experiments where I test one independent variable against one dependent variable, I can test all independent variables simultaneously. So, for example, I can look at all the final exam scores compared to the treatment factor of proctoring. This process allows me to examine the difference among the means of the four groups with the categorical values of proctoring and apps. Also, it allows me to attribute between-group variation to treatment.

3.4.2 *F-Statistic*

ANOVA provides a single number (the F statistic) and one p-value to help support or reject the null hypothesis. The F statistic will calculate the ratio of the between-group variability to the within-group variability. This statistic tends to be greater when the null hypothesis is not true. In this case, the null hypothesis would be that of no difference in the variances between the populations nor the interaction of the two populations.

In factorial ANOVA, each level and factor are paired up with each other or crossed. This pairing helps to see what interactions are going on between the levels and factors. If there is an interaction, then the differences in one factor depend on the differences in another. In my case, this two-way ANOVA tests proctored and non-proctored performance on a final exam when the subjects had either used apps or no apps.

- IV1: Proctoring (proctoring/no proctoring)
- IV2: Apps (apps/no apps)
- DV: Final Exam Score

3.4.3 *Assumptions*

Final exam scores for each of these four groups were entered in Excel and analyzed in the statistical program SPSS. There are three underlying assumptions for an ANOVA as listed below (Lane et al., 2003):

Normality: the populations are normally distributed.

Independence: Observations and groups are independent of each other.

Equality of Variance: The populations have the same variance. This assumption is called the assumption of homogeneity of variance.

Each of these assumptions was addressed in this study and reported in the results section.

3.5 Data Analysis

3.5.1 *How will the results be interpreted?*

A two-way factorial ANOVA would help answer the following questions:

1. In what ways does the presence or lack of a proctor significantly affect exam performance?
2. How does the treatment of the instruction of, and use of, apps affect exam performance?
3. How does the treatment of apps and proctoring interact with regard to exam performance?

The null hypotheses would be the following:

- H_0: Proctoring will have no significant effect on students' final exam score.
- H_0: Apps will have no significant effect on students' final exam score.
- H_0: Proctoring and apps interaction will have no significant effect on students' final exam score.

3.5.2 *Instrumentation*

Reliability is about the consistency of a measure, and validity is about the accuracy of a measure. In this case, the final exam test result represented a consistent measure across all groups. Reliable assessment is central to education and educational institutions. Some may argue that accurate assessment methods help to ensure the survival of educational institutions (Rowe, 2004).

Additionally, the exam aimed to accurately measure students understanding of the concepts of College Algebra. Construct validity is considered met in this study via a panel of experts familiar with the subject matter at hand. A committee of College Algebra instructors at ACTC meets each semester to analyze and report the results of this exam. This assessment report is submitted to the college administrators to comply with ACTC's accrediting agency Southern Association of Colleges and Schools Commission on Colleges (SACSCOC) requirement. This regional accrediting agency is in place to assure the public of the educational quality of courses taught. Therefore, ACTC assesses the outcomes of the general education course College Algebra. Each exam question must align to a preset curriculum guide with specific course competencies.

3.5.3 *Homogeneity of Population*

The population under study should show no signs of change from semester to semester. ACTC service region remains similar in makeup over time. A well-controlled population is noted with no significant differences between the four cohorts from Fall 2019 through Spring 2021. The treatment of apps and proctoring is noted as the only significant difference in the four cohorts. Thus, one should feel confident that this study determined whether proctoring or apps, or the interaction thereof produced an effect in the final exam results.

3.6 Limitations

Ideally, this research design would have been conducted within one semester. If a sufficient sample size could have been attained, students in the four cohorts would have been randomly assigned to groups within the same semester. Therefore, we cannot rule out the outside environmental factors present between the cohorts in this study. Within each semester time frame, some differences in outside environmental influences such as political, health, and financial turmoil could exist and affect the study. However, this population is believed to be consistent over time. The four cohorts appear to represent the typical student population at this institution.

For the non-proctored/no apps cohort, we cannot guarantee that students did not gain insight into the use of apps aside from the teacher's intervention. Since this group was not proctored, we cannot know the details of whether they used a 3 by 5-inch note card with no other helps, whether they phoned a friend for assistance, or whether Photomath answered some of the questions. What we do know is that the no apps cohort was not instructed on the use of apps in the treatment design.

Most notably, we cannot prove causation. We can only know if proctoring is a main effect. In other words, we may wish to theorize that the absence of proctoring inflates final exam scores due to academic dishonesty, but we cannot prove it. This study does not reveal the why behind the effect. The same can be said for the apps factor. We can only know if the use of apps is a main effect. We may wish to theorize that the presence of apps raises final exam scores due to pedagogy that led to the conceptualization of concepts. However, it is possible that students used their cell phone apps to gain answers in an academically dishonest manner. And lastly, we may theorize that the interaction of the two factors, apps and non-proctoring, inflated exam scores, but we will not know precisely why this is so. We can theorize and hope it is due to sound pedagogy and course design.

CHAPTER 4. RESULTS

4.1 The Four Cohorts

Descriptive statistics showed that the Fall 2019 cohort, that of proctored with no apps, scored the lowest on average of the four groups with a mean final exam score of 62.1%. The Spring 2021 cohort, that of proctored with apps, followed in second lowest place, with a mean exam score of 77.9%. Additionally, we can see a difference in the average means of the cohorts who were instructed in the use of apps at 84% compared to 82% in the non-proctored group. The proctored group shows a much more profound effect at 77.8% compared to 62.1%. This difference demonstrates that the instruction of apps made a difference in the mean averages of these cohorts.

Table 1

Four Semester Cohorts within the Design

College Algebra final exams	Non-proctored	Proctored
No Apps	Spring 2020 *(N=50)* cohort 2	Fall 2019 *(N=40)* cohort 1
Apps	Fall 2020 *(N=50)* cohort 3	Spring 2021 (*N=50)* cohort 4

Table 2
Between-Subjects Factors

		N
Proctoring treatment	Non-proctored	100
	Proctored	90
App treatment	Apps	100
	No apps	90

Table 3

Descriptive Statistics

Dependent Variable: Final exam %

Proctoring treatment	App treatment	Mean	Std. Deviation	N
Non-proctored	Apps	84.156	12.6945	50
	No apps	82.288	16.9137	50
	Total	83.222	14.9075	100
Proctored	Apps	77.860	17.7531	50
	No apps	62.147	28.2627	40
	Total	70.877	24.1908	90
Total	Apps	81.008	15.6769	100
	No apps	73.337	24.6741	90
	Total	77.374	20.7406	190

Additionally, there were more extreme low scores for those who were proctored. For example, in Fall 2019, pre-pandemic students took the final examination in a sterile environment either in a classroom under supervision or a computer lab with a hired employee designated to oversee the students' work. Two students enrolled in the online section correctly answered only one of the fourteen questions. A total of 9 out of 40 Fall 2019 students scored less than 40% overall. In contrast the Spring 2020 cohort who experienced no proctoring had only one student out of 50 who scored less than 40%. The overall average for Fall 2019 was 62.1%, whereas the Spring 2020 non-proctored average rose to 82.3%.

The Covid-19 pandemic of Spring 2020 resulted in no proctoring of the final exam for that semester. Proctoring continued to be disallowed in the Fall 2020 semester. Therefore, the second and third cohort of this study took non-proctored final exams. On average the 100 non-proctored students of Spring 2020 and Fall 2020 combined scored 83.2% compared to the 90 proctored students of Fall 2019 and Spring 2021 combined at 70.9%. Proctoring resurfaced for the Spring 2021 cohort. Again, the proctored group of Spring 2021 saw an overall decrease in scores from those who were non-proctored with an overall average at 77.9%. The Spring 2021 cohort was proctored but encouraged to use apps. It is believed that the use of apps in this cohort offset the lower scores seen in Fall 2019 when students were proctored with no access to apps.

4.2 Final Exam Instrument

The final exam instrument consisted of fourteen common questions that appeared on the final exam for the semesters of Fall 2019 through Spring 2021. Pearson's MyLab platform was used to create these exams. Of these fourteen questions, Pearson considered three of the questions to be hard, ten to be of moderate difficulty, and one to be easy. Follow up study is needed to mine for understanding at various difficulty levels. Unfortunately, there was not enough data to safely state whether this happened in this study as most all questions fell into the moderate category.

For a breakdown of the fourteen common questions, I looked further into the specific objectives that were most missed by students. Table 3 provides statistics for the entire population (*N=190*). From this I could see that the most missed objective is found in that of question 2, which asks students to use the factor theorem and synthetic division. Pearson's Mylabs rate this problem as moderate difficulty. On average, 60.5% of students answered question number two correctly. The question with the most correct responses, at 94.7%, was that of question 6, asking the students to graph the inverse of a function. Possibly this question rose to the top of the statistics in that it was a multiple-part question. The coding included in the study design was such that a student would be credited as correct as long as they answered any part of a multiple-part question correctly.

Table 4

Assessment Instrument: Final exam data of the 14 common questions (N=190)

Difficulty level	Question #	Pearson Question ID	Objective	Mean correct responses
Moderate	1	3.1.67	Solve applications involving quadratic functions.	.7263
Moderate	2	3.3.31	Use the factor theorem and synthetic division.	.6053
Easy	3	3.3.47	Find zeros of a polynomial function and their multiplicities.	.8526
Moderate	4	3.4.7	Factor polynomial functions and sketch their graphs.	.7684
Moderate	5	3.5.41	Find equations of asymptotes of rational functions.	.8947
Moderate	6	4.1.63	Graph inverses of functions.	.9474
Hard	7	4.2.97	Solve compound interest problems.	.7105
Moderate	8	4.3.53	Graph logarithmic functions.	.8211
Moderate	9	4.3.73	Use properties of logarithms to rewrite expressions.	.6895
Hard	10	4.5.101	Solve applications involving logarithmic and exponential equations.	.6842
Moderate	11	4.4.79	Use the change-of-base theorem.	.7632
Hard	12	4.6.15	Solve applications involving an exponential decay function model.	.7474
Moderate	13	5.1.7	Solve linear systems in two variables by substitution.	.8263
Moderate	14	5.5.15	Solve nonlinear systems algebraically.	.7947

A reliability analysis was conducted for the assessment instrument with a Cronbach's alpha of .776. This value falls in the acceptable range to demonstrate reliability of the instrument. Furthermore, this value demonstrates the internal consistency of the fourteen questions.

Content validity is noted in that each of the fourteen exam questions align to a required competency. Question numbers 9 and 10 are not directly linked but do represent a skill that scaffolds to competency number 4. Additionally, the exam instrument addressed all but one of the KCTCS College Algebra competencies as listed in table 5. Note that competency 8 occurred in content assessed at midterm.

Table 5

Alignment to KCTCS course competencies

	Competency	Alignment with Question #
1	Recognize functions and specify the domain and the range of a given function.	5, 8
2	Graph linear, quadratic polynomial, rational, exponential, logarithmic and piecewise functions.	5, 8
3	Write expressions from data, verbal descriptions, or graph.	4
4	Solve polynomial, rational, exponential, and logarithmic equations.	3, 7, 9, 10, 11, 12
5	Solve application problems using linear, quadratic, exponential, and logarithmic functions.	1, 7, 10, 12
6	Perform operations with functions and find inverse functions.	2, 3, 6
7	Solve linear and nonlinear systems of equations.	13, 14
8	Solve nonlinear inequalities.	

Additionally, this instrument is found to be reliable in that final exam results for students previously enrolled, Spring 2019 and Fall 2018, were similar to those reported in Cohort 1. Cohort 1 may be thought of as a reference group. Students in the Cohort 1 course were taught pre-pandemic, Fall 2019. Cohort 1 experienced final exam testing that was proctored with no cell phones. This testing environment represents the pattern of behavior for ACTC College Algebra final exam assessments prior to the pandemic.

Final exam averages for students enrolled Spring 2019 *(N=60)* was 65.0%. Fall 2018 (*N= 25)* final exam averages were found to be 61.8%. The group from Cohort 1 *(N= 40)* scored an average of 58.9% on the reference test. After cross referencing final exam assessments from Fall 2019 through Spring 2021 I attained the common fourteen questions used in this study. Cohort 1 was found to have scored an average of 62.1% on the final exam instrument used in this study. Therefore, it is believed that despite the elimination of some questions that were not equivalent across semesters for our four cohorts in this study, these fourteen common questions that make up our final exam instrument in this study demonstrate averages that were similar to those found in the reference course.

A further breakdown of the item analysis revealed that the most missed problem for Cohort 1 was question 4. For Cohort 2 question 2 was most missed. Cohort 3 shows a tie between question 2 and 7, and Cohort 4 again with question 2 as the most often answered incorrectly. Question 2 may be difficult in that students cannot readily answer it using apps. This question asks students to factor a fourth-degree polynomial into linear factors, given that k= -2 is a zero of multiplicity two. An app would help in determining the x- intercepts of said polynomial, but students would be required to interpret this finding. Still, it is promising to note that a higher percentage of students answered question 2 correctly when utilizing apps at an average of 63% for Cohorts 3 and 4 compared to 57.8% with no apps in Cohorts 1 and 2.

Table 6

Assessment Instrument: Final exam data of the 14 common questions by semester

Difficulty level	Quest. #	Pearson Quest. ID	Objective	Mean correct responses			
				Fall 19	Spr 20	Fall 20	Spr 21
Moderate	1	3.1.67	Solve applications involving quadratic functions.	.625	.760	.840	.660
Moderate	2	3.3.31	Use the factor theorem and synthetic division.	.550	.600	.680	.580
Easy	3	3.3.47	Find zeros of a polynomial function and their multiplicities.	.625	.960	.900	.880
Moderate	4	3.4.7	Factor polynomial functions and sketch their graphs.	.425	.860	.840	.880
Moderate	5	3.5.41	Find equations of asymptotes of rational functions.	.550	.980	1.00	.980
Moderate	6	4.1.63	Graph inverses of functions.	.875	1.00	.980	.920
Hard	7	4.2.97	Solve compound interest problems.	.700	.760	.680	.700
Moderate	8	4.3.53	Graph logarithmic functions.	.625	.860	.860	.900
Moderate	9	4.3.73	Use properties of logarithms to rewrite expressions.	.525	.640	.900	.660
Hard	10	4.5.101	Solve applications involving logarithmic and exponential equations.	.625	.700	.760	.600
Moderate	11	4.4.79	Use the change-of-base theorem.	.600	.880	.740	.800

Hard	12	4.6.15	Solve applications involving an exponential decay	.700	.780	.740	.760
Moderate	13	5.1.7	Solve linear systems in two variables	.650	.880	.940	.800
Moderate	14	5.5.15	Solve nonlinear systems algebraically	.575	.860	.920	.780

Question 4 shows the most promising result of utilizing apps. This question asks students to look at a graph to factor. This could be considered conceptual in nature as students would need to connect the idea of x-intercepts and zeros of polynomials as well as memorize the cut and bounce rule. In Cohorts 3 and 4, utilizing apps, 86 of the 100 students answered this question correctly compared to 60 of the 90 in the no apps cohorts. The conceptualized problem data is given in table 7 below. Additionally, we don't know if Cohort 2 utilized apps when not proctored. Therefore, the jump noted in Cohort 1 from 17/40 represents a possible case that apps aid in the conceptualization of concepts level.

Table 7

Conceptualized problem

Question	4		
Cohort 1	17/40	67%	NO
Cohort 2	43/50		APPS
Cohort 3	42/50	86%	APPS
Cohort 4	44/50		

Additionally, I have broken down the exam into questions that may be considered application based. Unfortunately, this study contained minimal data to implicate findings. However, we can look at four problems. In this study questions 1, 7, 10, and 12 were phrased in application form.

Table 8

Application-based problems

Question	1		7		10		12		
Cohort 1	25/40	70%	28/40	73%	27/40	69%	28/40	74%	NO
Cohort 2	38/50		38/50		35/40		39/40		APPS
Cohort 3	42/50	75%	34/50	69%	38/50	68%	37/50	75%	APPS
Cohort 4	33/50		35/50		30/50		38/50		

4.3 ANOVA Design and Assumptions

This study utilized an ANOVA model with final exam scores as the outcome variable and proctoring and apps as the two treatments being compared across groups. Final exam scores for each of these four groups were entered in Excel and analyzed in SPSS. There are three underlying assumptions for an ANOVA as listed below (Lane et al., 2003):

- Normality: the populations are normally distributed.
- Independence: Observations and groups are independent of each other.
- Equality of Variance: The populations have the same variance. This assumption is called the assumption of homogeneity of variance.

The first assumption of normality was tested within SPSS. Normality infers that 95% of the data fall within two standard deviations, plus or minus, of the mean. A visual inspection of a histogram is a quick and simple check; however, it can be misleading as the shape is affected by the scaling of the plot. A more rigorous graphical test is a normal probability plot. Shapiro-Wilk Test of Normality revealed a significant result for each cohort and thus means that the normality assumption has not been met. However, this assumption can be relaxed if the sample size is large enough. Even if the raw scores are not normally distributed, the Central Limit Theorem assures us that the sampling distribution of means is normally distributed for large enough samples (Tabachnick & Fidell, 2007). This study involved approximately 50 students in each of the four cohorts and should therefore be sufficiently large and equal among levels. Potentially the population size of cohort 1 with $N= 40$ as opposed to the other three cohorts at $N=50$ caused a disturbance in normality.

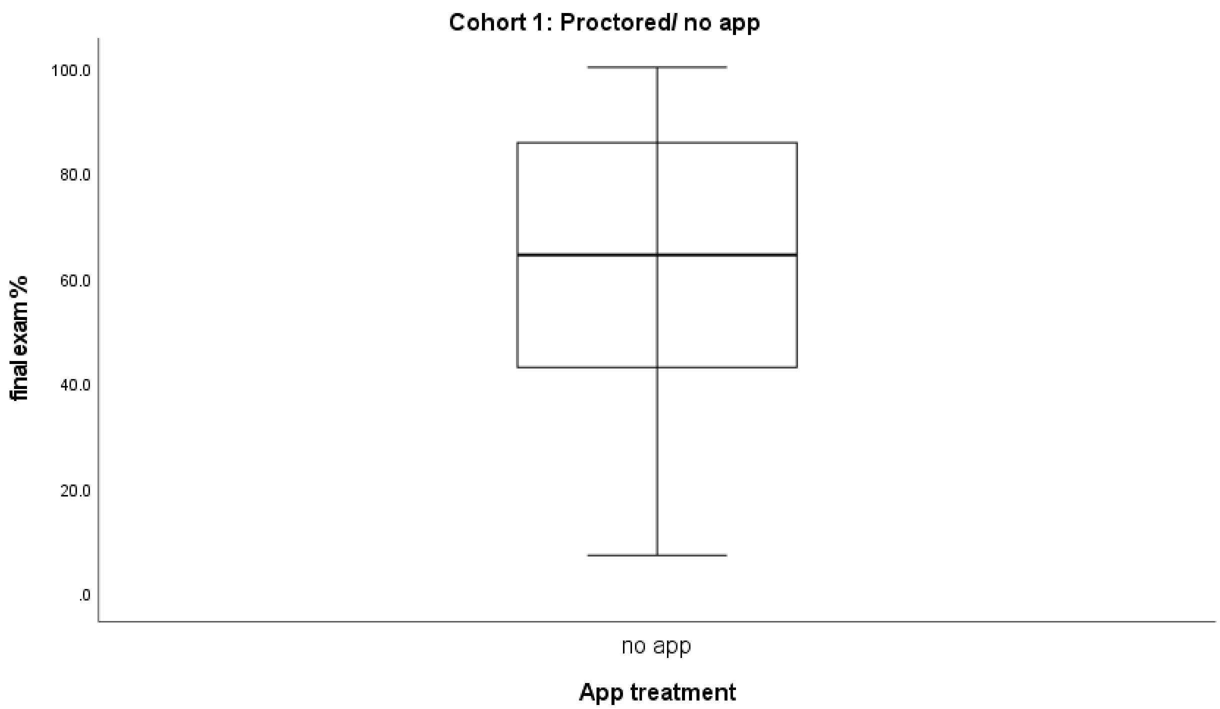
As for the third assumption, homogeneity of variance, ANOVA is again known to be robust in avoiding this violation if there are no outliers, sample sizes are large and fairly equal, the sample variances within levels (or combinations of levels) are relatively equal, and a two-tailed hypothesis is tested (Tabachnick & Fidell, 2007). Futhermore, Tabachnick and Fidell (2007) state that the largest to smallest sample size ratio should be no greater than 4:1. The ratio of largest to smallest variance should be no greater than approximately 10:1. Again the four cohorts of data in this study easily pass these requirements.

The assumption for homogeneity of variance was also tested in SPSS with Levene's Test for Equality of Variances (Levene,1961). Levene's test determines whether the variances are approximately equal. If the significance (Sig.) between two samples is greater than .05, equal variances are assumed. Unfortunately, Levene's Test was significant <0.001. This means that the homogeneity variance assumption was not met, and that the variance of the dependent variable is not equal across groups. This result is noted as a limitation of the study.

Boxplots show the outliers for each cohort. Here I have three total outliers, cases 15, 25, and 63. I choose to include these cases in my data and report this as a limitation once again. Case 63 falls within the second cohort of non-proctored with no apps. Cases 15 and 25 falls within the third cohort of non-proctored with the use of apps.

Figure 1

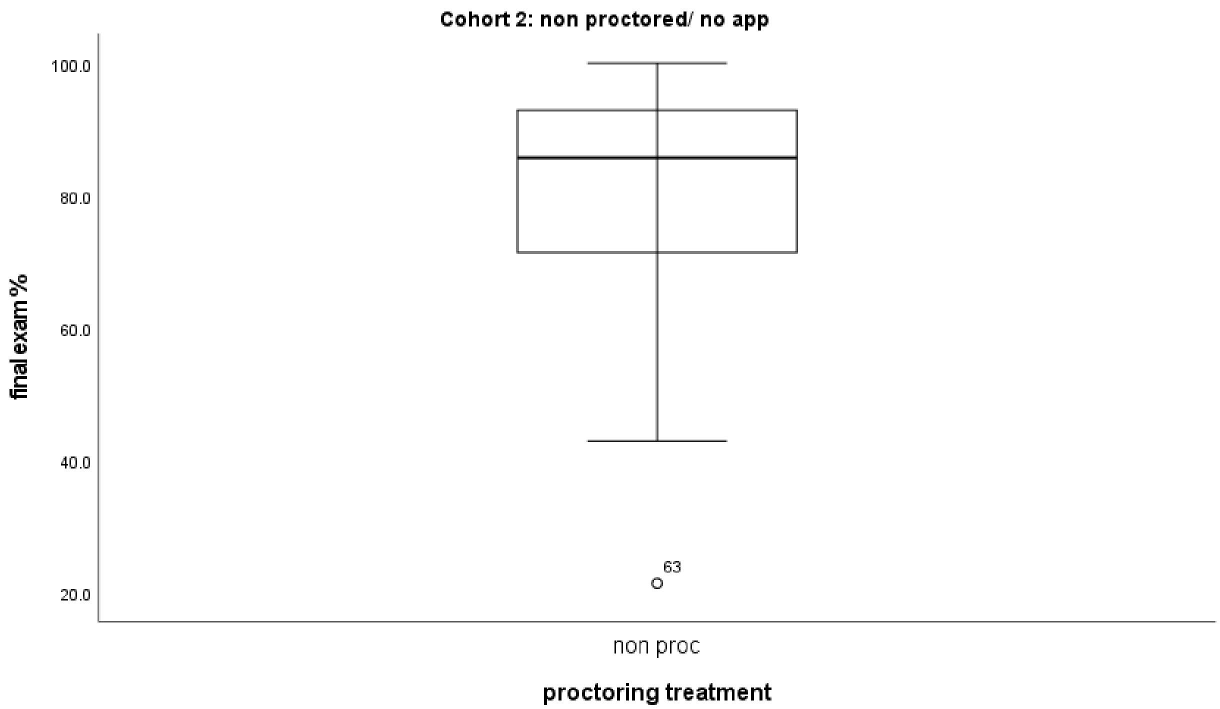
Boxplot for Cohort 1



Note. This figure demonstrates no outliers for the group proctored/no apps. Also, you can see that the median average score for group one was around 64%, the highest score achieved was 100% and the lowest score achieved was around 10%. The third quartile, or top 75%, achieved around 82% or higher.

Figure 2

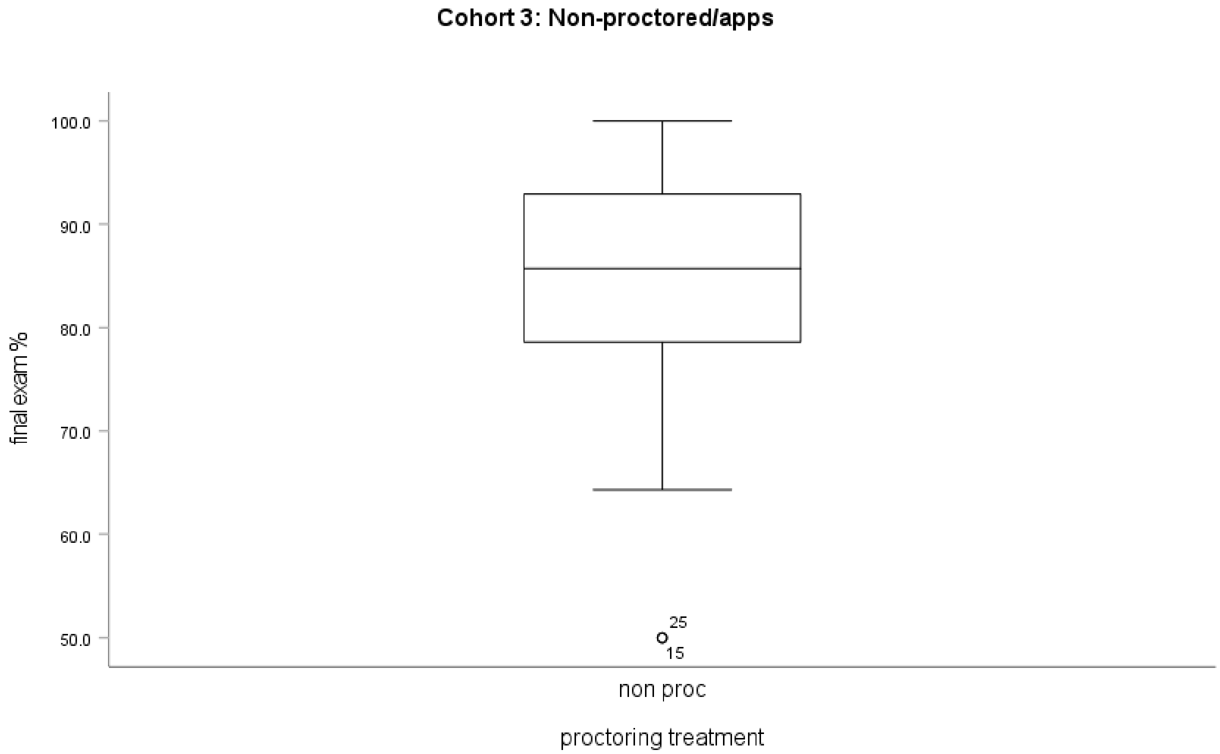
Boxplot for Cohort 2



Note. This figure demonstrates one outlier, case 63 scoring 21%, for the group of non-proctored/no apps. Also, you can see that the median average score for group two was around 86%, the highest score achieved was 100% and the lowest score achieved was around 21%. The third quartile, or top 75%, achieved around 88% or higher. Here you can note a sharp increase in overall scores from the proctored group in figure 1.

Figure 3

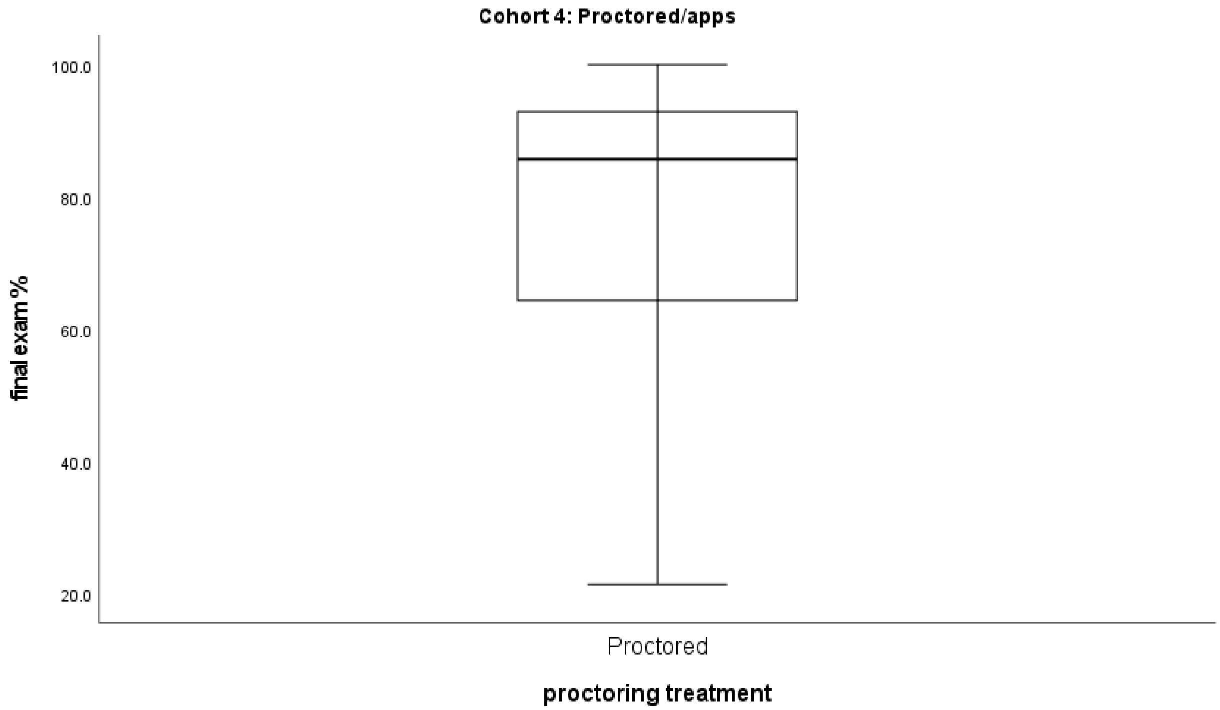
Boxplot for Cohort 3



Note. This figure demonstrates two outliers, cases 15 and 25 scoring around 50% each, for the group of non-proctored/apps. Also, you can see that the median average score for group three was around 86%, the highest score achieved was 100% and the lowest score achieved was around 50%. The first quartile average scores were around 65% when we discount the outliers. The third quartile, or top 75%, achieved scores around 95% or higher. Here again, you can note an additional increase in overall scores from group 2. This group represents the highest average of overall scores of the four cohorts.

Figure 4

Boxplot for Cohort 4



Note. This figure demonstrates no outliers for the group proctored/apps. Also, you can see that the median average score for group four was around 86%, the highest score achieved was 100% and the lowest score achieved was around 20%. The third quartile, or top 75%, achieved scores around 87% or higher. Here, you can note a decrease in overall scores from group 3.

The second assumption of independence is met per the research design. Independence of errors is assumed because groups are formed individually. The four groups in question are independent, randomly enrolled students who showed up on the class rosters. The enrolled students who persisted by the taking of the final exam are included in this study.

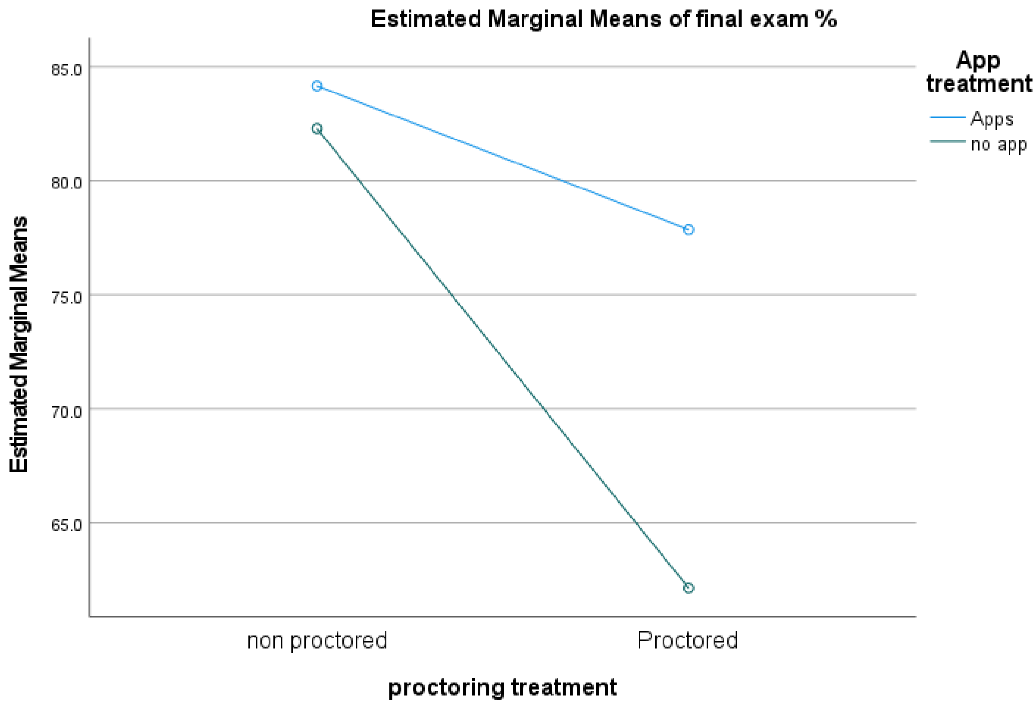
4.4 Results

There is a small difference in the mean scores of those in the apps vs. non-apps cohorts but the big story is the interaction effect. The two-way ANOVA showed a significant interaction between proctoring and apps with an F value of 6.122 and a p-value $< .01$. It was the interaction of apps and proctoring that made the difference. Student's score whether utilizing apps or not were profoundly affected by the proctoring treatment.

The final exam score of a student, given it was a proctored exam or not, depended on whether apps were used. Similarly, the final exam score of a student given the use of apps depended on whether the exam was proctored or not. Additionally, you can refer to Figure 2 to see a visual display of this interaction. Note that students who were not proctored and encouraged to utilize apps demonstrated more success on their final exam score than any of the other cohorts. Additionally, adjusted R squared computed as 0.144 tells us that 14.4% of variance is accounted for in the student final exam score by the proctoring main effect, apps main effect, and the interaction of the two.

Figure 5

Graph of final exam scores compared to each treatment



Note. This figure demonstrates the interaction effect most profoundly. This figure explains that the difference of differences is significant. Here you can see visually that when utilizing the treatment of apps, the means for a proctored exam decline. For students who are proctored without the treatment of apps the mean score also declines, but much more noticeably. Certainly, you can see that the two lines are significantly non-parallel. Here you can see that the use of apps made a difference, but it was the interaction of proctoring that made the most profound effect.

Table 9

Tests of Between-Subjects Effects with Dependent Variable of Final Exam %

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	12792.808[a]	3	4264.269	11.577	<.001
Intercept	1104853.198	1	1104853.198	2999.606	<.001
Proctoring	8222.218	1	8222.218	22.323	<.001
Apps	3636.164	1	3636.164	9.872	.002
Proctoring * Apps	2254.943	1	2254.943	6.122	.014
Error	68509.896	186	368.333		
Total	1218788.710	190			
Corrected Total	81302.704	189			

a. R Squared = .157 (Adjusted R Squared = .144)

SPSS produced an observed power value for the main effects and interaction effects. I used these values to calculate beta. Beta is the probability of committing a Type II error. The beta value for proctoring was 0.003, which informs that there is a 0.3% chance of concluding no significant effect of proctoring on the final exam score when one really exists. SPSS demonstrates a beta of .122 for apps and .308 for the interaction of the two. These values inform that there is a 12.2% chance of concluding no significant effect of the use of apps on the final exam score when one really exists and there is a 30.8% chance of concluding no significant effect of the interaction of proctoring and the use of apps on a student's final exam score when one really exists.

The F-statistic as well as p-value prove statistically significant for all our groups. Thus, we can reject the null hypotheses that proctoring, apps, or the interaction of the two have no effect on final exam scores in our study. We find strong support that each of the independent variables as well as the interaction of the two, affect the outcome variable of final exam score.

CHAPTER 5. CONCLUSION

The pandemic forced more instructors and students to move to online learning. For the first time, many experienced a loosening of the reigns and were forced to allow students to submit non-proctored work. Many may have questioned what students really learned in the year 2020. Many college math course competencies emphasize procedures. Now that apps can do that for students, where does that leave math instructors? Additionally, online instruction has exploded over the last decade and has challenged the teaching of college mathematics. While online instruction opens the door to access, it does beg the question of whether students complete their own work and thus whether proctoring is necessary. These thoughts were heavy on my mind as I conducted this research.

This research sought to answer questions pertaining to the use of apps and proctoring in College Algebra. These two seemed inter-related as a deeper question behind proctoring is whether students use cell phone apps to solve problems and if so, does this circumvent the purpose of the course. The review of literature demonstrated limited work on the two topics individually but appeared to be totally missing the interaction of the two.

Additionally, much of the review of literature found a theme of conceptual versus procedural assessments. This study further addressed this topic in the assessment instrument provided. This study included the analysis of fourteen common College Algebra questions across four semesters. Results showed that proctoring and apps do make a significant difference in outcomes.

My research sought to answer the following questions:

4. In what ways does the presence or lack of a proctor significantly affect exam performance?
5. How does the treatment of the instruction of, and use of, apps affect exam performance?
6. How does the treatment of apps and proctoring interact with regard to exam performance?

5.1 Results

The results showed a statistically significant yes to the question of whether proctoring, apps, or the interaction of the two influenced exam scores. Descriptive statistics showed that the Fall 2019 cohort, that of proctored with no apps, scored the lowest of the four groups with a mean final exam score of 62.1%. The Spring 2021 cohort, that of proctored with apps, followed in second lowest place, with a mean exam score of 77.9%. This aligns with the review of literature that shows that when comparing proctored versus non-proctored results, exam scores tend to be inflated in the non-proctored environment (Allessio et al., 2017; Ardid et al., 2015; Arnold, 2016; Carstairs & Myors, 2009; Daffin & Jones, 2018; Goedl & Malla, 2020; Flesh & Ostler, 2010; Michael & Williams, 2013; Moten et al., 2013; Staats et al., 2009; Trenholm, 2007; Wachenheim, 2009). Additionally, apps demonstrated a higher result with the two cohorts utilizing apps averaging 81% on the exam compared to 73.3% for the no apps group. This again aligns with the literature review in that apps can make a powerful difference in the classroom (Hoang & Caverly, 2013 Shahriari, 2019; Vieyra et al., 2015;). The interaction of proctoring and apps demonstrated the most profound difference with the Fall 2019 cohort of proctored with no apps at 62.1% and the Fall 2020 cohort of non-proctored with apps at 84.2%. Thus, when students were non-proctored and instructed in the use of apps the final exam average was the highest of the four cohorts.

Additionally, the review of literature showed that apps must be infused in the classroom with pedagogy to achieve the desired outcomes (Hernawati & Jailani, 2019; King & Robinson, 2012; Kolb, 2017). Heid and Blume (2008) make the point that the teacher must make decisions on how to use technology in math and be most prominent in the use thereof. This finding is demonstrated in our results as the non-proctored students who were unobserved could have used technology even though they were not instructed in the use thereof. Despite this possibility, we can see a difference in the average means of the cohorts who were instructed in the use of apps at 84% compared to 82% in the non-proctored group. For the proctored group the effect is much more profound at 77.8% compared to 62.1%. This demonstrates that the instruction of apps made a difference in the mean averages of these cohorts.

5.2 Social Cognitive Theory

This research sought to look at data through the lens of Bandura's (Bandura, 1986) Social Cognitive Theory (SCT), Usher's Appalachian research on student's self-efficacy in math and science (Usher et al., 2019), and more specifically on work of Burnett et al. (2016) on how it relates to academic honesty. There is much action to these findings behind the final exam results in that of course design. This study sought to look at students' final exam data in a controlled environment. This controlled environment is hoped to have been one where students encountered a rich course design that drew them to want to learn and feel self-efficacious to engage with the content. One where cheating was not the number one concern. One where I could sense the engagement of students and feel confidence that they were doing their own work because they knew it best.

Step one, according to SCT, is that students must feel some form of self-efficacy to engage in an activity. Bandura (1986) hypothesized that beliefs about one's capabilities derive from four primary sources: 1) Direct experiences of success and failure as indicators of what they can do (and cannot) do, 2) the actions of others as vicarious evidence of their own capabilities, 3) evaluative messages from students' social environment, 4) students' interpretation of their physiological and affective arousal in ways that inform their perceived efficacy.

It is my hope that course lectures and interactions with students allowed for incremental successes that led students to experience math self-efficacy. In person and online sections experienced the "you try" method which allowed students to work in groups or alone to practice in class problems. Additionally, course design gave immediate feedback and multiple attempts to homework/practice problems. After gaining confidence in a skill through practice, students would then take a quiz over the material. This continued until midterm when they took a larger exam. This process was repeated during the second half of the term.

Additionally, apps were noted as a main effect. The average exam scores rose significantly when apps were infused to the learning of College Algebra. The use of the apps in class appeared to have aided in all four areas of student's self-efficacy. Small successes were observed throughout each class in each of the semesters utilizing apps. Additionally, students witnessed other students successfully using the app and compared progress and expectation. Thirdly, positive messages were ample in the observed social environment. And lastly, active learning led to the physiological feeling of success and engagement.

The absence of proctoring was found to inflate final exam scores. This leads to the question of possible cheating. Regardless of course design, SCT explains why some cheating behaviors may be present in the classroom. This research should not be taken as a commentary on students' moral failings but as a natural consequence of human behavior as explained within the SCT framework. Fask et al. (2014) makes a powerful point in that the existence of student cheating on online exams should not only be viewed in the context of the moral failings of the students but should impose a moral burden on the professors and institutions to assure students, potential employers, graduate admissions departments, and other consumers of grade information the grades are genuinely reflective of the learning.

The review of research did find some alternative explanations for the non-proctored inflated scores that should be considered. The relaxed home environment may have provided a comfortable space for students to do their best work. The flexibility to test within a time frame may have provided students with the best optimal time of the day or week to test when most prepared. Alternatively, some students may find their home environments to have greater noise levels, temperature, light, and cognitive distractions compared to standardized proctored settings.

Some research suggest that proctored scores can be better due to the sterile environment and focus on the big event causing the student to study and prepare (Goedl & Malla, 2020; Lanier, 2006; Lorenzetti, 2006). Alternately, this big event can cause some students great anxiety leading to lower results (Woldeab & Brothen, 2019).

According to Hayes and Embertson (2013) highly distractible and anxious students do better in a standardized, controlled classroom than left to their own environment. Fask et al. (2014) believe that the pluses and minuses of non-proctored exams may cancel each other out.

The review contained mixed findings. Regardless, the bulk of the literature maintained that scores would be inflated with non-proctored exams as was found here in my results. It is possible that a variety of factors exists within each testing event with each student at any given time.

5.3 Course Design

The ACTC College Algebra course description states the following: MAT 150 College Algebra (3 credit hours), Includes selected topics in algebra and analytic geometry. Develops manipulative skills and concepts required for further study in mathematics. Includes linear, quadratic, polynomial, rational, exponential, logarithmic and piecewise functions; systems of equations; and an introduction to analytic geometry. Additionally, ACTC's General Education Outcome B (Intellectual and practical skills) includes inquiry and analysis, critical and creative thinking, written and oral communication, quantitative literacy, information literacy, and teamwork and problem solving. Grade inflation may have occurred because of proctoring, apps, or the interaction of the two, but qualitatively it appeared that students were gaining the above stated outcomes in this course. It is my hope that increased success/inflated scores was a byproduct of understanding.

As noted in the introduction, College Algebra is one of the most failed general education courses. About 50 percent of students do not pass College Algebra with a grade of C or above, as noted in a recent report, “Common Vision,” from the Mathematical Association of America (MAA). The report called Americans’ struggle with math the most significant barrier to finishing a degree in both STEM and non-STEM fields (Saxe & Braddy, 2015). Additionally, College Algebra serves to prepare students entering the Calculus sequence. Instructors may struggle to determine whether the ultimate goal of this course is to apply a few things well or acquire a vast skill set necessary to proceed to higher mathematics.

I cannot fully and solely attest to what students really learned in the year 2020, but I believe things worked out well for the circumstances. I was one of those instructors experiencing a first-time loosening of the reigns in the pandemic of 2020 who were forced to allow students to submit non-proctored work. I had always required at least one proctored test per semester to maintain rigor and consistency. I believe the main concern I feel personally, as well as hear expressed by others, is the possibility that a student could completely trick the system. To me, completely tricking the system, would mean that a student understood no College Algebra concept and passed the course, possibly with a strong grade of A. The concern is that a non-proctored test plus an app could possibly encourage this situation. Again, I cannot completely attest that this never happened in these results nor that it never happens in the bigger picture. Regardless, I can say that in the breakdown of my fourteen-question exam, there is not enough app ready questions to pass on that strategy alone. Whether students phoned a friend, again that I cannot know for certain. In a non-proctored environment, we simply can’t be sure of what goes on behind closed doors.

What I can say is that students seemed engaged in learning in all four cohorts. I interacted with most of my students and witnessed what appeared to be genuine student learning behaviors. The in-person app groups appeared to be the most engaged of all students. Live in person sessions, when available, provided ample evidence that active learning engaged student interest.

5.4 Apps

In the semesters Fall 2020 and Spring 2021, the use of cell phone apps was encouraged. Students were instructed in the proper use of multiple apps and told that they could make use of any app available on class assignments. The apps demonstrated in-class lectures were: Photomath, Mathway, and Calculate84. Student feedback demonstrated that students were not simply "cheating" by using these apps but were learning from the use of these apps. For example, Photomath and Mathway will directly answer any solve for x type of problem. However, students learned that they could not always rely on this technology as some problems needed further inspection. Operator error was found to be a big issue in the use of these apps.

Students must first understand the nature of the problem as the app may ask the student a follow-up question. For example, when using Mathway for question 9, the app asked them if they would like to evaluate, expand the logarithmic expression, find the exact value, simplify, or write as a single logarithm. For question 10, Mathway asks the user which variable they would like to solve for; moving forward, the app informs them that it cannot solve that type of problem. This theme continues. I noted that students could soon become frustrated with the app with follow-up questions that make little sense. It is believed that for students to use these tools well, they must possess a frame of reference and some level of understanding about the question presented. In class discussions, it was discovered that the app was a tool to be used. Used wisely, it could aid in understanding and speed up calculations. If a student had no base knowledge of the material, the app could be deemed useless. There are exceptions to this scenario, but it was my experience that a student could not simply pass a test using the apps without some base knowledge of the concepts. One exception may be if an instructor devised a test that only asks students to solve for x and graph equations with no follow up nor conceptual information.

Calculate84 became the favorite app during this study. This app is a replica of a Texas Instrument (TI) 84 calculator. Current pricing puts a handheld TI 84 (Texas Instruments TI-84 Plus CE Color Graphing Calculator) sold on Amazon at $126.04. The cell phone app is free. Furthermore, the display screen is colored, touch screen, and larger than the basic handheld. Students can touch the screen to move a point along a curve. Students were instructed to move the cursor along parabolic curves to estimate the vertex. Furthermore, students were instructed to use the calculate features to pinpoint a local minimum and maximum, as well as find zeros (x-intercepts).

5.5 Application

Additionally, the review of literature showed that students from Appalachia tend to require application to engage in learning (Usher et al., 2019). The review of literature showed that math is best taught using real-life applications and higher-order conceptualizations. A conceptualized, higher-order thinking exam may alleviate the differentiated results found between the proctored versus non- proctored groups. Further study needs to look at application-based assessments compared to theoretical assessments. This study contained minimal data to implicate findings. However, we can look at five problems. In this study questions 1, 7, 10, and 12 were phrased in application form. Additionally question 4 asks students to look at a graph to factor. Unfortunately, no significant findings were present for the application-based problems. However, you will notice a profound effect in conceptualized question 4. In cohorts 3 and 4, utilizing apps, 86 of the 100 students answered this question correctly compared to 63 of the 90 in the no apps cohorts. Regardless, further research is needed on this very important topic.

5.6 Implications

This research encourages instructors to be aware of current apps and proctoring options. To analyze assessments with apps in mind and to design courses that mesh with the reality of new technologies. If procedural questions are posed, then proctoring may be necessary. Additionally, problems can be stated in application form or tied to class experiences. The review of research as well as the results here suggests that grade inflation occurs when proctoring is not present. The implication here is that online, non-proctored, procedural based exams invite cheating behaviors. Social Cognitive Theory suggests this to be a natural consequence of behavior. Instructors possess the responsibility to provide the best course design to address the needs of students and engage them in learning. Therefore, the answers to our questions posed here are complex. As seen in the review of literature, there are many dimensions to the issue of proctoring as well as apps. Careful course design is critical for the success of College Algebra. Proctoring may be necessary for some course designs and not for others. Regardless, careful instructional design can be a step in the right direction. Courses that challenge students to want to learn should be the goal.

This research informs that instructors need to be aware of the multiple facets surrounding course design, SCT, technology, and pedagogy. There may be a time and place for ensuring student work and observing student engagement in content. For example, an instructor may require a student to submit a video or appear in a live classroom interaction to observe the solving of the quadratic formula. Once mastery of this manipulation of algebra is ensured they may allow students to proceed with the use of Photomath and Mathway to speed up such calculations and move on to the application phase. Procedural-based assessments may be done in class or as lower stakes assignments where students may gain credit for their efforts in obtaining necessary algebra manipulation skills. Once procedural-based skills, ones that the app may address, an instructor could ease the proctoring requirement by designing assessments that go above and beyond Bloom's taxonomy level one.

Research seemed to imply that the use of technology must be infused with pedagogy. Thus, the instructor must be front and center to ensure the proper use of technology. If testing a procedure-based skill set, proctoring may still be desirable. Respondus monitoring and other such online monitoring programs, show potential for easing hardships encountered with proctoring. Promising research showed that similar scores were obtained in proctored settings compared to online monitoring (Hylton et al., 2016).

5.7 Limitations

Multiple limitations are noted in this study. We cannot know with certainty what happens behind closed doors. The literature review raises many questions about proctoring and the use of apps. The overall conclusion was that non-proctored students receive inflated scores on exams. That said, there are many discrepancies depending on the type of exam. The literature tended to report that conceptualized, course specific assessments lead to less opportunity for students to cheat. Feinman (2018) spoke of the hierarchy of application as the goal for all learning. This study did not contain a sufficient amount of diverse difficulty and application problems to access this limitation.

Additionally, I do not feel this study was able to address the question of whether Photomath and Mathway went too far in the solving of math problems. I can say that I loved Calculate84 but had concerns with Photomath and Mathway. Students may have cheated with the apps and proctoring but we cannot know how they interacted. Follow up would help decipher findings between the apps. Additionally, even with proctoring in place, is it difficult to observe exactly which app a student is accessing at any given moment. It is possible that students accessed texting, notes, and websites while utilizing smartphone apps.

There were sample size issues in that two ANOVA assumptions were not met. These assumptions were explained in the results section. Levene's Test was significant <0.001. This means that the homogeneity variance assumption was not met, and that the variance of the dependent variable is not equal across groups. Additionally, Shapiro-Wilk Test of Normality revealed a significant result for each cohort and thus means that the normality assumption was not met.

As unintentional as this could be, I cannot guarantee the consistency of the four cohorts. Over the two-year span of this study, our world experienced a pandemic. Even without such a major event, environmental factors, as well as instructor factors can occur.

We cannot rule out such other factors may have been present that effected these exam results in the population under study.

Most notably, we cannot prove causation. We can only know if proctoring is a main effect. In other words, we may wish to theorize that the absence of proctoring inflates final exam scores due to academic dishonesty, but we cannot prove it. This study did not reveal the why behind the effect. The same can be said for the apps factor. We can only know that the use of apps is a main effect. We may wish to theorize that the presence of apps raises final exam scores due to pedagogy that led to the conceptualization of concepts.

5.8 Suggestions for Further Study

Further study is needed on this topic. Further study needs to replicate and expand these results to demonstrate consistency. Further study needs to consider a larger array of questions addressing conceptual versus procedural as well as difficulty levels. Additionally, apps need to be studied further. Do students utilize apps as intended? How far it too far in the use of apps? Is Photomath and Mathway too helpful?

I can say that the experience with this study has opened my eyes to the use of apps and non-proctored exams. Before the review of literature and this experiment I was firmly against non-proctored exams and the use of "cheating" apps. I was convinced that either of these would lead to the end of the world for College Algebra. I found myself identifying with some of the research such as Pape and Prosser (2018) who studied eight highly educated faculty members, who over the course of three years, and 27 full-day trainings could not make peace with their job description, contract, and curriculum promises, to implement a new technology. I was resistance to change in my traditional

College Algebra classroom as I was certain that I was already doing all things possible to maximize success. Due to College Algebra being one of the most failed college courses (Saxe & Braddy, 2015), I was concerned that increased application problems would lead to lower pass rates. This study forced me to look at conceptualized questions and authentic assessments. To my surprise, the infusion of apps was engaging for me and my students. I found more interesting class discussion and understanding of concepts than ever before. As an observer of the in-person experience with students, it certainly appeared that the apps were helping students to gain a deeper/conceptual level of understanding that had not been witnessed in the previous semesters.

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