FACTORS SUPPORTING COLLEGE MATHEMATICS SUCCESS: ORIENTATION, VOICE, AND TECHNOLOGICAL PEDAGOGICAL CONTENT KNOWLEDGE

A Dissertation

by

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ABSTRACT

The purpose of this study was to examine factors supporting college mathematics success. First, effect of a brief high school orientation to mathematical technologies used for college placement testing was examined. Secondly, the voice of participants in this orientation was heard. Finally, bootstrapped orientation data were presented to teachers and instructors of introductory statistics courses as a scaffold to their technological pedagogical content knowledge (TPCK) as these teachers and instructors strive to actively engage students to achieve college mathematics success.

Many entering college students are placed into developmental mathematics classes based on scores from college placement assessments that allow extremely limited use of calculating technology and have various time constraints. Students in a rural central Texas 3A high school that were enrolled in Algebra II course were given pre- and post- tests in Arithmetic and Algebra. Each 20-minute test contained 15 mathematical content questions and one qualitative question. The post-test was given approximately a week after the pre-test. During the week, students were provided time to explore review material using only pencil and paper for the arithmetic review, and a four-function calculator on the algebra review questions. Effects of the orientation were analyzed using mean scores, confidence intervals, effect size, and GLM for whole-group and sub-groups. A paired samples *t*-test was calculated. These effects were discussed.

A case study involving participants of the orientation was conducted. Twelve participants were interviewed after each had entered college. Five themes emerged from these interviews: (1) Knowledge of College Mathematics, (2) Technology and Mathematics,

(3) Mathematics Tests/Assessments, (4) Teaching and Learning Mathematics, and (5) Mathematical Experiences, Hopes and Dreams. Each theme is discussed.

Using Microsoft Excel, bootstrapping is presented to instructors of first year introductory statistics courses in support of student success as instructors' technological pedagogical content knowledge is developed. A course project demonstrating and developing application of computational technology by bootstrapping confidence intervals at the 95 % level using Microsoft Excel is presented. Data from the orientation were further analyzed in the bootstrapping project. Confidence intervals were empirically calculated from bootstrapped resamples of the mean. The number of resamples used was 250 at each of three levels: Over-sampling, at-sampling, and under-sampling. Graphs of bootstrapped confidence intervals, using the Rule of Eye 4, showed statistically significant differences between pre-test and post-test scores for all pairs of data sets.

DEDICATIONS

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To my Lord and Saviour, Jesus Christ.

Who gives me all good things and the strength to have met requirements for this degree.

To my loving husband, Ken.

Whose love, encouragement, support, and late-night driving made this journey a success.

To my beloved children, David, Benjie, Seth, Samantha, and Hannah.

Who encouraged me to become an Aggie “Dr. Mom”.

To my dear grandchildren, Trevor, Emily, Cason, Olivia, Abigail, Breck, and Sarah.

Who provided incentive to enjoy my life while pursuing this degree and battling BC.

To my strong parents, Benny & Nell Lucas.

Whose examples of educational service have inspired me to also serve educationally.

To my encouraging Delta Kappa Gamma International Sorority sisters.

Whose scholarship dollars, love and encouragement helped this dream to become reality.

To my dear friend and colleague, Dr. Anna S. Kantor.

Who encouraged and inspired me with words and food.
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INTRODUCTION

Student Success Quest

President Obama (2009) issued a challenge for the United States to regain the lead in having the highest proportion of college graduates in the world by the 2020. Organizations offering their support for similar goals include The Bill and Melinda Gates Foundation, pledging millions of dollars to support doubling the number of low-income students earning degrees by 2025 and Lumina Foundation for Education, aiming to increase the percentage of people with high-quality degrees by the time frame of 2025 (Parker, Bustillos, & Behringer, 2010). America, needing to develop the necessary workforce of the 21st century in order to hold on to its global prominence, is looking to harness the strengths of its citizenry (Parker et al., 2010). The President has urged every American to enroll in at least one year of postsecondary education in order to help increase America's global competitiveness (Obama, 2009). State policy makers have been similarly urged to support workforce development by empowering and embracing universities and community colleges to develop mechanisms to support postsecondary mathematics success: Mathematics is THE bridge to high paying jobs in STEM (Science, Technology, Engineering and Mathematics) fields (Capraro, 2011). This national focus on college completion has shifted the debate concerning remedial or developmental education from the philosophical view of access vs. excellence to a more evidence-based view of benefits vs. cost (Parker et al., 2010).

History of Developmental Education

Academically underprepared students have been of concern to American higher education since the 1630s when Harvard College provided Latin tutors for incoming students (Breneman & Haarlow, 1998). The first remedial education program that included courses in reading, writing, and arithmetic was offered at the University of Wisconsin in 1849 (Breneman & Haarlow, 1998). In the twentieth century, junior colleges and community colleges began to assume the front role in remedial education (Breneman & Haarlow, 1998).

The Serviceman's Readjustment Act or G. I. Bill of 1944 provided financial aid for education to veterans returning from World War II, thus providing community colleges a financially prepared population of academically underprepared students (Mellow, 2000). Financial aid provided by The Higher Education Act of 1965 removed the cost barrier for all students, thus opening the doors to higher education, effectively making community colleges the Ellis Island of American Higher Education (Breneman & Haarlow, 1998; Mellow, 2000). This influx of students, most of whom were underprepared for higher education experiences, led to the need for assessment testing in the areas of mathematics, reading and writing as a way for proper placement at an appropriate academic level. By the mid 1970s, institutions of higher education such as Navarro Community College of Corsicana, Texas were voluntarily using assessment testing, sometimes with volatile results (T. Stringer, personal communication, May 4, 2012). Assessment testing was federally mandated in the 1980s (Breneman & Haarlow, 1998).

Placement Assessment

The Texas Academic Skills Program (TASP), established in 1987, served as a diagnostic tool and placement device in the areas of mathematics, reading and writing (Breneman & Haarlow, 1998). More recently, the College Board's ACCUPLACER test battery was employed for placement and diagnosis (Mattern & Packman, 2009). However, many students take placement tests without realizing their purpose or the high-stakes nature of the assessment such as placement into developmental studies increasing the cost and time for degree completion (Bailey, 2009; Bailey, Jeong, & Cho, 2010; Safron & Visher, 2010).

Placement assessment testing is poorly understood by high school students, and not well aligned with entry-level courses, only assessing one dimension of college readiness – basic content knowledge (Conley, 2007). As Conley (2010) so aptly states in his address to the National Center for Postsecondary Research (NCPR) Developmental Education Conference, in which he gave comparisons of several college readiness assessment tests including the Computer-Adaptive Placement Assessment and Support System (COMPASS) developed by the American College Test (ACT), ACT, Assessment of Skills for Successful Entry and Transfer (ASSET), ACCUPLACER which was developed by the College Board, and the Scholastic Aptitude Test (SAT):

> The exam score is not designed to provide insight into the specific nature of and reason for any deficiency. It is not clear if the student simply has forgotten material learned previously and needs only to refresh his or her memory, or if he or she has never been exposed to the material in the first place. The test cannot determine if a student needs a small amount of focused review or re-teaching of the material from scratch. It may not be clear if the problem is lack of content knowledge or lack of study skills. In short, while tests may identify deficiencies, they are not particularly useful in helping to identify how to remedy any particular deficiency. (p. 6)

The assessment-placement policy of states can result in developmental education placement when supports and enrollment in college-level classes would better serve some students (Collins, 2009). Parker and colleagues (2010) declared "It is essential that college readiness be measured for the purpose of supporting student success and not for the facilitation of particular enrollment needs or other institutional interests" (p. 26).

Increased Cost of Developmental Education

Community colleges have an open door policy, although the door is not open quite so wide into transferable mathematics courses (Texas Higher Education Coordinating Board [THECB], 2004). It has been quite a shock to many Texas high school graduates to find that "college eligible" was not the same as "college ready" (Bailey et al., 2010; Conley, 2007). Years of mathematics coaching, practicing and instruction have been invested in giving Texas high school students academic support to pass the Exit Level Mathematics TAKS, thus becoming college eligible (Texas Education Agency [TEA], 2008). However, in order to be college ready and actually enroll and succeed in a transferable college mathematics course, certain assessment criteria must be met on tests such as the COMPASS or ACCUPLACER (Bailey et al., 2010; THECB, 2004). When a student's score has failed to meet the criteria, the student is placed in one or more developmental classes (THECB, 2004). Typically, three levels of developmental mathematics courses are used for placement: Basic math skills, Introductory Algebra and Intermediate Algebra (Bailey et al., 2010; THECB, 2004). These developmental classes have been designed to provide support to students who enter college with weak skills (Bailey et al., 2010, Bettinger & Long, 2009).

> The costs of remediation to the taxpayer are substantial, but the financial, psychological, and opportunity costs borne by the students themselves may be even more significant. While they are enrolled in remediation, students accumulate debt, spend time and money, and bear the opportunity cost of lost earnings. In some states, they deplete their eligibility for financial aid. (Bailey et al., 2010, p. 257)

"More and more students and their families believe that a college education is the key to success in the new economy. To respond to students' growing expectation, secondary schools and post-secondary institutions must bring their programs into closer alignment" (Conley, 2007, p.29). These developmental mathematics classes have been costly to students, taxpayers and colleges in terms of time, money and resources (Bailey et al., 2010; Bettinger & Long, 2009). There is evidence that a single standardized assessment actually does a disservice to students from diverse racial and cultural groups (Sedlacek, 2004).

Time Spent in Developmental Education

Placement in developmental coursework extends the time to graduation and increases the cost of a college education for the student's financier whether that be taxpayers in the case of federal financial aid, the student personally, or some other sponsor (Morgan, 2010). More than 50% of all community college students enrolled in at least one developmental class during their college career (Bailey et al., 2010; Calcagno, Crosta, Bailey, & Jenkins, 2007). Students placing into developmental education, particularly the lower levels have diminished odds of eventually moving on to credit coursework (Hughes & Scott-Clayton, 2011). Only 30% to 40% of students that have been referred to developmental courses actually complete the entire sequence of courses to which they were assigned (Bailey et al., 2010). Better outcomes do not seem to result for students assigned to developmental education on the basis of assessments, but the costs of remediation are significant for students, colleges, and taxpayers (Hughes & Scott-Clayton, 2011).

Persistence & Retention of Students Placed in Developmental Education

This one-shot type of assessment for students coming into college can have dire consequences (Venezia, Bracco, & Nodine, 2010). The placement into either developmental education or immediately into transfer-level courses had a terrific impact on students' trajectories: Course placement not only affects the time it takes a student to finish a degree, but also the likelihood the degree will ever be completed (Venezia et al., 2010).

> Students are assigned to remediation on the basis of assessments, but remediation is not clearly improving outcomes. This calls into question not only the effectiveness of remedial instruction, but also the entire process by which students are assigned to remediation. (Hughes & Scott-Clayton, 2011, p. 328)

Considering the implications of developmental education placement and the evidence that incoming students are usually not well informed about assessment and placement policies and practices (Behringer, 2008; Safran & Visher, 2010; Venezia et al., 2010), a need exists to identify and expand strategies aimed at improving awareness of and preparation for college placement assessments (Hughes & Scott-Clayton, 2011). Efforts to minimize the need for developmental education include administering college-readiness placement tests to high school juniors and/or seniors prior to high school graduation to determine if remediation might be needed, then supplying help to master competencies before graduating high school (Collins, 2009).

Student Voices

Students arrive at college with an abundance of baggage. Among this baggage for many students is stress and anxiety concerning whether their mathematical proficiency is strong enough to sustain college level academics. (Hall & Ponton, 2005; NRC, 2001; Quilter & Harper, 1988). Recent state budget cuts have heightened interest and awareness of the amount of time and money that is being consumed by students, many times at the expense of taxpayers, in an effort to strengthen mathematical proficiency (Bailey, Jeong, & Cho, 2010).

The new Completion or Momentum Points Model of funding for Texas two-year colleges makes it fiscally imperative for students to successfully complete both developmental mathematics and first year college mathematics in a timely manner (THECB, 2011b). Our increasingly technical economy demands employees proficient in the Science, Technology, Engineering and Mathematics (STEM) fields (Capraro, 2011; Cohen, 1995; McCormick & Lucas, 2011). Student voices are crucial, yet generally missing in the policy process: Despite many studies concerning placement assessments, little is known about students' related perspectives and experiences (Venezia, Bracco, & Nodine, 2010).

Student Access AND Success

Students need both access and success in completing their degree to keep Texas' economy strong (THECB, 2012). As stated in the THECB (2012) Outcome-based Funding Model Recommendation

> The widening gap between the dramatic growth in enrollment and modest growth in degree completion threatens the state's continued economic competitiveness. Additionally, the rising cost of tuition and fees, combined with constrained state resources, have put a sense of urgency on Texas institutions of higher education to achieve state goals with greater efficiency (p. 6).

Texas is lagging behind in producing enough graduates to meet workforce demands. By 2015, the state will need a 90% increase in graduates in the STEM fields (THECB, 2012). Colleges can be awarded completion points toward their funding for students' completion of a first year college level math course (THECB, 2012) such as Introductory Statistics or MATH 1342.

Technology tools can support students' understanding and reasoning about important statistical ideas (Chance, Ben-Zvi, Garfield, & Medina, 2007). Spreadsheets such as Microsoft Excel have been advocated due to their widespread use in industry and easy access (Chance et al., 2007). Microsoft Excel is prevalent, easy to learn and can be applicable to numerous statistical projects (Rochowicz, 2011). While traditional approaches to teaching statistics focus on skills, procedures, and computations, which do not encourage students to reason or think statistically, projects within a work-based learning environment have a positive effect on the study motivation of students – especially students initially low in self-regulation (Helle, Tynjala & Olkinuora, 2006; Makar & Ben-Zvi, 2011).

Supporting College Mathematics Success

This study will address the need of providing support for college mathematics success for students by orientating exiting high school students to assessment and placement policies and practices, especially concerning the technology use and time constraints, for college mathematics placement assessment. The research resulting from this study will provide insight into the effect(s) of a high school orientation to college mathematics placement assessment. Post-test scores will be compared to pre-test scores. Factors supporting college mathematics success including, but not limited to early orientation, will be investigated as student voices are heard through a case study of approximately 12 student participants. Technological Pedagogical Content Knowledge (TPCK) will be presented to provide scaffolding to teachers of first year statistics courses. A technology project suitable for students in a first year college mathematics course – Introductory Statistics – will be presented by bootstrapping data with Microsoft Excel. Generalizability of the results of the orientation will be explored by use of the bootstrap to empirically compute means along with their 95% confidence intervals from under-sampling, at-sampling and over-sampling. This dissertation study is presented in three articles outlined below, by addressing support for college mathematics success in each of three phases; (1) as students prepare to exit high school mathematics, (2) as students transition into college mathematics, and (3) as students experience a first year college mathematics course.

Article 1

Article 1 answers the research question: Can a high school orientation to the purpose, consequences, time limitation, and restrictions of technology use on college mathematics placement assessments support students' college mathematics success by improving students' scores, and if so, which student groups can benefit most from early orientation? Participants were 88 high school Algebra II students classified as sophomores, juniors or seniors enrolled in a rural central Texas 3A high school who were given a pre-test and post-test in Arithmetic and Algebra computation, as well as a scale on which the student could rate their perceived confidence in these areas. The intervention included time to explore review material using only pencil and paper for the arithmetic review questions, and a four-function calculator on the algebra review questions. Consequences of low mathematics placement test scores were discussed with students.

Mean scores, confidence intervals, and effect size of pre-test scores and post-test scores for whole-group and sub-groups were computed, compared and analyzed. A paired samples *t*-test was calculated using paired pre-test and post-test scores for both Arithmetic and Algebra in each of the areas of computation as well as students' perceived level of confidence. A GLM analysis was carried out. Results and findings were discussed. Recommendations were made.

Article 2

Article 2 answers the research question: How did students who participated in a brief high school orientation to college mathematics placement assessment perceive that orientation experience and what factors do these students believe support college mathematics success?

The population for the case study included in this article consisted of students who participated in a brief orientation to college mathematics placement assessment while in high school. This complex issue was examined by a holistic case study (Verschuren, 2003). Students meeting the criteria of having participated in the orientation to college mathematics placement assessment for this judgment sampling and willing to share their voice of experience were considered as potential data sources (Patton, 2002). The lower variability of complex issues as compared to separate variables justified a small sample size of approximately 12 (Verschuren, 2003). During the progression of the interviews, snowball sampling (Lincoln & Guba, 1985) was used to identify other students with information salient to this study. Data gathered from the interviews were analyzed using the constant comparative method (Lincoln & Guba, 1985). Data were unitized and categorized in an on-going effort to identify patterns. Five themes were identified and discussed.

Article 3

Article 3 answers the research question: By using Microsoft Excel as a technology project platform appropriate for a first-year college introductory statistics course, can under-sampling, at-sampling, and/or over-sampling yield similar results when means and 95% confidence intervals about those means are bootstrapped from original data sets of $50<n<100$?

This study utilized Microsoft Excel to bootstrap empirically computed means along with their 95 % confidence intervals from over-sampling, at-sampling and under-sampling. Technological Pedagogical Content Knowledge (TPCK) (Koehler & Mishra, 2008) of bootstrapping with Microsoft Excel was presented to teachers and instructors of first year college introductory statistics courses in order to support students' college mathematics success. The results of the bootstrapping will serve to inform measurement protocols and provide evidence of generalization of results of data. The study presented in article 1 supplied the original data set. Resamples were produced using Microsoft Excel: 250 over-samples, 250 at-samples, and 250 under-samples (Efron & Tibshirani, 1986). Mean scores along with their 95th percentile confidence intervals for whole group resamples were computed. Results of the three samples were compared and discussed.

CHAPTER II

SUPPORTING COLLEGE MATHEMATICS SUCCESS: HIGH SCHOOL ORIENTATION TO COLLEGE PLACEMENT ASSESSMENT

Motivation

For every 100 middle school students, 93 claimed a desire to go to college, 70 managed to graduate high school, 44 actually enrolled in college and only 26 made it to the finish line with a college degree. Due to remedial coursework, the duration of this college journey was approximately 6.2 years carrying a cost of about $18,000 per year. Postsecondary education became a more realistically attainable goal for students able to have completed their degree within 4 years ("College & Career Readiness", 2013). For these reasons, it is imperative students understand the placement assessment process so as not to undermine their dream of a college degree by languishing unnecessarily in developmental classes.

Learning mathematics with a graphing calculator has been reported to support conceptual understanding more than computational skills (Ganter, 2001). College mathematics placement tests, however, have continued to focus mainly on computational skills (Davis & Shih, 2007). If placement assessments continue to decide the fate of thousands of college-hopeful students each year, this disjunction needs to be addressed (Davis & Shih, 2007).

Assessment Disjunction

Many incoming college freshmen recently passed a high school exit exam such as the Exit Level Mathematics portion of the Texas Assessment of Knowledge and Skills (TAKS) as a requirement to graduate from high school (Texas Education Agency [TEA], 2008).

These TAKS tests were untimed and the mathematics portion of the test required test administrators to supply each student with a graphing calculator (TEA, 2008). On the other hand, most college placement assessments include a timed section forbidding the use of any type of calculator as well as a timed section allowing the use of a only a simple four-function calculator (Texas Higher Education Coordinating Board [THECB], 2004). These two tests as well as the environment in which they are administered are very different, yet the results of each contain critical repercussions. Students' scores on these college placement assessments determine their mathematics college entry level.

College Ready vs. College Eligible

Community colleges have had an open door policy, although the door is not quite so open to transferable mathematics courses. It has been quite a shock to many new high school graduates to find that “college eligible” was not the same as” college ready” (Bailey, Jeong, & Cho, 2010; Conley, 2005). Years of mathematics coaching and practicing have been invested in giving high school students academic support to pass exit tests such as the Exit Level Mathematics TAKS, thus becoming college eligible. However, in order to be college ready and actually enroll and succeed in a transferable college mathematics course, certain assessment criteria must be met on placement assessments such as the COMPASS or ACCUPLACER (THECB, 2004). High school students seemed to be unaware of the content or ramifications of these placement assessments (Kerrigan & Slater, 2010). As many as one million high school graduates per year failed these placement exams while attempting to enroll in college (Strong American Schools, 2008). Curriculum misalignment and poorly communicated expectations have been mentioned as possible reasons for the struggles of first-generation, rural students who successfully navigated their high school mathematics curriculum only to find themselves in developmental mathematics courses (McDaniel, 2012). More effective ways of preparing students to make a successful transition from high school to college was considered to be part of the solution (Bailey & Morest, 2006).

Developmental Education

When a student's score fails to meet criteria, this student is placed in one or more developmental classes (THECB, 2004). Typically there have been three levels of developmental mathematics courses: Basic math skills, Introductory Algebra and Intermediate Algebra. These developmental classes have been designed to provide support to students entering college with weak skills (Bailey et al., 2010). However, the ramifications for enrolling in these noncredit bearing courses are monumental.

> The costs of remediation to the taxpayer are substantial, but the financial, psychological, and opportunity costs borne by the students themselves may be even more significant. While they are enrolled in remediation, students accumulate debt, spend time and money, and bear the opportunity cost of lost earnings. In some states, they deplete their eligibility for financial aid. (Bailey et al., 2010, p. 257)

These developmental mathematics classes have been costly to students, taxpayers and colleges in terms of money and other resources such as time (Bettinger & Long, 2009).

Time Spent in Developmental Education

In an environment of budget shortfalls and cuts, it has become imperative that students and colleges spend technology dollars efficiently and effectively. Mandates to reduce time students spend in developmental courses have been common. The City University of New York (CUNY) allowed only two semesters of developmental work (Epper & Baker, 2009). More than 50% of all community college students have enrolled in at least one developmental class during their college career (Bailey et al., 2010; Calcagno, Crosta, Bailey, & Jenkins, 2007). Data gathered by the Achieving the Dream Initiative gave a dire outlook for students placed into developmental education with just 15% completing their education, 40% only partially completing their education, and 46% failing to complete their first semester (Education Commission of the States, 2010).

Placement

The number of students and their families who believe that a college education is key to success in the new economy has been increasing. To respond to this growing expectation, secondary schools and post-secondary institutions must more closely align their programs (Conley, 2007). It was imperative that all institutions of higher education assure the placement of students into the proper course, the content of which should have been optimal for students in terms of preparedness for college mathematics as well as life beyond college (Johnson, 2007). One of the indicators of college completion for entering freshmen was their mathematics placement (Berenson, Carter, & Norwood, 1992). Possible reasons for students being placed into developmental mathematics classes include skills that are "rusty" from non-use, serious skill deficiencies (Calcagno et al., 2007), or the possibility of having been assessed under unfamiliar time and technology constraints. This study will investigate the third reason.

Method

The purpose of this study was to investigate the effect of orienting high school students to the testing environment of many college placement mathematics assessments. These high school students had recently been tested in the Mathematics TAKS environment that included no time constraint and unlimited use of a graphing calculator. Many college placement assessments such as COMPASS or ACUPLACER have time constraints, as well as restrictions on calculator use (Conley, 2005; Kerrigan & Slater, 2010; Mattern & Packman, 2009). Because of the close proximity to their college entrance, these students were considered to form a highly motivated sample.

Participants

All Algebra II students in a rural central Texas 3A high school were participants in this study that was conducted near the conclusion of the spring semester. These sophomores, juniors and seniors were targeted because of their close proximity to registering for college mathematics; demographics were illustrated in Table 1 and Figures 1, 2, & 3. Their race/ethnicity was approximately evenly distributed between Black, Hispanic and White with one Middle Eastern female student. There were approximately three times as many Blacks in regular classes as in honors classes; two and a half times as many Hispanics in regular classes as in honors classes, and about the same number of Whites in regular class as in honors class. The race/ethnicity of greatest frequency was Whites in the honors class and Hispanics in the regular class. Females accounted for 59.5% of participants. Of the seven Algebra II classes, two classes were considered honors sections and the remaining five classes were considered regular sections. Students in the honors sections were sophomores and had completed Algebra I in the 8th grade. Placement into the honors program was initiated at the conclusion of fifth grade. Students in the regular sections were juniors or seniors and had completed Algebra I in the 9th grade. Sophomores and juniors would have the opportunity to take dual credit mathematics during the upcoming school year with no tuition or book cost to their families if the entrance criteria could be met. Seniors planned to graduate high school and enter college.

Table 1

Demographics of Participants

Class	Female *N*=47	Male *N*=32	Black *N*=25	Hispanic *N*= 27	Middle Eastern *N*=1	White *N*= 26	Class Time	Absentees *N*=9
HL	10	7	5	3	1	8	am	0
HG	9	3	2	5	0	5	am	0
A	3	7	2	5	0	3	am	0
B	12	4	3	7	0	6	am	1
C	7	3	6	2	0	2	am	4
D	1	4	2	1	0	2	pm	2
E	5	4	5	4	0	0	pm	2

Note: HL= Honors with Mrs. L. HG=Honors with Dr. G.

Honors students. In order to be placed as an honors student, TAKS scores, classroom grades and teacher recommendations of the fifth grade students were examined by the sixth grade teachers. After placement in a sixth grade honors class, the student had the option of accepting the placement or rejecting the placement and going back on the regular track. A different teacher taught each of the two classes of Honors Algebra II in the morning containing all sophomores. All honors Algebra II students participated in both the pre-test and post-test. Participant demographics are illustrated in Table 1 and Figure 1.

Regular students. The five regular Algebra II classes were taught by the same teacher, Mrs. L. and all of them contained both juniors and seniors. The juniors planned on enrolling in either pre-calculus for high school credit or dual credit mathematics classes in the upcoming school year. Seniors were planning on graduating high school and entering higher education in either an academic or vocational school.

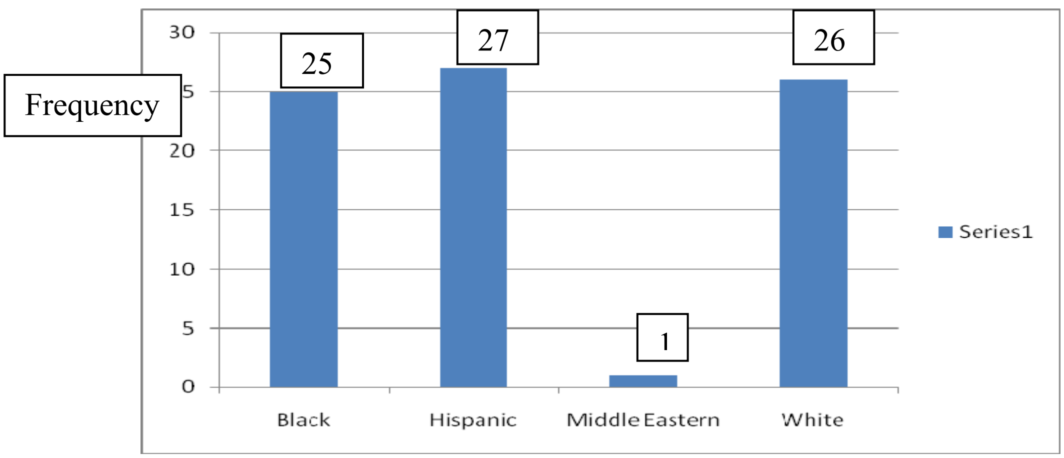


Figure 1. Race/ethnicity of participants.

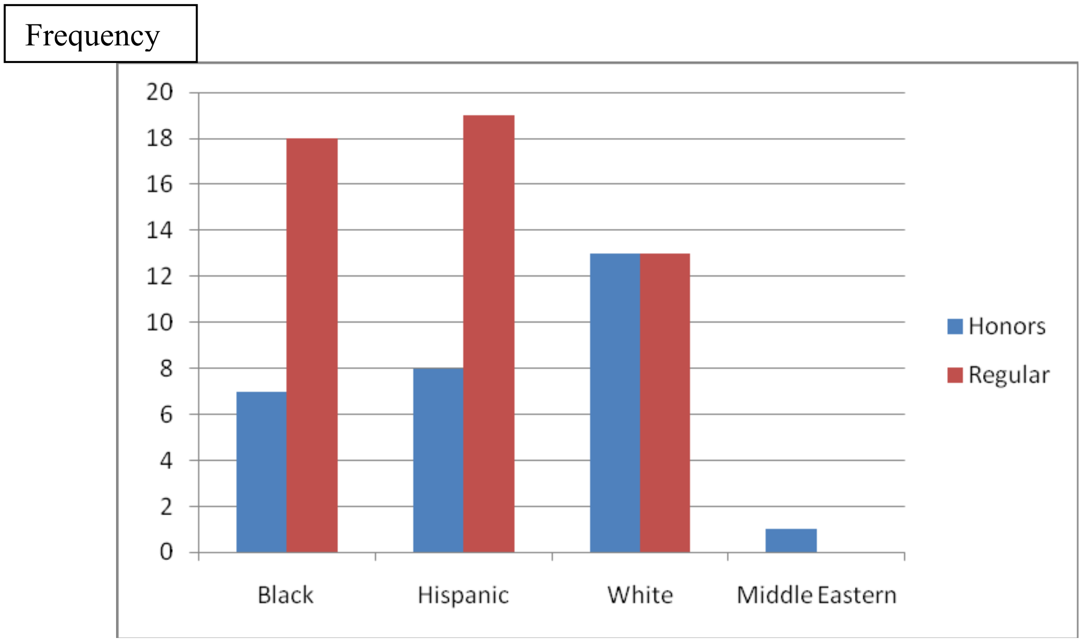


Figure 2. Race/ethnicity partitioned by academic level.

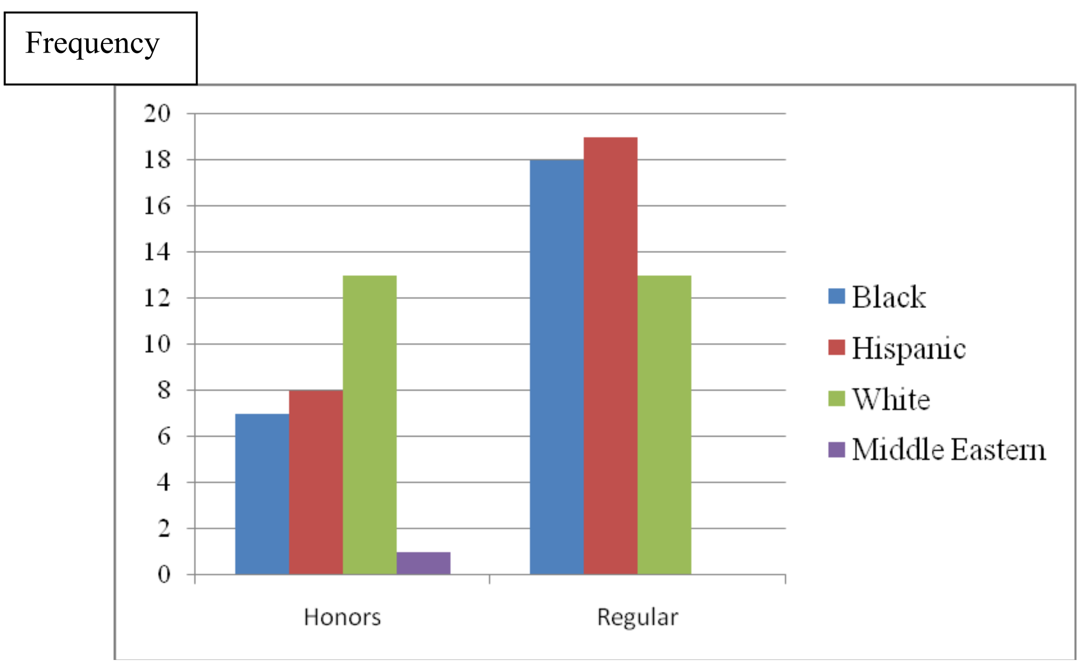


Figure 3. Academic level partitioned by race/ethnicity.

Materials

Each student was assessed with both an arithmetic and algebra pre-and post-test. Each test consisted of 15 multiple choice questions as well as a five-point Likert scale assessment measuring the student's level of confidence on the test. Six versions of the test were used. Each version contained the same questions, in a randomized order, with answer choices also randomized. No calculator was allowed on the arithmetic test and a four-function calculator was allowed and supplied for the Algebra test. A 20-minute time limit was observed on each test. Question topics on the arithmetic test included simplifying, adding, subtracting, multiplying and dividing fractions; finding the area or perimeter of a triangle or composite figure; problem solving with perimeter and/or area and cost of materials; percent, percent increase and percent markup or markdown. Question topics on the algebra test included simplifying, evaluating, adding, subtracting, multiplying, dividing, and factoring algebraic expressions; translating statements into mathematical equations; solving linear and quadratic equations and inequalities; and the application of the Pythagorean Theorem. These topics were chosen from the topics covered on a typical college placement test such as COMPASS and ASSET which are produced by the American College Testing (ACT) service and ACCUPLACER which is produced by the College Board. The confidence scale required students to "Please circle your confidence level on this test". Reply possibilities were 1(Really Bad), 2(Bad), 3(OK), 4(Good), and 5(Really Good). The 20-minute time limit was chosen to give the students a feel for a timed assessment, while allowing both the arithmetic and algebra tests to be administered in the same 48 minute class period.

Each teacher was supplied with practice and review materials that addressed the arithmetic and algebra topics on the pre-tests and post-tests. The review materials were sorted by topics, and included direct instructional materials with examples and solutions, and problems for practice with an answer key for the problems for practice. Arithmetic practice and review was to be pencil and paper only, while algebra practice and review was to be with a four-function calculator. Teachers were encouraged to exercise their professional judgment in the use of the practice and review materials, although they were strongly encouraged to compare and contrast the capabilities of the four-function calculator with the graphing calculators to which students were accustomed. Enough practice and review materials for two weeks were supplied, although only one week of classroom time was allotted for the practice and review.

Each teacher was certified in secondary mathematics. Dr. G. held a PhD in mathematics education from a research 1 institution, and had more than 15 years of mathematics classroom teaching experience. Mrs. L. had just finished her master's degree in school administration, and had 23 years of secondary mathematics classroom teaching experience. Each teacher had about five years experience in middle school mathematics, and the remainder of their experiences were in high school mathematics classrooms.

Procedures

The research was explained to the students on a Day 1. The procedures of taking a pre-test, having an opportunity to practice and review, then taking a post-test were presented to the students. An information sheet was disseminated to each student, and students were assured that they did not have to participate in the research study, although the pre-test, review and practice, and post-test would be considered part of their high school Algebra II grade. The students were instructed to either let their teacher or the researcher know, if they decided not to participate in the research study. No student declined the opportunity to be a part of the study.

Pre-tests were administered on the following day. Each teacher reported that on Day 3 the review and practice topics included fractions, and no calculator was used. Students in Dr. G's class worked independently on their own time. Mrs. L used a whole class approach when working with the fraction review and practice materials. On Day 4, the TAKS results were released to the students, therefore, there was little time to work on the research review and practice materials, although Dr. G did hand out some review and practice materials on decimals for the students to work through independently over the weekend. All of Dr. G's Algebra II students were honors students. On Day 5, each teacher had her class focus on the algebra practice and review materials using paper and pencil as well as the four-function calculator. Ms. L's classes worked in dyads on Tuesday Day 6, splitting their time between arithmetic and algebra. Dr. G's class worked in small groups on a practice arithmetic test, using only paper and pencil. On day 7 the post-tests were administered.

Analysis

The differences between the post-test scores and pre-test scores were analyzed by whole group through paired samples *t*-tests (see Table 2). Effect sizes, Cohen's *d* scores, and 95% confidence intervals were computed for the differences between mean scores of the whole group as well as various subgroups. SPSS was used to compute the paired samples *t*-tests and confidence intervals. Cohen's *d* and effect sizes were computed using the calculator on the website located at http://www.uccs.edu/~faculty/lbecker/#meansandstandarddeviations. The GLM analysis was performed in SPSS, with fixed factors of Gender, Ethnicity and/or course level (regular or honors). Results of statistical analysis were displayed in appropriate graphs and tables. If a positive effect size existed, or *p*-values < 0.05 from the paired samples *t*-test, or 95% confidence intervals contained all positive endpoints, the intervention of familiarizing and orientating students to calculator and time constraint on college placement assessments was considered effective. Effect sizes in excess of 0.33 or below -0.33 will be discussed.

Results

To compare post-test scores with pre-test scores, data were first analyzed in paired samples *t*-tests (Table 2). The mean difference in the post-test and pre-test of all four assessments was positive and statistically significant ($p < 0.01$). All endpoints of the 95% confidence intervals were positive, indicating positive changes from pre-test to post-test on all four assessments. Subgroups were then analyzed individually on each of the four assessments (see Tables 3, 4, 5, & 6). In each of the paired samples, the pre-test score was subtracted from the post-test score, the mean value, standard deviation of the mean value and a 95% confidence interval of the mean value were computed. Effect size and Cohen's *d* values were computed for each subgroup in each of the four assessments in order to determine not only statistical significance but practical significance as well.

Results of the difference of the Arithmetic post-test scores from the Arithmetic pre-test scores are summarized in Table 3. All mean values were positive, and no confidence interval included zero, indicating gains for all groups and subgroups from the pre-test to the post-test in arithmetic. Effect sizes ranged from 0.2 to 0.4, indicating a small, but positive effect size. The greatest effect size (0.4) was observed with the Honor students. Effect sizes of 0.3 were observed in the subgroups of female students, black students, and Hispanic students, while the remainder of the subgroups (male students, white students, and regular students) all reported an effect size of 0.2. Results of the difference in the Likert scale response to the self-confidence question from the Arithmetic post-test compared with the Arithmetic pre-test are summarized in Table 4.

Table 2

Results of Paired Samples t-test

Post-Test – Pre-Test	Mean difference	Lower 95% CI	Upper 95% CI	Significance (two-tailed)
Arithmetic	1.461	0.868	2.053	0.001
Algebra	0.908	0.391	1.425	0.001
Arithmetic Question	0.373	0.138	0.609	0.002
Algebra Question	0.323	0.108	0.54	0.004

Table 3

Results of Arithmetic Assessments: Difference of Post-test and Pre-test

Arithmetic: Post-Test - Pre-Test

	N	*M*	*SD*	*95% CI lower limit*	*95% CI upper limit*	Cohen's *d*	Effect size
All	76	1.5	2.6	0.9	2.1	0.5	0.2
Female	45	1.8	2.4	1.1	2.5	0.6	0.3
Male	30	1.1	2.8	0.01	2.1	0.3	0.2
Black	23	1.4	2.2	0.5	2.4	0.6	0.3
Hispanic	26	1.5	2.9	0.3	2.6	0.5	0.3
White	25	1.5	2.8	0.3	2.6	0.5	0.2
Regular students	46	0.9	2.6	0.1	1.7	0.3	0.2
Honor students	29	2.5	2.3	1.6	3.3	0.9	0.4

Table 4

Results of Arithmetic Self-Confidence: Difference of Post-test and Pre-test

Arithmetic Self-Confidence: Post-test – Pre-test

	N	*M*	*SD*	*95% CI lower limit*	*95% CI upper limit*	Cohen's *d*	Effect size
All	70	0.36	0.99	0.13	0.60	0.40	0.20
Female	39	0.50	0.95	0.12	0.81	0.60	0.29
Male	30	0.27	0.98	-0.1	0.63	0.27	0.13
Black	22	0.55	1.17	0.03	1.07	0.55	0.27
Hispanic	23	0.41	0.81	0.06	0.76	0.51	0.25
White	23	0.26	0.93	-0.14	0.66	0.27	0.13
Regular	40	0.40	1.08	0.06	0.74	0.42	0.20
Honor	29	0.40	0.81	0.09	0.70	0.50	0.24

All mean values reported were positive, indicating a gain in self-confidence from the pre- to the post-test. The subgroups of male students as well as white students generated the lowest positive mean value of all groups, as well as the lowest Cohen's *d* scores. Confidence intervals do include zero for these subgroups, indicating the possibility of no real gain in self-confidence from the pre-test to the post-test in arithmetic. Algebra post-test and pre-test results were compared and summarized in Table 5.

Table 5

Results of Algebra Assessments: Difference of Post-test and Pre-test

Algebra: Post-Test - Pre-Test

	N	*M*	*SD*	*95% CI lower limit*	*95% CI upper limit*	Cohen's *d*	Effect size
All	76	2.2	3.2	1.5	2.9	0.3	0.2
Female	45	2.6	2.8	1.7	3.4	0.4	0.2
Male	30	1.6	3.7	0.2	3.0	0.1	0.1
Black	23	3.4	3.0	2.1	4.7	0.5	0.3
Hispanic	26	1.5	3.0	0.3	2.7	0.1	0.1
White	25	1.5	3.4	0.1	2.9	0.3	0.2
Regular	46	1.4	3.1	0.5	2.3	0.3	0.2
Honor	29	3.3	3.0	2.2	4.5	0.4	0.2

All groups and subgroups reported a positive mean value, indicating a gain in proficiency from the Algebra pre- to post-test. There were no 95% confidence intervals that included zero, giving more evidence of gain for all groups and subgroups. Extremely small (0.1), although positive, effect sizes were reported in the subgroups of male students and also Hispanic students. The greatest effect size (0.3) was generated by the subgroup of Black students. Results of the Algebra self-confidence question are displayed in Table 6.

Table 6

Results of Algebra Self-Confidence: Difference of Post-test and Pre-test

Algebra Self-Confidence: Post-Test - Pre-Test

	N	*M*	*SD*	*95% CI lower limit*	*95% CI upper limit*	Cohen's *d*	Effect size
All	70	0.33	0.92	0.11	0.55	0.39	0.19
Female	39	0.51	0.89	0.22	0.8	0.61	0.29
Male	30	0.1	0.92	-0.25	0.45	0.11	0.06
Black	22	0.23	0.86	-0.15	0.61	0.25	0.13
Hispanic	23	0.3	0.81	-0.05	0.65	0.44	0.22
White	23	0.52	1.07	0.06	0.99	0.54	0.26
Regular	40	0.33	0.83	0.06	0.59	0.42	0.20
Honor	29	0.35	1.05	-0.06	0.75	0.36	0.18

All mean values reported were positive indicating an increase in self-confidence on the Algebra assessments from the pre-test to the post-test, although four subgroups reported the possibility of a zero in the 95% confidence interval: These four subgroups were male, Black, Hispanic and honor. Females reported the greatest effect size (0.29), while males reported the least effect size (0.06) on the Algebra self-confidence measure.

The GLM analysis (see Table 7) showed that the benefit for Hispanic students as a group in the Algebra self-confidence question was significant. On the Algebra test, the GLM analysis indicated the greatest benefit for females as a whole. An improvement was also shown Black females in regular Algebra II, and Hispanic females in regular Algebra II.

Table 7

Results of GLM Analysis: Difference of Post-test and Pre-test

Test/Group	Parameter Estimate B	Significance (p-value)	Mean	N
Algebra/Hispanic, Female, Regular	8.371	0.043	0.670	6
Algebra/Black, Female, Regular	8.371	0.049	3.000	10
Algebra/Female	6.455	0.007	2.620	39
Algebra Question/Hispanic, Female	2.886	0.019	0.304	23

Discussion

Timely and efficient use of higher education resources is imperative. Methods that assist students in streamlining their mathematical journey through post-secondary education into career readiness should be implemented. Developmental mathematics courses can be costly speedbumps in this journey, and can sometimes even become a roadblock or time-consuming detour. This study found that orienting high school students to the testing environment of college placement mathematics assessments can be one of the methods that helps make the journey smoother. All four of the assessments showed a statistically significant increase from pre-test to post-test scores with the highest increase manifesting in the Arithmetic assessment. The highest gains in the arithmetic assessment were reported by honors students (Cohen's $d = 0.9$), Black students (Cohen's $d = 0.6$), and female students (Cohen's $d = 0.6$). Self-confidence scores showed the largest gain among female students (Cohen's $d = 0.60$) and Black students (Cohen's $d = 0.55$). The results of this study showed that in a very brief period of time - only 3 instructional days and 3 non-instructional days - motivated high school students were able to refresh their prior knowledge and develop sharper pencil and paper arithmetic skills, as well as raise their levels of arithmetic self-confidence.

Calculators can be considered anything from a mindtool to a cognitive landmine. Summative testing requirements that forbid calculator usage through 8th grade have been juxtaposed against required graphing calculator usage from grades 9 through 11. This "none or one" philosophy of calculator technology use has hampered efforts in developing appropriate and powerful calculator skills in mathematics classrooms at all levels of education. Teachers should be given the encouragement and freedom to choose to use any or many of the plethora of mindtools presently available in order to mathematically prepare students for their technology-rich future. Students involved in this study received only 3 instructional days and 3 non-instructional days to become familiar with a four-function calculator rather than the graphing calculator to which they had become accustomed, possibly even dependent upon. This study reported gains from pre-test to post-test on the Algebra assessment for all students as well as all groups. The largest effect size (Cohen's d =

0.5) was reported by Black students, closely followed by female students (Cohen's $d = 0.4$) and honor students (Cohen's $d = 0.4$). The GLM indicated Hispanic, as well as Blacks, females in regular classes derived the greatest benefit (B=8.371) from the orientation on the Algebra test, and female students as a whole realized a gain (B=6.455) from the orientation on the Algebra test. Hispanic students as a group showed a gain (B=2.886), according to the results of the GLM analysis, on their Algebra self-confidence level. Self-confidence levels showed the highest gains from pre-test to post-test for female students (Cohen's $d = 0.61$). These results indicate high school students who are mathematically college eligible, can become closer to being mathematically college ready through orientation to the time and calculator constraints found in many college placement assessments.

Conclusions

The landscape of mathematics education is rapidly changing. On one hand, our nation is in desperate need of more college graduates in STEM fields if we are to meet the goals of *Closing the Gaps by 2015* (THECB, 2012). On the other hand, many states are lowering the mathematics requirements for high school graduation (TEA, 2013), and compacting the common core for undergraduate education (THECB, 2011).

Further research is needed to determine additional factors that support success in college mathematics. As new funding formulas (THECB, 2012) are tweaked and implemented, high school graduation requirements are restructured (TEA, 2013), and the undergraduate core is compacted (THECB, 2011), the need for students to be accurately placed into their first year mathematics course is critical. For those students placed into developmental mathematics, it is imperative that timely and effective ways to support their journey to college level mathematics be identified.

Teachers need to be asking the deep, robust question of how technology can be used to engage meaningful learning (Jonassen, Howland, Marra, & Crismond, 2008), rather than simply viewing the short-term goal of how technology can be used to raise the next test scores. This meaningful learning with mathematical technological tools that will support college mathematics success will provide students with computational agility with a variety of technology tools, ranging from pencils to spreadsheets.

The calculator wars continue to rage on in mathematics education, although the question under argument, "Should students be allowed/required to use calculators in mathematics class?" is really not the question at all. The question that should be debated is a more philosophical one concerning the very nature of mathematics. A view of mathematics as a static set of rules will yield the idea that calculators are "cheating" and should be banned from mathematics entirely. A view of mathematics as a dynamic and evolving discipline will yield an embracement of the effective integration of technology of all types in the mathematics classroom. A deep understanding of, and appreciation for, the beauty and utility of mathematics will motivate a teacher to seek and gain technological knowledge that can be integrated into the mathematics classroom. Good research practices and further research will help identify what that effective integration of technology might look like.

CHAPTER III

SUCCESS IN COLLEGE MATHEMATICS?!

STUDENT VOICE IDENTIFIES SUPPORTING FACTORS

Introduction

Increasing student success in mathematics is imperative if the goals of *Closing the Gaps by 2015* are to be met (Texas Higher Education Coordinating Board [THECB], 2012). Texas lags behind in producing enough graduates to meet workforce demands in STEM (Science, Technology, Engineering and Mathematics) fields, in fact, graduation percentages in these fields need to increase by 90% just to meet the goals of *Closing the Gaps by 2015* (THECB, 2012). Students arrive at college carrying stress and anxiety concerning whether their mathematical proficiency is strong enough to sustain college level academics (Hall & Ponton, 2005; National Research Council [NRC], 2001; Quilter & Harper, 1988). Recent state budget cuts have heightened interest and awareness of the amount of time and money that is being consumed by students, many times at the expense of taxpayers, in an effort to strengthen mathematical proficiency (Bailey, Jeong, & Cho, 2010). The new Momentum Points or Completion Model of funding for Texas two-year colleges makes it fiscally imperative for students to successfully complete both developmental mathematics and first year college mathematics in a timely manner (THECB, 2011b). Our increasingly technically driven economy demands employees proficient in the STEM fields (Capraro, 2011; Cohen, 1995; McCormick & Lucas, 2011).

Student voices are crucial, yet generally missing, in the policy process. Despite many studies concerning placement assessments, little is known about students' related perspectives and experiences (Venezia, Bracco, & Nodine, 2010). This case study research comes in response to the urgent need to support students' successes in college mathematics and will address the need for these crucial student voices to be heard.

Methodology

Case study is a research vehicle allowing for a deeper level of understanding and explanation than conventional survey or experimental design is able to provide: Case study provides a thick description and interpretation of the phenomenon (Merriam, 1985). As such, case study is suitable for pondering questions of how or why (Corcoran, Walker, & Wals, 2004) and is especially suitable for studying phenomena that are embedded in their context and/or are highly complex (Verschuren, 2003). College mathematics placement is highly complex, and deeply embedded in the context of the student (Hall & Ponton, 2005).

A case is a unique, specific, bounded system (Hayes & Singh, 2012). "Qualitative case study is an intensive, holistic description and analysis of a bounded phenomenon such as a process " (Merriam, 1988, p. xiv). Case study is defined by significance in an individual case (Stake, 2005). This case was bounded by the specific and unique students that participated in the orientation to college mathematics placement assessment, a significant event in their college readiness journey. Providing insight into the issue of orientation to college mathematics placement assessment and other factors that support college mathematics success were the underlying themes of this instrumental case study (Stake, 2005). The disposition students have toward mathematics is a major factor in determining their educational success (NRC, 2001). The essence of a naturalistic study is the ability to portray social contexts in order to share constructed realities with consumers and stakeholders, and to construct new realities enhancing the knowledge of both the researcher and the stakeholders (Erlandson, Harris, Skipper, & Allen, 1993). Researchers viewing life through naturalistic lenses sense multiple socially constructed realities that cannot be separated into independent parts, but ought to be studied holistically in the light of a particular context or natural setting (Lincoln & Guba, 1985; Neuman, 1989). The study of human behavior and the context in which that behavior happens is the rich environment for this naturalistic study (Erlandson et al., 1993).

Case study has been found to help transform public thinking and create passionate arguments concerning educational policies and practices (Tierney, 2000). Transferability of this study was supported by thick description of the data and purposeful sampling of participants (Lincoln & Guba, 1985). This case study will append the existing knowledge base by exploring early orientation to college mathematics placement assessment and its subsequent effect on students' college mathematics placement and experiences through student voice.

The motivation for this case study was intrinsic. The researcher's positionality stemmed from having professional experience with the education of students of high school mathematics, college developmental mathematics, as well as transferable college mathematics; and therefore, has an internally guided interest in this particular case or phenomenon (Stake, 2005). This "virtuous subjectivity" of the researcher served to allow for a thick description of the data, framed the study's process and paved the road for the study's outcome (Hayes & Singh, 2012; Peshkin, 1988). This qualitative research study was conducted and perceived through the lens of a mathematics teacher-instructor-professor who has observed the before, during, and after of developmental mathematics education along with its effects on individual students' lives and career choices, as well as the lives of their families.

Research Question

How did students who participated in a brief high school orientation to college mathematics placement assessment perceive that orientation experience, and what factors do these students believe support college mathematics success?

Case Boundary

Many entering college students are placed into developmental mathematics classes based on scores from time constrained college placement assessments that allow extremely limited use of calculating technology (Conley, 2005; Kerrigan & Slater, 2010; Mattern & Packman, 2009). Students in a rural central Texas 3A high school Honors Algebra II or Algebra II class were given pre- and post-tests in Arithmetic and Algebra. Each 20-minute test contained 15 mathematical content questions and one qualitative question asking the student's level of confidence on that particular test. The post-test was given approximately a week after the pre-test. During the week, students were provided time to explore review material using only pencil and paper on the arithmetic review questions, and utilizing only a four-function calculator on the algebra review questions (Alpert, 2013). These students who experienced this brief orientation to the time and technology constraints imposed on many college mathematics placement assessments will be the bounds of this case study.

Data Sources

Students who experienced the orientation to college mathematics placement assessment comprised the bounds, thus the population, for this case study. Potential data sources were students who agreed to be interviewed, thus forming a judgment sampling (Patton, 2002). Students willing to share their voice and opinions of the orientation as well as their experiences with college mathematics formed this purposive sample which was diverse in terms of gender, ethnicity, and mathematical proficiency (see Table 8) providing rich data.

Sampling was done in a way to maximize the scope and range of information obtained to a point of redundancy (Lincoln & Guba, 1985). The small sample size was justified by the lower variability of complex issues as compared to separate variables (Verschuren, 2003). During the progression of the interviews, snowball sampling (Lincoln & Guba, 1985) was used to identify other students within the case having information salient to this study. This purposive sample was 12 participants (see Table 8), as the data collected had reached the point of saturation (Erlandson et al., 1993; Guest, Bunce, & Johnson, 2006; Hayes & Singh, 2012; Lincoln & Guba, 1985) and was chosen in order to augment the discovery of various patterns and problems occurring concerning appropriate college mathematics assessment, mathematics placement, and factors that support college mathematics success (Erlandson et al., 1993).

Data Collection

Data were collected through informed consent (see Appendix A) interviews and observations in order to provide a thick description of mathematical experiences of the participants, their perception of the high school orientation to college mathematics placement assessment, and factors they believed did or would have supported their success in college mathematics (Erlandson et al., 1993; Hays & Singh, 2012; Merriam, 1985). An interview protocol (see Appendix B) served as a guide for the in-depth, semi-structured digitally recorded interviews that were initially conducted with participants. These interviews provided the data for deep, rich voices that resonated with the mathematical experiences, perceptions and beliefs of these students (Hays & Singh, 2012; Merriam, 1985).

Table 8

Demographics of Participants

	Male	Female	Dual Credit	College Mathematics	Developmental Mathematics	Honors Algebra II	Regular Algebra II
Black	1	2	1	2	0	1	2
Hispanic	2	1	2	0	1	2	1
Middle Eastern	0	1	1	0	0	1	0
White	0	5	5	0	0	5	0
Total	3	9	9	2	1	9	3

Contact was initiated by the researcher with a participant during a happenstance face-to-face meeting during which e-mail addresses and cell phone numbers were exchanged. Snowball sampling occurred when this participant shared other participant's e-mail addresses and cell phone numbers with the researchers. Some e-mail addresses were obtained by the researcher from FaceBook, after participants had accepted the researcher's friend request. Arrangements for interviews were accomplished through texts, e-mails and face-to-face meetings. Participants chose the site and time for their interviews. Sites of interviews included restaurants and various locations on the local community college campus such as the researcher's office, student lounge, and/or unused classrooms. Time of interviews ranged from early morning to late evening. Participant names were masked with pseudonyms in the report to ensure confidentiality (Hayes & Singh, 2012). The researcher conducted naturalistic observations during these interviews and recorded these observations as field notes in a reflexive journal as soon after the interview as possible (Erlandson et al., 1993). Memos and reflections of the researcher before and after the interview were recorded in the reflexive journal. The interview protocol was continually updated based on results of previous in-depth interviews, document analysis of the reflexive journal, and peer de-briefing (Hays & Singh, 2012; Lawrence-Lightfoot & Davis, 1997). Follow-up interviews were conducted for data clarification as needed (Merriam, 1985).

Peer debriefing built credibility by providing alternative explanations, playing the devil's advocate, and allowing the researcher to think aloud, vent emotions and/or frustrations (Erlandson, et al., 1993). A peer debriefer was selected who has 15 years experience teaching in university, community college, junior high and high school environments. This peer debriefer is the inquirer's peer as she has recently been awarded her doctoral degree and is familiar with not only the academic area but also the method of inquiry (Lincoln & Guba, 1985).

Each participant was provided a copy of the consent form (see Appendix A), allowed enough time to read the form, then given a brief explanation of the form with elicitation of questions concerning the form, then requested to sign the form (see Appendix A). The researcher kept the signed copy of the consent form, and provided an unsigned copy of the consent form to each of the participants. Researcher and participant each had a copy of the interview protocol questions. Participants were given a copy of the interview protocol questions to keep. The researcher complied by the following standards to ensure confidentiality: 1) identification of all participants by a code; 2) omission of details that could attribute a quotation to a specific individual; and 3) omission of details that could identify any of the participants (Gonzalez, 2004).

Member checks are considered the most important activity in establishing credibility, thus trustworthiness (Erlandson et al., 1993; Lincoln & Guba, 1985) and were carried out during the interview, at the conclusion of the interview, after interview data had been transcribed, and after the final case study report had been composed. After each interview was transcribed, a copy of the interview was e-mailed to the participant, asking for a review of the file for accuracy and completeness. Four participants responded with no changes to the data.

Data Analysis

Qualitative data analysis for this holistic case study was an ongoing, iterative process of sense-making: First by a detailed description of each of the participants, then by a deeper, more reflexive inspection of the data for emergent themes (Erlandson et al., 1993; Lincoln & Guba, 1985). Interviews and reflexive journal entries were transcribed into written transcripts. The emergent design was a result of continuous data analysis (Lincoln & Guba, 1985). Data were analyzed using the constant comparative method of content analysis including unitizing the data, forming categories and identifying patterns that suggest a shared reality (Lincoln & Guba, 1985). Names of individuals were removed from the analysis in order to maintain confidentiality (Lincoln & Guba, 1985). Peer debriefing was an on-going process occurring after each interview, after each interview transcription, and as themes were emerging, and was utilized to help establish credibility (Lincoln & Guba, 1985).

Credibility was additionally supported by member checking (Hayes & Singh, 2012; Lincoln & Guba, 1985). During the interviews, information and understanding was verbally verified, thus captured by a digital recording and placed in the transcript(s). Each participant was provided an opportunity to respond to the transcript of their interview before data were analyzed. The complete and final case study report was supplied to each participant with a request for feedback (Erlandson et al., 1993).

Transferability or external validity was established by the use of thick description, purposive sampling and reflexive journaling (Erlandson et al., 1993). Dependability, consistency and reliability were supported by the dependability audit and reflexive journaling (Erlandson et al., 1993; Hayes & Singh, 2012). Adequate records such as raw data, interview transcripts, notes, index cards, and a reflexive journal were kept during the study for the audit trail, thus establishing trustworthiness (Erlandson, et al., 1993).

Participants

Pseudonym names were used in order to provide confidentiality of the actual participants.

Participant #1 Haley Posey

The interview took place late on a cool Saturday morning in November of 2012. Haley was home from her private university for the weekend, to greet her parents who had been traveling for several weeks. The interview was held in the student lounge of the local community college, having made arrangements through e-mail and text. Haley's thick long black hair hung loose, she was wearing skinny jeans and Mary Jane slippers, her knit shirt was layered over a camisole. Her jacket was complemented by a fringed neck scarf. The happy, confident look in her eye completed her ensemble. She looked very much the college girl on a mission. Haley was elated to be completing her first semester, getting closer to realizing her dream of attending medical school and becoming a physician.

Participant # 2 Richard Fontenot

Richard had kindly answered an inquiry e-mail that I had sent, and agreed to meet between his morning classes in November of 2012. He was given his choice of locations, and chose to meet in my office at the local community college. We visited about his plans during and after college. His tall, thin frame looked very studious wearing jeans, sneakers and a T-shirt, none of which were of a distinct or high-dollar brand. Richard is quietly looking forward to completing his studies at the community college, then finding a place where he can study and further his career in art. That place has not yet been decided upon, but he is pondering his possibilities.

Participant #3 Maggie Gray

Maggie had also replied to my inquiry e-mail, and agreed to a meeting after her morning classes in November of 2012. As Richard was wrapping up his interview, Maggie was patiently waiting. Her chosen attire for this day of college classes included jeans, flip-flops, and a solid green shirt that matched her eyes. A sensible pony-tail of blond hair completed the outfit. Maggie was energetic and eager to share her experiences and opinions. Both her parents are math teachers, so she had a great deal of stories and opinions to share! She, too, is looking forward to finishing up at the community college, and is in the process of deciding whether to go into education or something less stressful such as dental hygiene.

Participant #4 Sallie Smith

Sallie had also answered the inquiry e-mail. There had been several scheduling conflicts, but a meeting time and place was finally agreed upon. The interview took place between her late afternoon and night classes in November 2012 at the local community college. She was elated at the A she had just received on her MATH 1350 test, and was very excited about becoming an Early Childhood teacher, looking forward to finishing her teaching credentials at Texas A&M-Commerce. Sallie was happy about someone listening to her opinions about mathematics and the teaching and learning of mathematics! Her mathematical opinions were as vivacious and colorful as her psychedelic T-shirt, jeans and converse sneakers.

Participant #5 Anna Keeling

Anna and I had been texting, e-mailing, even running into each other at WalMart, and were finally able to settle on a meeting time and place convenient for Anna that was during her Christmas break from her university. Anna bounced into my office, bundled up against the damp chill of early January wearing an A&M hoodie covering her school-girl pigtails, A&M T-shirt layered with a camisole, stone-washed jeans complete with frayed holes, and tennis shoes during an early afternoon of January in 2013– A walking billboard that hollered for Texas A&M! Thrilled that she would soon be classified as a junior at Texas A&M, even though only her second semester there, she was energetic and eager to share her experienced voice concerning student success in college. Anna had declared a major of Telecommunications Media Studies, with two minors – Film Studies and Agricultural Communications.

Participant #6 Danielle Anders

Danielle agreed to share her opinions and experiences concerning the orientation with the readers of this research, so we met during January of 2013 before her morning Biology class. She arrived for the interview wearing the blue shirt and khaki pants required by her job at the local WalMart where she will report to work after class. Since Jr. High School, she has dreamed of owning her own business, and is now taking classes to prepare her for that eventual reality.

Participant #7 Myra Robertson

Myra had answered my e-mail that she would like to be in the study, but was not going to be home so I interviewed her at an out-of-town location in February of 2013. Myra was dressed comfortably as it was a study and errand day for her. Her college and mathematics story was shared with the readers of this research over lemon-pepper wings and Dr. Pepper, beside a vintage picture of Kyle Field. Myra is planning on becoming a plastic surgeon, and is already looking into potential medical schools.

Participant #8 Daniel Martin

Daniel agreed to meet and share his mathematical experiences. He did not seem to think his opinion was important, but was assured his experiences contained rich data for the readers of this research. We met on Valentine's morning before his Biology class. He was dressed as a typical community college student – T-shirt under an earbud-hiding hoodie, jeans and Nike slip-ons. Daniel is looking forward to graduating from community college this May 2013, and searching for a university where he can realize his dream of becoming an engineer so that some day he may design communities.

Participant #9 Emmy Edwards

Emmy respectfully knocks on the door, trained by the many years she has been involved in 4H and FFA, even though the door is already open. She has chosen this early afternoon in February of 2013 to share her mathematics story with the readers of this research. Her dream was to be a nurse, but as reality of witnessing blood, guts and/or gore moved closer, she decided to pursue Occupational Therapy. Her new career choice remains in the medical field, providing care for people, but in hopefully a more pleasant environment. Emmy has a great deal of rich mathematical experiences and opinions to share!

Participant #10 Sophie Killerman

Sophie and I meet in February 2013 after her job as a substitute teacher. She is on her way back to UT-Tyler where she is taking courses and making plans to enter their school of nursing. Professionally dressed in a periwinkle blue pant-suit, she quietly sips on her tall glass of iced tea as her mathematical voice is shared.

Participant #11 Maria Cardova

Maria is very eager for her mathematics story to be heard. The meeting was held in an empty classroom before her developmental mathematics class in February 2013. She is dressed for work at the WalMart Vision Center where she will report as soon as her class is over. As a first generation high school - now college student, she has important insights into factors that can support college success. Her prayer is for college success for herself and her eventual family, with hopes of becoming an Optometric Technician.

Participant #12 Jose Gonzalez

Jose, who had been contacted through an e-mail address obtained from his FaceBook account, agreed to meet in February of 2013, to share his mathematical stories. He and his girlfriend arrive on time, and he shares his mathematical insights about the orientation and other factors to support student success in college. Having experienced dual credit mathematics his junior year in a high school environment and his senior year on a college campus, he finds the collegiate atmosphere is more empowering than the high school environment. Being one of the first members of his family to attend college, he hopes to attend Texas A&M after community college, then continue on to medical school and one day become a cardiologist.

Findings

Five themes emerged from the data collection phase of this research.

(1) Mathematics Assessments/Tests

(2) College Knowledge of Mathematics

(3) Technology and Mathematics

(4) Teaching and Learning Mathematics

(5) Mathematical Experiences, Hopes and Dreams\

1) Mathematics Assessments/Tests

For many students, the orientation to the environment of a college mathematics placement assessment was the first time they ever heard about placement assessments. These students had recently taken their Exit Level TAKS test allowing unlimited time, and unlimited use of a graphing calculator. The orientation helped to bring awareness to the limited time and calculator policies of these types of assessments (Alpert, 2013). The idea that a math assessment would be timed, or calculator use might be limited, was the cause of much surprise among students (Alpert, 2013).

Assessment Experiences. When students arrived at college, if their scores on the Exit Level Mathematics TAKS were not high enough, they were assessed with the ACCUPLACER on a computer, although pencil and paper were allowed. The discontinuity between high school students' mathematical learning environment and the testing environment of assessments such as the ACCUPLACER could be frustrating. In the words of one student "Taking the ACCUPLACER on the computer made me feel pretty weird. I am more of a hands-on type of person. I like to have something in front of me and be able to read it. With me, I like to use my finger and point out the words when I am reading – so reading from the computer screen – I really can't understand it. I ended up failing my ACCUPLACER – well, not making a high enough grade to take college level math, so I am in the developmental class. They said I can re-take the ACCUPLACER to try not to have to take all these classes, but I don't think I can pass the ACCUPLACER without a calculator. I might try to re-take the ACCUPLACER math at least one more time, but if I fail it the second time, I don't think there is a point in taking it a third time and spending that money. "

Types of Mathematics Assessment. As students transition from high school into college, many types of assessments have been experienced. The TAKS test was declared to be difficult, but because time and calculator use were unlimited, very do-able. The ACT (American College Test) was found to be challenging due to the time constraint of 60 questions in 60 minutes, although a graphing calculator was allowed, and guessing was not penalized. After taking the ACT 4 times with no improvement in her scores, one student tried the SAT (Scholastic Aptitude Test) in which guessing was penalized. She was more satisfied with her score on the SAT than she had been with the previous 4 attempts on the ACT. Scoring high enough on the TAKS test to gain access to dual credit mathematics classes was one way to circumvent the requirement of taking a college placement assessment. The curriculum in one of the dual credit classes - MATH 1316 College Trigonometry – was found to be quite helpful on improving students' subsequent ACT scores. Mathematics assessments in the form of certification tests were found to be requirements for students to become teachers. Students applying for schools of nursing would be required to take the TEAS (Test of Essential Academic Skills), no matter how they had scored on the TAKS test.

Extra classes were taken in order to avoid having to experience the TEAS, a mathematics assessment.

Time Constraint. Time constraint was foreign to most high school students, as declared through quotes from several participants: “Nobody in school ever pushed the idea of time in any subject – the teaching was all aimed at the TAKS test, and on the TAKS test, you had all day.”; “ In the Orientation study was the first time that I felt the time pressure.” “During high school, we were always encouraged to take our time and do our best.” ;and “In high school, some things were timed, like projects and stuff but the time was measured against the person that would take the longest and everyone got that amount of time, so I always had enough time.” The time constraint of mathematics assessments was a source of anxiety and distraction that negatively affected student performance. When there were illustrations, charts and/or graphs, students did not feel they had enough time to decode everything, much less answer questions over the information. Students felt pressured into guessing, rather than thinking the situation through because of the pressure of time constraints, making timed tests perceived as not a good judge of what a person truly knows. Using a calculator would save time, but calculator use was also restricted. Without a calculator, math comes slowly.

Outside Influences. The awareness of time constraints, calculator restrictions and college requirements can originate from outside high school, such as from parents or family members who have been successful in college. Self-imposing time constraints is a common practice among students striving to prepare themselves for success in higher education. Taking the Honors classes which imposed a “finish the test in one class-period” policy, disallowing students to return at lunch, and/or before or after the school day in order to finish a test gave students realistic experience, practice and awareness of time constraints. Experience practicing and taking the ACT and SAT, which are each timed tests, can give students training under timed conditions. Advance knowledge and understanding of the time constraints on a high stakes assessment was reported as an empowering and calming procedure.

2) College Knowledge of Mathematics

Parental and family involvement greatly influenced students' perceptions and decisions. Students whose parents are mathematics teachers felt that math came naturally to them, possibly due to the support they received at home. Viewing the job demands and stress involved in being a teacher negatively influenced student's career choices. When all parents and grandparents were professional degree holders, students had an innate expectation of succeeding in college. If neither parent went to college, some students were encouraged to go to college, while other students had to struggle to turn the tide in prospect of a better economic outlook for themselves and future generations.

Feelings of Preparedness. At the time when students had completed Algebra II, whether that be the conclusion of their sophomore year in the case of Honors students, or as a junior or senior for Regular students, most felt prepared for, although apprehensive of college mathematics. Students had respect and confidence in their Algebra II teacher, and felt the teacher had adequately prepared them for college mathematics. Although some students thought college mathematics was more do-able than they thought it would be, many quickly came to the conclusion they were not as prepared as they first thought. Some of this confidence stemmed from the fact that many of the Honors students took dual credit mathematics on the high school campus, and they knew the dual credit class would have the same classmates as their Honors classes, so whatever challenges arose, they would face it together with familiar comrades. This sense of familiarity became a detriment to the success of some students.

Dual Credit. One of the perks of taking advanced or Honors classes was the privilege of taking dual credit mathematics during the junior or senior year of high school, effectively skipping high school mathematics during those years, and going straight into college mathematics. The dual credit mathematics class was offered on the high school campus with a college professor traveling to the high school. Even though not having a teacher every day was difficult, especially in mathematics, students soon learned to adjust to the more college-like schedule. Familiarity of classmates was a comfort as students strove to adapt to the differences between high school mathematics and college mathematics. The fast pace of dual credit mathematics classes along with a lack of good study habits created challenges. The experience of taking dual credit mathematics convinced students their high school math background was not as strong or as deep as they once thought. College mathematics was found to be much more specific than high school mathematics. Topics such as imaginary numbers were not a TAKS topic, therefore new territory in dual credit College Trigonometry, creating a challenge for dual credit students. Tests in dual credit were formatted differently than the familiar multiple choice TAKS format of high school. These tests of unfamiliar format that required deep critical thinking weighed more heavily toward the final course grade than high school mathematics tests had.

Dual credit mathematics was viewed as difficult and frustrating at the time, however, in retrospect the experience was deemed extremely beneficial to future academic success. Taking dual credit mathematics helped streamline the transition after high school into university academics, encouraging students to think outside the box and learn more.

Arriving at your university with your mathematics credits satisfied was deemed an awesome thing! Taking dual credit classes in general allows for early university graduation, saving both time and money for students and their parents. Students found that classes were much larger and more impersonal at a university than they had been in dual credit classes or community college classes in general. Good study habits, such as personal learning preferences and time management, formed and learned in dual credit and community college classes were supportive of academic success at the university. Success in dual credit mathematics required hard work but was viewed as a good step between high school and university, and definitely a good thing for qualified students to do.

Developmental Mathematics. Students placed into developmental mathematics were frustrated that they felt they already knew quite a bit of the topics and didn't see any point in taking classes for which they were not receiving credit, but for which they still had to pay. In order to reach transfer level mathematics, students either needed a passing score on the ACCUPLACER, taken without a calculator, or languish through developmental mathematics classes where they could use a calculator some of the time.

3) Technology and Mathematics

Nowadays, in this technological age, students think they will never be without a calculator. The arithmetic portion of the placement assessment was viewed as hard since no calculator was allowed. Mental computation skills seemed to have atrophied as students became more accustomed to their graphing calculators. This dependence on calculators made doing mathematics with just pencil and paper seem strange. Without a calculator, all computations had to be done mentally – like being on the UIL Number Sense Team - or with pencil and paper, and that took time, but time was limited also! No calculator and time limitation really raised the anxiety level, making the arithmetic portion of the assessment test a scary experience.

Classes delivered on-line can also have calculator restrictions, as one student found out the hard way. Even though she had heard stories of people "back in the day" having to compute everything by hand – especially in college, she never thought it would become a personal experience. Due to personal schedule conflicts, an on-line rather than a face-to-face College Algebra class was chosen, but little did she know, until she read the syllabus, that this was a "no-calculator" class! Although scary and difficult at first, she soon learned tricks on how to identify specific types of problems and ways to make mental or pencil and paper computation go smoothly. What had been one of her most challenging mathematical experiences morphed into an empowerment when she successfully completed the course.

Four Function Calculators. The algebra portion of the assessment test allowed the use of a four-function calculator. Students viewed this as better than nothing, but not as good as if they had been allowed to use the graphing calculator to which they were accustomed. The unfamiliarity of the four-function calculator greatly decreased its benefit for students on the assessment. One student pondered "How is this little calculator going to help instead of the big calculator?". Another students declared "We had to actually know what we were doing!". Students lamented the fact that the screen on the four-function calculator was not big enough for checking or viewing previous input. The differences between the four-function calculator and the graphing calculator were seen as so astronomical that the four-function calculator, for many students, was viewed as no help at all. Having a calculator of any type was viewed by some students as a bit of a comfort by easing computational anxiety.

As one student is quoted in reference to the placement assessments "If you had given me my graphing calculator, I would have breezed right through both of those tests!".

Graphing Calculators. Even though their cost can be approximately $100, graphing calculators seem to be the entitled norm for these students. Graphing calculator use in mathematics classes began in Algebra I – 8th grade for Honors students and 9th grade for regular students. Even though using the graphing calculator was reported overwhelming at first, as students became familiar with its power and utility, they were reluctant to accomplish any sort of mathematics without one. In fact, many students reported they presently use their graphing calculator for all sorts of real life applications such as figuring grades, GPA, expenses and such like. Although many times the graphing calculator had been used as a texting tool in high school, students taking dual credit mathematics found out those letters were not actually for texting, but rather for storing values! The experience of dual credit mathematics helped many students realize and utilize more of the graphing calculator's power than they had in high school mathematics.

Learning to use calculators is seen as important to students' future vocation; although their use has sometimes been viewed as a crutch that kept students from learning because all they had to do was type in the numbers. The inability to do much of any sort of mathematics without a calculator is seen in retrospect as a limiting factor.

Computational Agility. Students reported that it was a good thing to know how to do mathematics in different ways. Dual credit mathematics had the requirement to be able to accomplish many tasks both with and without a calculator – usually several differing ways with a graphing calculator. Microsoft Excel was also utilized as a computational tool. The ability to accomplish mathematics in various venues was viewed as powerful, giving students a choice in the method and/or technology appropriate for the situation.

4) Teaching and Learning Mathematics

Mathematics teachers greatly influenced students' confidence in their own mathematical abilities. The school years in which there had been a lot of teacher turn-over were times the students felt less prepared and less confident. The lack of a face-to-face teacher in a college class being taken on-line created student anxiety. Dual credit classes in which the teacher was only present a few days a week created challenges for students. Teachers strong in Algebra II fostered a confident feeling of college preparedness in their students. A TAKS remediation teacher was credited by the student as having taught her a lot, helping her gain the skills and confidence to pass her TAKS test.

The abrupt change from no calculators in elementary and junior high mathematics classes to graphing calculators all the time in high school mathematics classes was reported as disturbing. Calculators should not be all or none, there should be a mixture of calculator and non-calculator in learning mathematics. Students felt high school teachers should sometimes test without a calculator, so when students went to college, students would know how to do mathematics without a calculator if needed. It was considered a good idea to use calculators if the mathematics was taught correctly. In order to keep students more awake and focused, mathematics teachers were admonished to make mathematics fun, rather than just trying to pound the mathematics into students' brains.

Practice Makes Perfect. Practice and repetition was lauded by one student in particular. She reported that if she had known from the beginning that she was not allowed to use her graphing calculator on the assessment test, she would have practiced without her calculator until she felt familiar with the mathematics. Taking the ACT four times gave her practice with the time constraint on the ACT (60 questions in 60 minutes), although the ACT allowed the use of her graphing calculator. She felt foreknowledge and practice was key to success.

Learning Preferences. Calculators are a big part of learning mathematics, and have a place – not the whole place, but a place, in learning mathematics. Some students thought the way they learned mathematics was good, but others thought their mathematical learning was too attached to the graphing calculator. Many students reported that mathematics and especially algebra should be learned both with and without a calculator – possibly using the four-function calculators a bit when learning arithmetic, and using the graphing calculators when learning algebra. One student declared "It would be a blessing if I knew how to do math without a calculator. That would same me a lot of time to not have to punch in every single one of those numbers. To know how to do it from the top of your head would be awesome, I would love to be able to do math without a calculator!". Students expressed the insight that calculators should be used as a guide to support learning, not replace learning.

The dual credit experience was a place where students learned good study habits and effective study procedures such as flash or study cards, color codes, and memorization techniques. These practices supported academic success for these students after transferring to a university. The realization that you are responsible for your own learning was another vital skill acquired through dual credit and community college classes.

One student reported preferring the college campus environment to the high school environment for dual credit classes as heard through his voice, "My dual credit class was on the high school campus. It did not feel any different than the high school math classes I had taken – same building – same room – same classmates. On the days the college teacher wasn't at the high school, you tended to play off because you thought you had a free day, rather than study time. When I began attending a section of the same class held on the college campus, it felt much more collegiate. I was really able to focus and pay better attention to what was going on. The classmates were different also and I enjoyed hearing their comments. I felt more like a college student. I was more successful in a college class when it was in the college environment.".

Multiple modes of learning are appealing to some students. A student taking a developmental mathematics class in which the homework is done on the computer enjoys not only reading the problems, but listening to the computer read the problem while she is writing the problem.

5) Mathematical Experiences, Hopes and Dreams

Early mathematical experiences seemed to be mostly positive and pleasant, with math being declared a favorite subject for numerous students. A sense of power developed as students mastered their "math facts" with flash cards. One student reported that mathematics got much better when he acquired glasses toward the end of his 4^{th} grade year. His 5^{th} grade year was then a pivotal year as he could actually see what the teacher was writing on the board, and not try to memorize what he was hearing. This 5^{th} grade year was also pivotal for other students as anxiety built concerning whether their TAKS test scores would be satisfactory enough to enter junior high, or whether they might be left behind in intermediate school. Placement into the Honors track happened during the 5^{th} grade year as well. Some students were elated to gain entrance to the advanced track, giving their mathematical confidence quite a boost. One student, who had been languishing in regular mathematics during his 6^{th} and 7^{th} grade year, recalled the assistance of his 8^{th} grade teacher to get him in the 8^{th} grade Honors class of Algebra I. At that point, mathematics started clicking for him and he eventually took dual credit mathematics in high school. Many students reported Algebra I as being a pivotal time for them either one way or the other. For some students, Algebra I along with the use of a graphing calculator began a happy and confident era of mathematics, while for others, Algebra I with its use of variables began a confusing and frustrating era of mathematics. However, Geometry seemed to be universally a favorite course providing a break in the Algebra I and II sequence. A pivotal point of reported great frustration was when Honors students transitioned from high school mathematics to dual credit mathematics. Taking a college mathematics class in which calculators are forbidden was described as a huge source of consternation, considering that all mathematics since Algebra I had been learned and applied using a graphing calculator. The lack of readily available calculation technology was considered a mathematical disadvantage. However, overcoming mathematical challenges and gaining insight and understanding was pictured as mathematically empowering. These challenges included passing the 6^{th} grade TAKS after months and months of practice without a calculator, placing into Honors mathematics classes, taking and acing the ACT after struggling through dual credit Trigonometry, gaining insight and understanding in dual credit Calculus, and conquering an on-line no-calculator College Algebra class.

Mathematical Experiences beyond Algebra II. Students expressed concern about many aspects of their mathematical life beyond Algebra II. Taking Pre-Calculus with a new teacher and also Physics during the senior year really fractured the confidence of students. The realization they had been “spoon-fed” mathematics up through Algebra II in an effort for everyone to pass the TAKS test made the demands of college level mathematics classes rather startling. The requirement to eventually pass a course in Calculus was cause for trepidation for some. One student studying Pre-Med at Texas A&M had passed Calculus I, but was postponing Calculus II until her last semester due to the stress involved. College Algebra in a face-to-face section was deemed similar to Algebra II in high school with the graphing calculator being the students' best friend, but College Algebra in an on-line, no-calculator section was seen as a nightmare.

Dual Credit Speedway. Students who took dual credit classes in high school were elated at being able to move into their major classes quickly upon arriving at their university, saving time and money. Many students, having taken dual credit in high school, were classified as sophomores or juniors after just one semester at their university. However, one student lamented the fact that dual credit classes actually caused difficulties once she got to her university. Wanting to circumvent the application process that included assessment testing without a calculator, she chose to take her four lab science classes at that university. This choice forced her to take several electives in order to maintain full-time student status. Many students arrived at their university with their mathematics credits completely satisfied due to their dual credit classes.

College Majors and Future Professions. Students observed that each of the mathematical topics they learned would probably apply to at least one profession or career. Surviving and thriving in the "real world" without calculator or computer skills would be nearly impossible. Employed students mentioned they used calculators and computers in their present job, whether that be in an office, checking or stocking at WalMart, or working in the Vision Center at WalMart. One student declared that she was not going to let mathematics or anything else for that matter hinder her from pursuing her dream of becoming a physician.

Still another student declared although mathematics had not hindered her, science had caused her to change her career plans completely! Another student was happy in his choice of digital art as a career and was looking forward to learning the mathematics specific to that career. Engineering as a career choice for several students held the promise of future mathematics classes. The daughter of math teachers said her observation of the day-to-day activities and frustrations of being a math teacher has actually deterred her from pursuing a career teaching mathematics in junior high, choosing instead a career involving less schooling, less stress and more pay. Teaching kindergarten or elementary grades and being a person that can influence lives at an early age is a career dream of several students. Considering graduate school in the future, one student was concerned about the GRE, a sort of placement test, and the graduate school Statistics requirements. Even though she had arrived at her university with her undergraduate mathematics requirements fulfilled, she realized there could always be more math requirement down the road. She summed up her relationship with mathematics thusly; “I have had a lot of support, so I’ve always been pretty good with mathematics”.

Conclusions

How did students who participated in a brief high school orientation to college mathematics placement assessment perceive that orientation experience, and what factors do these students believe support college mathematics success?

Students who participated in a brief high school orientation to college mathematics placement assessment perceived the orientation as effective, although possibly too brief “I felt like a week was not long to practice the new environment of no calculator and time constraints”. Awareness of the time and technology constraints of upcoming mathematics assessment was accomplished through the orientation “When we did the orientation to math placement tests, it was a surprise to me that I would ever be required to take a math test with no calculator” , although many students felt the week-long intervention was not enough to fully prepare them for college mathematics assessment “I had never heard of a mathematics placement assessment before we had that orientation at the end of Algebra II – that was the first time I heard of it”. Other factors believed to support success in college mathematics included college knowledge, technology knowledge, ways in which mathematics was taught and learned, and mathematical experiences.

Knowledge of college mathematics was supported for students through teachers “I felt confident when I graduated high school that I could handle math in college”, parents, and dual credit experiences “I thought I was prepared for dual credit, but it was different than I thought it would be - the math topics were covered deeper and faster than what I had been used to”. Experienced, knowledgeable mathematics teachers supported college mathematics success for students “Mrs. L. was a pretty good teacher and I felt ready to move on even though I was a little scared about how I was going to do”. Having several different teachers in one year “My senior year we had at least four different teachers – we seemed to go through a lot of math teachers” “During that year, we kept getting different teachers and they all taught different” or having an inexperienced teacher “she was new” was a frustration to students. The encouragement and wisdom of parents who had been successful in college proved to be of invaluable support for students “Each of my parents earned college degrees … so I was always expected to go to college and do well”. Experiencing dual credit mathematics classes while still in high school laid a good foundation for future college success “The tests in dual credit were formatted differently, and weighed heavier on your final grade than in high school", and "I learned good study habits, like flash cards, color codes, and how to memorize well while taking dual credit and community college classes". This was especially true when those classes were held on a college campus in a college atmosphere with a college professor "When I began attending a section of the same class held on the college campus, it felt much more collegiate. I was really able to focus and pay better attention to what was going on. The classmates were different also and I enjoyed hearing their comments. I felt more like a college student. I was more successful in a college class when it was in the college environment", rather than in a high school setting with a high school teacher "My dual credit class was on the high school campus. It did not feel any different than the high school math classes I had taken – same building – same room – same classmates. On the days the college teacher wasn't at the high school, I tended to play off because I thought I had a free day, rather than study time".

Becoming experienced and adept at various and sundry mathematical technology tools was cited as a skill that would scaffold student success in college mathematics. These mathematical technologies included different types of calculators such as simple four-function calculators or more complex graphing calculators, and spreadsheet programs such as Microsoft Excel "we even had a project with Microsoft Excel for one of my dual credit math classes". Sharp computational agility, either mentally or with pencil and paper, was noted as a necessary skill for success in college mathematics "It seems my quick computation skills – I used to do Number Sense – left quickly after the calculator became a permanent part of my mathematics", and "I think teachers should test sometime without the calculator, so when students get to college, they will know how to do the math without the calculator if needed". Becoming familiar with a computerized classroom and learning platform such as BlackBoard during either dual credit or early admit was viewed as a highly valuable skill “technology is used to deliver this class on-line”, supporting student’s successful transition into the collegiate environment.

Teaching and learning mathematics with a long range vision for what might be required beyond high school rather than a short-term goal of simply exiting high school “I had been really spoon-fed mathematics up until that time and the demands of a college level class were quite startling”, was a longing of students as they looked in the rear-view mirror at their public education “It would be a blessing if I knew how to do math without a calculator – that would save me a lot of time not to have to punch in every single one of those numbers! To know how to do it from the top of your head would be awesome”. Dual credit and early admit students were able to get a glimpse of the expectations of mathematical life beyond high school “In dual credit, the fact that you were responsible for your own learning and whether you knew the material or not was quite different from what I had been used to up until that time”. Students expressed regret that while in high school they were not aware of, nor were able to practice, many of the mathematical skills under the time and technology constraints that would support success in college and beyond. “I believe that calculators should be used as a guide to learning, not just to figure out the answer”, “I really don’t like timed tests because I feel they are not a good judge of what a person knows”, “The time constraint was nerve-wracking because I wanted to finish everything but without the calculator, math comes slowly”, and “I could use my graphing calculator on the TAKS test, and all the time I needed” were many of the strong opinions voiced by these students as they reflected upon their high school experience in retrospect from their just starting out college reality.

Students were passionate about their hopes and dreams – many of which demand a high level of success in college mathematics “Accounting”, “Own my own business”, “Teacher”, “Dental Hygienist”, “Physical Therapist”, “Occupational Therapist”, “Nursing”, “Plastic Surgeon”, “Cardiologist”, Engineer”, and “Optometric Technician”. Determination was evident in their quest for acquiring the needed skills for these visions to become reality “I am not going to let mathematics or anything else hinder me from pursuing my dreams”. Self-determination and encouragement from professors, former teachers, family and friends, will provide support on their journey to college mathematics success and degree completion “I came to the university with a good GPA and was able to by-pass those freshmen and sophomore ‘weed-out’ classes because of dual credit – getting right into my chosen field of study, which makes me happy, and allows me to graduate earlier, saving my family boo-koos of money!”.

Discussion and Recommendations

The orientation to college mathematics placement assessment was perceived as successful in that it helped students to become more aware of the time and technology constraints under which they could be assessed. However, the orientation was deemed very brief. A more in-depth and prolonged orientation could create greater benefit and support for students. Incorporating the time constraints and/or technology tools from the orientation into day-to-day mathematics, whether in mathematics or other classes (Parr, Edwards, & Leising, 2006) could help students become more accustomed to working under these conditions.

Dual Credit classes were considered extremely supportive of success in college mathematics. When these classes met in the college environment of a college campus which encompassed a diversity of students in terms of age and experiences, students felt their college mathematics success was better supported than when the classes met in the high school with a high school teacher and their familiar group of high school classmates. Valuable study skills that support college mathematics success were gained while still in high school by taking dual credit classes. These classes also served to highlight the rigor, or lack thereof, that had been present in high school mathematics classes. Parents could provide a plethora of encouragement and support, although some parents did not have current knowledge of college environments.

Students realized the need to develop computational agility with many different technology tools to support college mathematics success. These tools include techniques with mental computation, four-function calculators, graphing calculators, and spreadsheets such as Microsoft Excel. Technology experience with on-line classroom platforms such as BlackBoard was deemed crucial to college mathematics success.

The teaching and learning of mathematics in support of college mathematics success included multiple modes of learning mathematics, various study techniques, and showing mathematics to be an enjoyable and relevant subject. Practice using different tools for mathematical computation was deemed supportive of success in college mathematics. Extreme policies and abrupt changes in the use and availability of mathematical tools were viewed as a source of frustration among students.

Mathematical confidence and success could many times be traced back to specific teacher(s) and/or class(es). Educators who taught with profound care, depth of knowledge and understanding were lauded as empowering students' abilities and confidence in mathematics. Classes in which there had been many different teachers were remembered as frustrating for students. Students reported that a sole, outstandingly knowledgeable, caring and supportive teacher can have an infinitely positive impact on students' confidence and future successes in mathematics.

CHAPTER IV

TPCK FOR STATISTICS:

SUPPORTING STUDENT SUCCESS

THROUGH MICROSOFT EXCEL BOOTSTRAPPING

Introduction

A work force competent with statistics would allow the United States to more effectively compete in the global marketplace, thus improving its position in the international economy (Franklin, Kader, Mewborn, Moreno, Peck, Perry, & Scheaffer, 2005). Our society is dependent on information and technology, thus making statistics more pervasive than ever (Ben-Zvi, 2000). Statistical literacy gives people the power to survive in the modern world, providing tools to enable independent thought, and to ponder and ask intelligent questions of experts (Franklin et al., 2005). Statistical literacy has become a major aim of curriculum, regardless of what students' professional future holds for them (Gal, 2002). Investing in statistical literacy is investing in our nation's economic well-being, as well as the well-being of its citizenry (Franklin et al., 2005). High school curriculum is woefully lacking in statistical concepts, and although it would be advantageous to introduce these concepts in high school, it is absolutely essential they be part of every college graduate's portfolio (Stith, 2001). College mathematics has begun to include more statistics classes that include applications (Ganter, 2001). These applications demand the power of technology (Chance & Rossman, 2006).

Access to Success

Access to success, rather than simply access to college entrance, must be the goal for our students (Adeleman, 2006). Performance in a student's first-year mathematics course is the strongest retention predictor for first semester freshmen (Herzog, 2005). Mathematics performance in the second semester is more important than overall grades in predicting future retention (Herzog, 2005). The three courses most likely for college students to fail are in the area of mathematics. Likewise, all four courses from which students are most likely to repeat or withdraw are math related (Adeleman, 2006). Three times more students who participated in a statistics course eventually went on to earn a bachelor's degree than students who did not participate in a statistics course (Adeleman, 2006). The consequence a student's first-year mathematics experience has on second-year retention necessitates the need to closely appraise preparation and curricular requirement in mathematics (Herzog, 2005).

Technology

The use of technology in conjunction with the teaching of concepts and problem solving should be common practice in all fields of mathematics. This was the formal proposition in *Curriculum and Evaluation Standards* (National Council of Teachers of Mathematics [NCTM], 1989) and was reaffirmed in *Principles and Standards for School Mathematics* (NCTM, 2000; Gratzer, 2011). Technological Pedagogical Content Knowledge (TPCK) is the integration of knowledge of technology with subject matter knowledge along with knowledge of learning and teaching (Niess, 2005). For teachers of statistics, this knowledge encompasses ways to effectively teach important statistical skills and ideas, and ways to help students use technology tools such as graphing calculators, spreadsheets or statistical software (Garfield & Everson, 2009). TPCK is a discernment of the manner in which technology tools and content knowledge shape and constrain one another (Koehler & Mishra, 2008). Lee and Hollebrands (2008) present an integrated approach taken in the design of their Preparing to Teach Mathematics with Technology (PTMT) project for developing prospective teachers TPCK. The following provides an illustrative example:

> Findings from research on students' understanding of statistical ideas are used to make points, raise issues, and pose questions for teachers throughout the materials . . . After teachers have engaged in examining a statistical question with a technology tool, pedagogical questions aimed at developing their understanding of how technology and various representations can support students' statistical thinking are often posed (p. 330).

Curricular Recommendations

Recommendations for an introductory course in statistics include (1) incorporating more data and concepts, (2) automating computations and graphics by relying on technology tools, and (3) fostering active learning through alternatives to lecturing (Ben-Zvi, 2000). In the past half-century, classroom computational technology has gone from hand-held slide rules and cumbersome books of computational tables to hand-held graphing calculators and compact laptop computers and tablets (Grandgenett, 2008). Technology will continue to be a driving force in the enhancement of student learning of statistics as tools of technology scaffold the development of statistical literacy in college students (Chance, Ben-Zvi, Garfield, & Medina, 2007), opening the opportunity for development of rich, powerful and flexible learning environments in which students become active learners of statistics (Ben-Zvi, 2000). As a plethora of technology tools have become available, and as student competencies with such tools has increased, it has become increasingly important to focus on the best ways to utilize these tools in classroom (Chance et al., 2007). Technology has the ability to bring exciting curricula, rooted in real-world problems, into the classroom, provide support and tools to enhance student learning, and give students and teachers more opportunities for feedback, reflection, and revision (Brandsford, Brown, & Cocking, 2000).

The Guidelines for Assessment and Instruction in Statistics Education (GAISE) include the following recommendations:

(1) Emphasize statistical literacy and develop statistical thinking;

(2) Use technology for developing conceptual understanding and analyzing data;

(3) Stress conceptual understanding rather than mere knowledge of procedures;

(4) Foster active learning in the classroom; and

(5) Use real data (Franklin & Garfield, 2006).

Technology has been one of the driving forces that has recalculated the course of introductory statistics from a traditional view of a mathematical topic emphasizing computation, formula, and procedure to the more current emphasis on statistical reasoning along with the ability to interpret, evaluate and flexibly utilize statistical ideas (Ben-Zvi, 2000). Students can become lost or overwhelmed in the details of the programming commands or instructions of statistical software packages, failing to see the bigger ideas being developed, thus Microsoft Excel has been advocated for use in introductory statistics courses due to its prevalent use in industry and relatively easy student access (Chance et al., 2007).

Teaching Resampling

Statisticians have embraced resampling methods for quite some time, but it has only been recently that resampling methods have been included in the teaching of statistics (Stephenson, Froelich, & Duckworth, 2010). Technology tools bring abstract concepts such as sampling distributions and confidence intervals to a more concrete level. Students' understanding of sampling and resampling is developed by carrying out repetitions, then explaining and describing the observed behaviors, rather than relying exclusively on theoretical probability distributions and discussions (Chance et al., 2007).

The purpose of this article is to support students' successes in college mathematics by introducing college teachers of introductory statistics to the technological pedagogical content knowledge (TPCK) needed to teach bootstrapping with Microsoft Excel to first year college students in a statistics course.

The Bootstrap

A primary task of inferential statistics is estimation - the attempt to generalize a sample of data from a study to the parent population - in a scientific manner (Bluman, 2012). Statistics computed from a sample will vary from sample to sample: Practitioners and statisticians are interested in the magnitude of the fluctuations of the sample statistic around the corresponding population parameter (Bluman, 2012). A sampling distribution is a distribution of the sample statistic computed from all possible random samples of a specific size taken from a population (Bluman, 2012). When the sampling distribution is not known, a researcher is in quite a quandary as to what to do for statistical inference (Rochowicz, 2011). Textbooks abound with theoretical knowledge of sampling distributions (Singh & Xie, 2010). A general intuitive method that is applicable to most any kind of sample statistic, while keeping the user distanced from technical tedium has a special appeal: Bootstrap is just such a method (Singh & Xie, 2010). Bootstrapping, first intended to explain the success of an older methodology called the jackknife, began as the muscled up big brother to the Quenoulle-Tukey jackknife, having the same principal task of routine calculation of biases and standard errors, then taking on the job of automatic computation of bootstrap confidence intervals (Efron, 2000). Bootstrapping, by substituting raw computing power for theoretical analysis, effectively gave statisticians and practitioners an effective and relatively simple way to compute a standard error for even the most complicated of estimators (Efron & Tibshirani, 1986). Efron (1979), considered to be the father of bootstrapping, contemplated various names for this method such as *Swiss Army Knife*, *Meat Axe*, *Swan-Dive*, *Jack-Rabbit*, and Efron's personal favorite, the *Shotgun*. "The "bootstrap" has been so named because this statistical procedure represents an attempt to "pull oneself up" on one's own, using one's sample data, without external assistance from a theoretically-derived sampling distribution" (Thompson, 1999, pp. 34-35). The bootstrap provides a vehicle to statistically test and explore modern statistics (Thompson, 1999).

Bootstrapping, a resampling with replacement method, aims to gain information about the distribution of an estimator (Härdle & Bowman, 1988). The essence of bootstrapping is to use only the sample data, then resample from that sample to generate different realizations of the experimental results (Stephenson et al., 2010). A typical applied statistical problem involves the estimation of an unknown population parameter: Two main questions are what estimator to use, and how accurate that estimator might be (Efron & Tibshirani, 1986). Resampling methods - nonparametric computer-intensive strategies - have been used in a wide array of disciplines (Gratzer, 2011). The bootstrap is a general methodology for answering the concern of the accuracy of the estimator (Efron, & Tibshirani, 1986). Bootstrapping - a computer-based, numerical method - substitutes great amounts of computation in place of theoretical analysis, routinely answering questions too complicated for traditional statistical analysis - a good analytical bargain in this era of exponentially decreasing cost of computation (Efron & Tibshirani, 1986; Rochowicz, 2011).

Even though bootstrapping was originally intended to compute the accuracy of an estimator, more sophisticated uses have led to better approximations of confidence intervals (Efron & Tibshirani, 1986). Bootstrapped empirical estimates require fewer assumptions (Thompson, 1999).

Appropriate Uses

Cases in which the sample size is somewhat large are appropriate for bootstrap methods, however, for cases in which the sample size is small, other methods need to be used (Thompson, 1999). Applications involving inferential purposes, such as to estimate the probability of sample statistics and statistical significance tests are appropriate for bootstrapping as a large number of resamples can be produced (Thompson, 1999). The ability for bootstrapping to empirically compute confidence intervals has been lauded by educational researchers (Capraro, 2002). When a researcher's focus is descriptive, such as the mean or median, bootstrapping does not require a very large number of resamples; this descriptive use provides evidence the results of the study may generalize (Thompson, 1999).

The bootstrap cannot change reality: An unrepresentative sample cannot be bootstrapped into a representative sample nor can a quasi-experimental study be bootstrapped into a true randomly assigned experimental study, therefore it is vital to match study design purposes with bootstrap modeling procedures (Thompson, 1999).

Calculation

Efron (2000) readily admits that it took him quite a long time to trust in the efficacy of computer-based methods such as the bootstrap for routine calculations. While there are undoubtedly many ways to deal with the nonparametric, numerical method of bootstrapping, most of which involve computers: A spreadsheet program such as Microsoft Excel is an excellent and readily available tool (Rochowicz, 2011). Efron (2000) himself referred to bootstrapping as a “disappointingly simple device” (p. 1296) giving the data analyst the freedom to find standard error for hugely complicated estimators, subject only to computer time constraints (Efron & Tibshirani, 1986).

Algorithm

Gratzer (2011) provided the following algorithm to create Bootstrap confidence intervals:

1. Number the observations from 1 to *n*.
2. Use a random number generator to draw *n* numbers between 1 and *n* inclusive, allowing repetition.
3. Create a list of data points by replacing each random number with the observation associated with it, called a *bootstrap sample*.
4. Calculate the statistic of interest for each bootstrap sample found in step 3. This result is called a *bootstrap estimate*.
5. Repeat steps 2, 3, and 4 a large number of times, recording each bootstrap estimate BSE_1, BSE_2, BSE_3,…, BSE_k where BSE_i is the statistic generated by the *i*th bootstrap sample.
6. Sort the list of bootstrap estimates into ascending order.
7. For a C% confidence interval, find the bootstrap estimates that cut off the top and bottom (1-C%)/2 of the list. These values result in the C% confidence interval sought. The “unthinkable” of this method is the need to create a large number, maybe thousands, of samples using random number generators and calculate the statistic of interest for each.

This technique illustrates clearly to students that in an interval of the form (*a, b*), the *a* and *b* are data generated numbers (Gatzer, 2011). Because no critical value is used in the formation of this type of confidence interval, the importance of data in the statistical process is emphasized to students who will hopefully become proficient practitioners and consumers of statistics (Gatzer, 2011). The relationship between the confidence level of the desired interval and the width of the interval becomes apparent, because the confidence level C is used in determining the number of bootstrap estimates to be ignored from each end of the list of bootstrap statistics created (Gatzer, 2011). The amazing ability to form confidence intervals for parameters other than means and proportions is revealed, thus statistics becomes more of a process and less a bunch of formulas (Gatzer, 2011). Though labor-intensive, many experts feel bootstrapping is a worthwhile procedure for students to practice and learn, giving an effective way to combine confidence intervals with effect sizes in the ongoing effort to make research more meaningful for readers (Capraro, 2002). Care should be taken by statistics instructors to choose technology that facilitates student accessibility and interaction while keeping focused on the statistical concept rather than the intricacies of the software (Chance & Rossman, 2006).

Interpretation

Most of the time, the Bootstrap will give a good picture of the accuracy of an estimator, however there are a few samples for which the Bootstrap does not work. This is not so much a failure of the Bootstrap as it is a restatement of the uncertainty condition under which all statistical analysis proceed (Diaconis & Efron, 1983). In an effort to understand the Bootstrap, suppose it were possible to draw repeated samples (of the same size) from the population in which one is interested. This would give a fairly good idea of the sampling distribution. However, this makes little sense as it would be far too expensive and defeat the purpose of a sample study – that of gathering information in a timely and financially efficient manner. The Bootstrap uses the data generated from a sample study as a surrogate population for the purpose of approximating the sampling distribution of the statistic of interest, replacing the population with the empirical population of the sample (Singh & Xie, 2010). Thompson (1999) further explained, "Because each sample is only a subset of the population scores, the sample does not exactly reproduce the population distribution. Thus, each set of sample scores contains some idiosyncratic variance, called "sampling error" variance. . .". (p. 40)

B $\rightarrow\infty$

In the practical sense, one would want to know what is a large number of times: Studies have indicated when n=50, run 800 bootstrap resamples, for n=25, run 500 bootstrap resamples, although equally accurate results come from 250 bootstrap resamples, but only 100 bootstrap resamples yielded more conservative results (Akritas, 1988). In estimating coefficients of variation, running only 200 bootstrap replications was found to yield accurate results, however in the case of bootstrap confidence intervals 1000 bootstrap replications was a rough minimum while only 250 bootstrap replications were needed to give a useful percentile confidence interval (Efron & Tibshirani, 1986). When bootstrapping is employed for inferential purposes such as statistical significance tests, the number of resamples required is extremely large due to the fact that data density is typically less stable in the tails of the distribution (Thompson, 1999). However, fewer resamples are required when bootstrapping is used to estimate descriptive statistics such as the mean or median (Thompson, 1999).

Advantages/Disadvantages

Bootstrapping has many advantages, some of which are listed:

(1) Verifying the normality and equality of variances assumption for the population is not necessary: Inferences are valid even when assumptions have not been verified (Gratzer, 2011; Rochowicz, 2011).

(2) A large sample is not required (Gratzer, 2011).

(3) Determining the underlying sampling distribution for any population parameter is not needed (Gratzer, 2011; Rochowicz, 2011).

(4) The method is versatile and not restricted to proportions and means (Gratzer, 2011).

(5) Results and interpretations are based upon many observations (Rochowicz, 2011).

Bootstrapping also has a few disadvantages such as:

(1) Powerful computers are necessary (Rochowicz, 2011).

(2) Randomness must be understood (Rochowicz, 2011).

(3) Computers have built-in error (Rochowicz, 2011).

(4) Large sample sizes must be generated (Rochowicz, 2011).

Time series data seem to be especially difficult to bootstrap, as does data that originates from either two stage sampling or stratified sampling (Singh & Xie, 2010). There are various conditions under which the bootstrap resampling method becomes inconsistent such as when bootstrapping sample minimum value or sample maximum value, the sample mean in the case when the population variance is infinite, and the sample median in the case when the population density is discontinuous at the population median: The remedy is to keep the bootstrap resample size much lower than the sample size in these cases (Singh & Xie, 2010).

Future

Modern computer-based numerical statistical techniques such as bootstrapping have catapulted statistics education into the debate of the proper place computer-based techniques have in introductory courses. Akin to the calculator debate presently raging in mathematics education, the result is likely to be the best of the old should be kept, and the best of the new should be introduced (Gratzer, 2011). Considering the topics taught in many introductory courses, statistics seems to have stopped dead in the 1950's (Efron, 2000). The educational return that makes the effort worthwhile of exposing students to these previously tedious and time-consuming techniques will be a deeper conceptual understanding of statistics (Gatzer, 2011). Although bootstrapping can be labor-intensive, many statistics experts consider it a valuable procedure for students to learn and practice (Capraro, 2002). This suggests a need for bootstrapping methods that can be utilized in an introductory statistics course.

Microsoft Excel

Applying the INDEX function in Microsoft Excel is a way to accomplish bootstrapping analysis without the use of an add-in or macro, thus allowing bootstrapping to be an appropriate method for an introductory statistics course (Rochowicz, 2011). The principal use of the INDEX function is to return a value from a range of cells or table. Structure of the INDEX function for bootstrapping is: INDEX (table or range or array, row location, column location). The use of RAND()+1 is used to generate a random row or column location. Command syntax to generate a datum in a cell from random rows and columns of sample data is: "=INDEX((range of cells), ROWS (range of cells)*RAND()+1, COLUMNS(range of cells)*RAND()+1)" . This command should then be copied and pasted into as many cells as required for the desired resamples. Each click of the F9 key on the computer keyboard will generate a new recalculation of the bootstrapped data. Using the INDEX function, bootstrapping can be performed on any statistic (Rochowicz, 2011).

Confidence Intervals

Widely used methods for computing confidence limits are based on beginning with a measurement of central tendency then giving or taking some amount of measurement of standard error of either measurement or estimation (Capraro, 2002). Bootstrapping has the ability to empirically compute the middle 95% of the data by trimming off the upper and lower 2.5% of the measurements. These bootstrapped confidence intervals can be used as any other to make inferences about the population (Rochowicz, 2011). The Rule of Eye 4 provides an intuitive and visual interpretation stating when the overlap is no more than about half the average margin of error or the proportion overlap is about 0.50 or less, statistical significance of difference between the means is indicated (Cumming & Finch, 2005).

Purpose

This study intends to employ bootstrapping to empirically compute 95 percentile confidence intervals using over-sampling, at-sampling and under-sampling of the original data set of pre-test scores and post-test scores from a week-long intervention in a high school algebra class. Microsoft Excel procedures will be used in a way appropriate for use in an introductory statistics classroom.

Research Question

By using Microsoft Excel as a technology project platform appropriate for a first-year college introductory statistics course, can under-sampling, at-sampling, and/or over-sampling yield similar results when means and 95% confidence intervals about those means are bootstrapped from original data sets of $50<n<100$?

Method

Data collected during the study for College Mathematics Placement Assessment Environment Orientation: Effects on Algebra II Students' Scores will provide the original sample with 50<n<100. Scores in the four data sets labeled Ar Pre T, Ar Post T, Al Pre T and Al Post T refer to the number of correct responses on 15 question tests (see Table 9).

Table 9

Description of Eight Data Sets

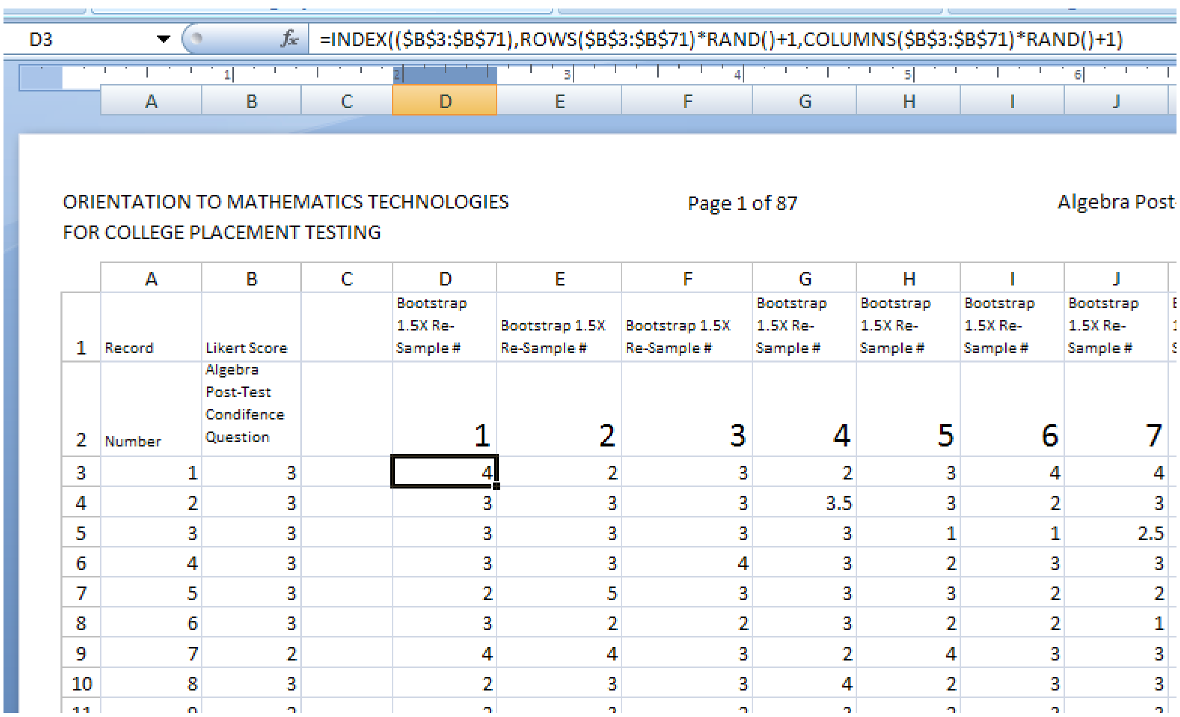
Data Set	*n*	Mean	*SD*	Range
Ar Pre T	76	6.461	2.793	12
Ar Post T	76	7.921	2.986	12
Al Pre T	76	7.737	2.876	12
Al Post T	76	8.645	2.917	15
Ar Pre Q	76	2.407	0.878	4
Ar Post Q	72	2.792	0.916	6
Al Pre Q	76	2.553	0.916	4
Al Post Q	69	2.899	0.769	4

These four tests included arithmetic pre-tests and post-tests as well as algebra pre-tests and post-tests. Scores in the data sets labeled Ar Pre Q, Ar Post Q, Al Pre Q and Al Post Q refer to the students' Likert scale responses to a statement regarding their feelings of confidence on each of the four aforementioned tests (see Table 9).

Procedure

Bootstrap re-samples were produced in Microsoft Excel 2007 using the INDEX command (see Figure 4). The specific command used to randomly choose a data element in this analysis with data sets of *n*=76, residing in cells B3 through B78 was: "=INDEX(($B$3:$B$78),ROWS($B$3:$B$78)*RAND()+1,COLUMNS($B$3:$B$78)*RAND()+1)" and was copied into each of 250 columns, and as far down in each row as required for each of the seven resample factor sizes. Over-samples of size 3*n*, 2*n*, and 1.5*n*, at-samples of size *n*, and under-samples of size 2/3*n*, 1/2*n*, and 1/*3n* were produced for each of the 8 data sets in 56 individual Microsoft Excel files. Each of these files contained 250 bootstrap resamples, along with the computed mean for each of the re-samples (see Figure 5). A 95% confidence interval was empirically computed for the means of the bootstrapped resamples for each of the resample factors. The specific commands used to empirically compute 95% confidence intervals of the 250 means residing in cells D80 through IS80 from the 250 re-samples was: "=PERCENTILE($D$80:$IS$80,0.025)" for the lower limit of the interval and "=PERCENTILE($D$80:$IS$80,0.975)" for the upper limit of the interval (see Figures 6 & 7).

Approximately 12 recalculations of each bootstrap file were performed. For each F9 Microsoft Excel recalculation, the mean of the means was recorded, the 2.5 percentile value was recorded as the lower limit of the 95% confidence interval, and the 97.5 percentile value was recorded as the upper limit of the 95% confidence interval. The mean average of the 12 values was used as a representative mean of the means, and a representative 95% confidence interval for each data set for each resample factor.



	A	B	C	D	E	F	G	H	I	J
1	Record	Likert Score		Bootstrap 1.5X Re-Sample #	Bootstrap 1.5X Re-Sample #	Bootstrap 1.5X Re-Sample #	Bootstrap 1.5X Re-Sample #	Bootstrap 1.5X Re-Sample #	Bootstrap 1.5X Re-Sample #	Bootstrap 1.5X Re-Sample #
2	Number	Algebra Post-Test Condifence Question		1	2	3	4	5	6	7
3	1	3		4	2	3	2	3	4	4
4	2	3		3	3	3	3.5	3	2	3
5	3	3		3	3	3	3	1	1	2.5
6	4	3		3	3	4	3	2	3	3
7	5	3		2	5	3	3	3	2	2
8	6	3		3	2	2	3	2	2	1
9	7	2		4	4	3	2	4	3	3
10	8	3		2	3	3	4	2	3	3

Figure 4. Microsoft Excel syntax for producing an element in a bootstrap re-sample. This command should be copied across 250 columns for the bootstrap re-sample, and as far down as required for the proper re-sample factor.

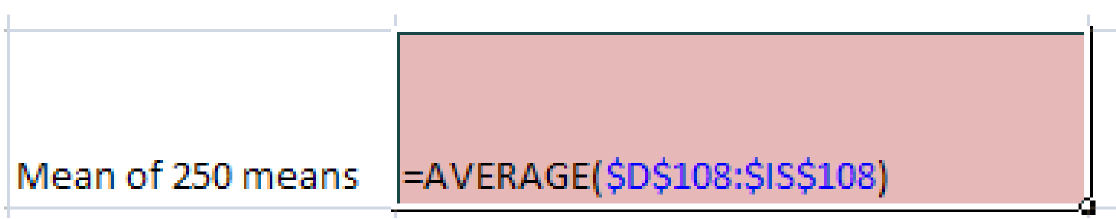


Figure 5. Microsoft Excel syntax for computing the mean of the 250 means of the bootstrap re-samples. The means for this example were residing in cells D108 through IS108.

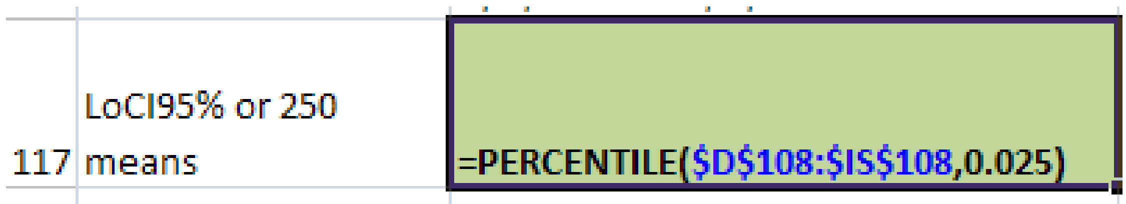


Figure 6. Microsoft Excel syntax for computing the 2.5 percentile value of the 250 means. The means for this example were residing in cells D108 through IS108. This value is the lower limit of the empirical 95% confidence interval.

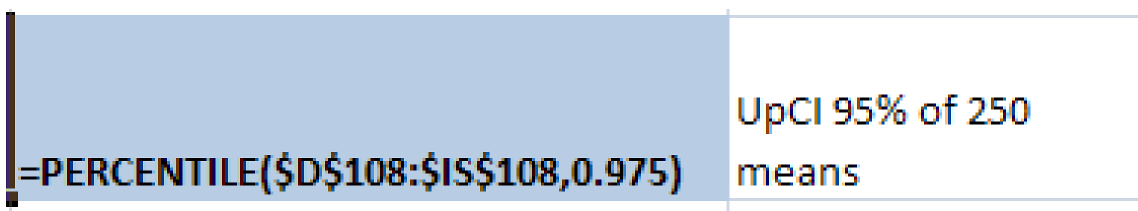


Figure 7. Microsoft Excel syntax for computing the 97.5 percentile value of the 250 means. The means for this example were residing in cells D108 through IS108. This value is the upper limit of the empirical 95 % confidence interval.

Results

The mean of the means remained relatively constant as the resample factor increased (see Figures 8, 9, 10, and 11). The width of the bootstrapped 95 percentile confidence intervals narrowed as the resample factor increased (see Figures 8, 9, 10, and 11). Bootstrapped 95% confidence intervals for the mean of the four sets of Pre-test / Post-test scores tended to overlap during under-sampling (see Figures 8, 9, 10, and 11). Many of these overlaps exceeded the Rule of Eye 4 (Cumming & Finch, 2005). As the re-sample factor increased, the bootstrapped 95% confidence intervals converged toward the mean. This convergence morphed the overlap between the higher limit of the pre-test confidence interval and the lower limit of the post-test confidence interval into an ever increasing gap. This morphing of overlap into gap became apparent when the confidence intervals were constructed and viewed in the Microsoft Excel CHART WIZARD using the STOCK Wizard as advocated by Thompson (2008) and illustrated in Figures 8, 9, 10, and 11. This overlap of less than 50% indicates statistical significance of the difference in the means of the Pre-test scores and Post-test scores (Cumming & Finch, 2005).

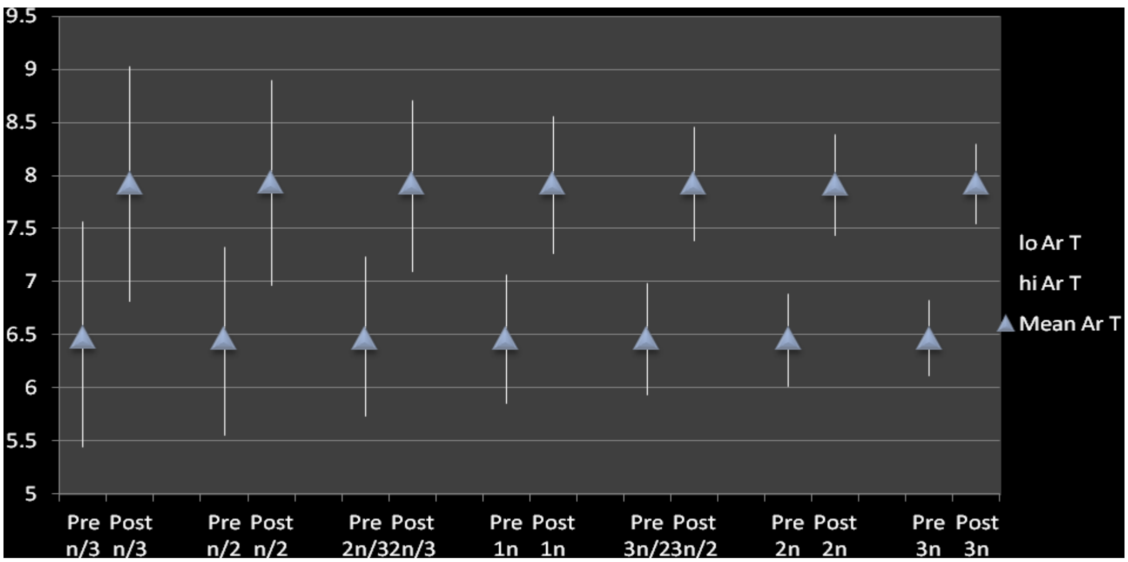


Figure 8. Bootstrapped 95 % CIs of pre/post arithmetic test by resample factor.

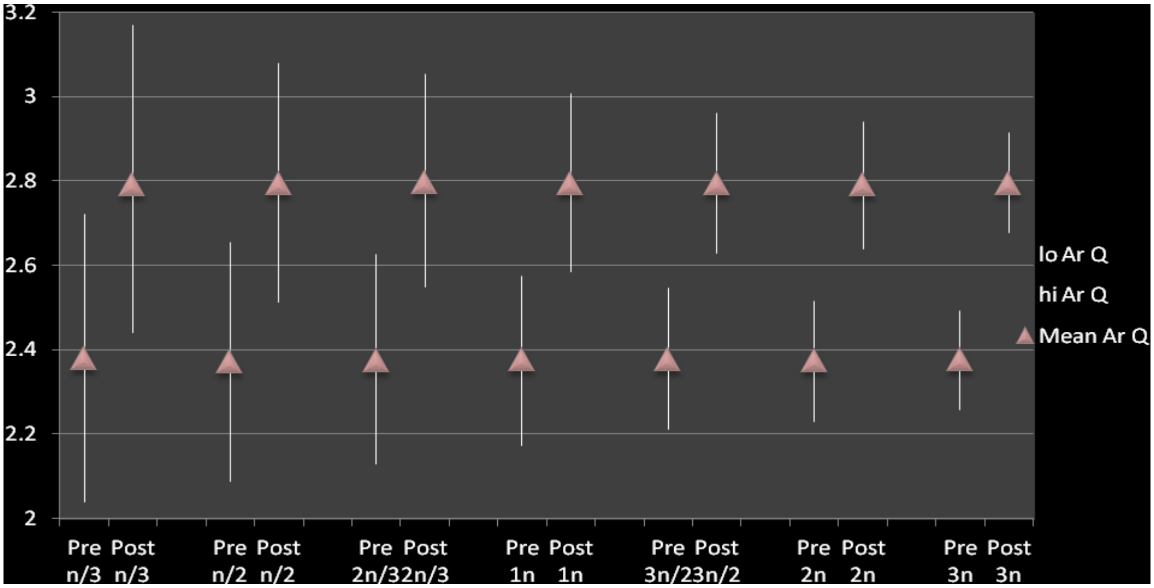


Figure 9. Bootstrapped 95 % CIs of pre/post arithmetic question by resample factor

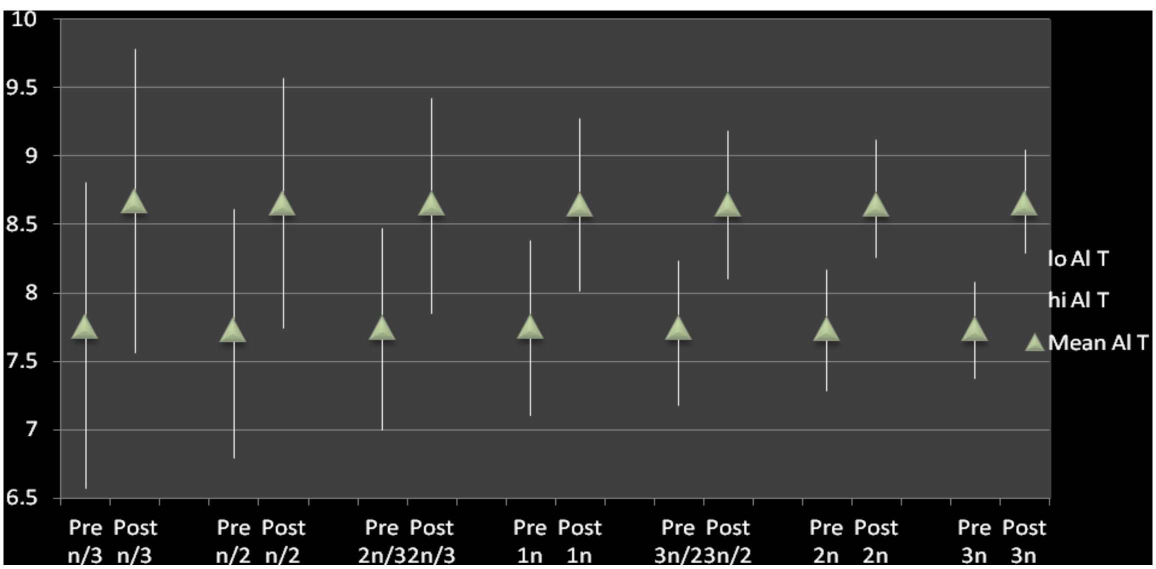


Figure 10. Bootstrapped 95 % CIs of pre/post algebra test by resample factor.

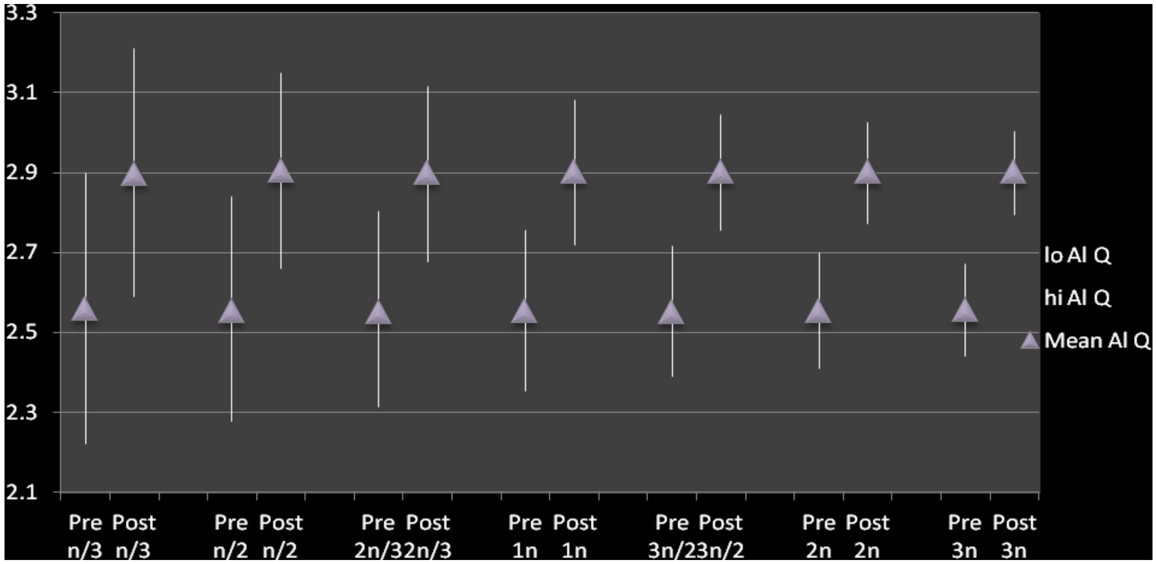


Figure 11. Bootstrapped 95 % CIs of pre/post algebra question by resample factor.

Discussion

Under-sampling, at-sampling and over-sampling can produce similar results for the mean, as illustrated by this study. As the resampling factor increases from under-sampling (factors of one-third, one-half, and two-thirds) to at-sampling to over-sampling (factors of one and a half, two, and three), the widths of 95% confidence intervals converge toward the means. In this study, under-sampling produced mixed results of significance. Both at-sampling and over-sampling demonstrated significant differences between Pre-Test and Post-Test means according to the Rule of Eye 4 (Cumming & Finch, 2005). The statistics that were bootstrapped in this study, namely the mean and 95% confidence interval, are considered descriptive statistics, thus providing evidence the results of the study may generalize (Thompson, 1999).

Limitations

Although this study utilized 8 different data sets, these data sets originated from the same group of students during the same 1-week period of time, which could cause some bias across the data sets. The sample size of the original data set was limited to $50<n<100$. Bootstrapping was accomplished in Microsoft Excel 2007 which has some inherent limitations, especially that of 260 columns per worksheet, thus limiting the re-samples to approximately 250 re-samples per bootstrap recalculation. Convergence of the width of the confidence intervals toward the means as the resample factor increases suggests the possibility over-sampling could be utilized at such a great factor as to falsely demonstrate significance. Further research is needed to investigate a range of resample factors that will produce valid results.

Recommendations for Future Research in Statistics TPCK

Technological Pedagogical Content Knowledge (TPCK) of bootstrapping with Microsoft Excel was introduced to teachers and instructors of first year college introductory statistics courses in this article. More research is urgently needed to determine effective ways to use appropriate technology tools to promote student learning in statistics or TPSK (Chance et al., 2007; Lesser & Groth, 2008). As the number of college students taking statistics classes continues to rise (Cobb, 2005; Lutzer, Maxwell, & Rodi, 2000), good research delving into effective teaching and learning of statistics at the college level is more important than ever before (Zieffler, Garfield, Alt, Dupuis, Holleque, & Chang, 2008). The present knowledge base in regard to exploiting the power of technology tools in statistics education is meager in the face of an enormous task (Ben-Zvi, 2000; Lesser & Groth, 2008; Sorto & Lesser, 2010).

CHAPTER V

SUMMARY AND DISCUSSION

Quandry

The landscape of mathematics education is rapidly changing. On one hand, our nation is in desperate need of more college graduates in STEM fields if we are to meet the goals of *Closing the Gaps by 2015* (Texas Higher Education Coordinating Board [THECB], 2012). On the other hand, many states are lowering the mathematics requirements for high school graduation (Texas Education Agency [TEA], 2013), and compacting the common core for undergraduate education (THECB, 2011a).

Orientation to Mathematics Placement Assessments

This dissertation study showed effectiveness when orienting high school Algebra II students to the testing environment of college placement mathematics assessments. Article 1 illustrated improvement in Post-test scores as compared to Pre-test scores. Article 2 broadcast the voices of students involved in the orientation "When we did the orientation to math placement tests, it was a surprise to me that I would ever be required to take a math test with no calculator", and "I had never heard of a mathematics placement assessment before we had that orientation at the end of Algebra II – that was the first time I heard of it". The data were bootstrapped in Article 3 with the Rule of Eye 4 (Cumming & Finch, 2005) illustrating statistical significance in the difference of the Post-test compared to the Pre-test. The bootstrapped statistics - mean and 95% confidence interval - were descriptive, thus providing evidence the results of the study may generalize (Thompson, 1999). For these reasons, it is highly recommended that high school teachers and students become familiar with future mathematical testing environments. Students should be given opportunities to demonstrate their mathematical competence under a variety of time and technology constraints, not only in mathematics classes, but in other math-enhanced classes such as agricultural power and technology classes or any other math-enhanced career and technical class in which mathematical concepts are presented in context (Parr et al., 2006).

Factors Supporting College Mathematics Success

Students were vocal concerning factors they perceived supported college mathematics success. Among these factors were the orientation to the time constraints "The orientation did make me aware that placement tests are timed.", and technology constraints " . . . we were brought up to use a calculator and are so attached to the calculator that my mind went blank and I really felt anxious not having a calculator . . .". This dissertation study showed that students could increase their score when oriented to college mathematics placement test environment, thus increasing their opportunity to be initially placed into college level mathematics (Alpert, 2013).

Support of Parents and Teachers

The support of parents and teachers was proclaimed as a factor supporting college mathematics success. "I was strongly encouraged to go to college", "the way she taught got me really excited like college math was going to be easy – a piece of cake!" and "my parents want a better life for me than they have, and a college degree is the way to accomplish that" were repeated mantras. Students' perceptions of their own mathematical confidence and abilities were many times directly connected to their former mathematics teachers. "My TAKS remediation teacher taught me a lot!", "Usually, I have always gotten math, as long as I understand it, and they are teaching it the right way – I'll get the hang of it.", and "When I was growing up, I had good teachers early on that were strong in mathematics.". These voices give additional credence to research that has shown a strong link between instructional environments that students have repeatedly experienced in elementary school and their later successes in mathematics (Stodolsky, 1985).

Dual Credit

The dual credit experience was cited as extremely supportive of college mathematics success. “dual credit helped ease me into college” and “this jump from high school math to dual credit math was really good for me because it made me think outside the box and learn more”. Student voices resonated and echoed that providing college-level work to high school students is a promising way to better prepare diverse groups of students for college success. A rising body of research and practices upholds these suggestions (Hoffman, Vargas, & Santos, 2009). “I do think it was a good thing to have taken dual credit because when I go to my university, the classes were large, and my teacher wasn’t very good at explaining, but I had a good background from my dual credit classes at a community college to understand where we were going and what we were doing, and why”. Because the strongest predictor of success in completing a bachelor’s degree is the quality and intensity of students’ high school curriculum (Adelman, 2006), and since dual credit has been shown to increase the intensity and rigor of high school curriculum, students challenged through these dual credit programs could lead to high levels of college success (Bailey, Hughes, & Karp, 2003). Students experiencing dual enrollment in high school were more likely than their counterparts to still be enrolled in college two years after graduating from high school (Hoffman et al., 2009). “I learned in dual credit classes how much time I need to allow for me to accomplish the necessary tasks, what those necessary tasks are and how to prioritize them”, and “my roommate here at the university did not have any dual credit classes, and I can see the difference – she had to develop good study habits quickly" give voice to at least some of the reasons for why dual credit offers potential smoothing of the high school-to-college transition for a wide range of students (Bailey et al., 2003).

Technological Pedagogical Content Knowledge (TPCK)

Wise and powerful choices in the teaching, learning and application of mathematical technology tools was voiced as a factor that would support college mathematics success. Calculator dependency was bemoaned "It seems my sharp computation skills left quickly after the calculator became a permanent part of my mathematics", "we were brought up to use a calculator and are so attached to the calculator that my mind went blank and I really felt anxious not having a calculator", and "I was really dependent upon my calculator – doing math with just pencil and paper was so strange". Lack of familiarity with four-function calculators was reported as a detriment to success on college mathematics assessments. "That was my first experience trying to do Algebra with a four-function calculator, I didn't feel like I was familiar enough with it for it to be helpful", "Using the four-function calculator, I wasn't sure where to start, or how this little calculator could help me", and "I had gotten so used to the graphing calculator, I couldn't figure out what all to press on the four-function calculator to get the right values".

Students felt a mathematics background in which there was a balance of technology tools learned and applied would have supported college mathematics success. "calculators should be used as a guide to learning, not just to figure out the answer", "calculators should be used to support learning, but not replace learning", "it would be a blessing if I knew how to do math without a calculator", "students should learn how to do math both with and without a calculator", "students should still be taught how to use the calculator, and should still be able to use the calculators, but not how we were – so attached to a graphing calculator" and "in dual credit math, we were required to be able to do the math both without and with a calculator – usually three of four different ways with a calculator – then we could choose the method that worked for us individually. I think that was good – to know how to do the math different ways". Projects applying spreadsheets such as Microsoft Excel were mentioned as supportive of college mathematics success, "in one of my dual credit mathematics classes, we had to figure an amortization table in Microsoft Excel". Article 3 presented an Microsoft Excel bootstrapping project for an introductory statistics class. This project supports college mathematics success by scaffolding Technological Pedagogical Content Knowledge (TPCK) (Koehler & Mishra, 2008) of teachers and gives students familiarity and practice with Microsoft Excel as a mathematics technology tool.

Conclusions

Further research is needed to determine additional factors that support success in college mathematics. As new funding formulas (THECB, 2012) are tweaked and implemented, high school graduation requirements are restructured (TEA, 2013), and the undergraduate core is compacted (THECB, 2011a), the need for students to be accurately placed into their first year mathematics course is critical. For those students placed into developmental mathematics, it is imperative that timely and effective ways to support their journey to college level mathematics be identified.

Teachers need to be asking the deep, robust question of how technology can be used to engage meaningful learning (Jonassen, Howland, Marra, & Crismond, 2008), rather than simply viewing the short-term goal of how technology can be used to raise the next test scores. This meaningful learning with mathematical technological tools that will support college mathematics success will provide students with computational agility with a variety of technology tools, ranging from pencils to spreadsheets.

The calculator wars continue to rage in mathematics education, although the question under argument, "Should students be allowed/required to use calculators in mathematics class?" is really not the true question under consideration at all. The question that should be debated is a more philosophical one concerning the very nature of mathematics. A view of mathematics as a static set of rules will yield the idea that calculators are "cheating" and should be banned from mathematics entirely. A view of mathematics as a dynamic and evolving discipline will yield an embracement of the effective integration of technology of all types in the mathematics classroom. A deep understanding of, and appreciation for, the beauty and utility of mathematics will motivate a teacher to seek and gain technological knowledge that can be integrated into the mathematics classroom. Good research practices and further research will help identify what that effective integration of technology might look like.

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APPENDIX A

TEXAS A&M UNIVERSITY HUMAN SUBJECTS PROTECTION PROGRAM

CONSENT FORM

Project Title: College Mhematics Placement Assessment Orientation: Student Voices

You are invited to take part in a research study being conducted by Anna Pat Alpert, a researcher from Texas A&M University. The information in this form is provided to help you decide whether or not to take part. If you decide to take part in the study, you will be asked to sign this consent form. If you decide you do not want to participate, there will be no penalty to you, and you will not lose any benefits you normally would have.

Why Is This Study Being Done?

The purpose of this study is to investigate factors leading to college mathematics placement and student beliefs concerning college mathematics placement assessment.

Why Am I Being Asked To Be In This Study?

You are being asked to be in this study because you previously participated in an orientation to college mathematics placement assessment that involved a pre-test, intervention, and post-test.

How Many People Will Be Asked To Be In This Study?

Twelve people (participants) will be invited to participate in this study locally.

What Are the Alternatives to being in this study?

The alternative to being in the study is not to participate.

What Will I Be Asked To Do In This Study?

You will be asked to answer questions concerning your experience in the orientation to college mathematics placement assessment, or any factors that might have affected your mathematical experiences. Your participation in this study will last up to a year, and includes an initial interview and any follow-up interviews necessary for data clarification.

Will Photos, Video or Audio Recordings Be Made Of Me during the Study?

The researcher will make an audio recording during the study so that the interview can be transcribed accurately. If you do not give permission for the audio recording to be obtained, you cannot participate in this study.

________ I give my permission for audio recordings to be made of me during my participation in this research study.

________ I do **not** give my permission for audio recordings to be made of me during my participation in this research study.

Are There Any Risks To Me?

The things that you will be doing are no more greater risks than you would come across in everyday life. Although the researchers have tried to avoid risks, you may feel that some questions that are asked of you will be stressful or upsetting. You do not have to answer anything you do not want to.

Will There Be Any Costs To Me?

Aside from your time, there are no costs for taking part in the study.

Will I Be Paid To Be In This Study?

You will not be paid for being in this study.

Will Information From This Study Be Kept Private?

The records of this study will be kept private. No identifiers linking you to this study will be included in any sort of report that might be published. Research records will be stored securely and only Anna Pat Alpert will have access to the records. Information about you will be stored in locked file cabinet; computer files protected with a password. This consent form will be filed securely in an official area. People who have access to your information include the Principal Investigator and research study personnel. Representatives of regulatory agencies such as the Office of Human Research Protections (OHRP) and entities such as the Texas A&M University Human Subjects Protection Program may access your records to make sure the study is being run correctly and that information is collected properly. Information about you and related to this study will be kept confidential to the extent permitted or required by law.

Who may I Contact for More Information?

You may contact the Principal Investigator, Anna Pat Alpert, to tell her about a concern or complaint about this research at 254-625-2230 or ms_pert@yahoo.com. You may also contact the Protocol Director, Mary M. Capraro, Ph.D. at 979-845-8384 or mmcapraro@tamu.edu.

For questions about your rights as a research participant; or if you have questions, complaints, or concerns about the research, you may call the Texas A&M University Human Subjects Protection Program office at (979) 458-4067 or irb@tamu.edu.

What if I Change My Mind About Participating?

This research is voluntary and you have the choice whether or not to be in this research study. You may decide to not begin or to stop participating at any time. If you choose not to be in this study or stop being in the study, there will be no effect on you.

STATEMENT OF CONSENT

I agree to be in this study and know that I am not giving up any legal rights by signing this form. The procedures, risks, and benefits have been explained to me, and my questions have been answered. I know that new information about this research study will be provided to me as it becomes available and that the researcher will tell me if I must be removed from the study. I can ask more questions if I want. A copy of this entire consent form will be given to me.

______________________________	______________________________
Participant's Signature	Date
______________________________	______________________________
Printed Name	Date

INVESTIGATOR'S AFFIDAVIT:

Either I have or my agent has carefully explained to the participant the nature of the above project. I hereby certify that to the best of my knowledge the person who signed this consent form was informed of the nature, demands, benefits, and risks involved in his/her participation.

______________________________	______________________________
Signature of Presenter	Date
______________________________	______________________________
Printed Name	Date

APPENDIX B

Interview Protocol

What has been your relationship with mathematics?

How do you see your relationship with mathematics progressing in the future?

When did you feel the most mathematically empowered? Can you explain that experience to me a bit more? What about the experience made you feel mathematically powerful?

When did you feel the least mathematically empowered? Can you explain that experience to me a bit more? What about the experience made you feel mathematically weak?

Can you describe your mathematical experiences up to now?

What do you think college mathematics will like for you?

What field(s) are you considering going into? What are you considering studying or majoring in during college? What college are you contemplating attending? How has your relationship with mathematics affected those decisions?

Before the orientation to College Mathematics Placement Assessment Environment, how prepared for college mathematics did you feel?

After the orientation to College Mathematics Placement Assessment Environment, how prepared for college mathematics did you feel?

Did the orientation to College Mathematics Placement Assessment Environment help you in any way be more aware and/or prepared for placement assessment? How?

How did you feel about the arithmetic section using only paper and pencil?

Do you think the time constraint affected your performance on the arithmetic test?

How did you feel about the algebra section using only a four-function calculator?

Do you think the time constraint affected your performance on the arithmetic test?

What do you feel the role of calculators should be in mathematics learning? Why?

What do you feel the role of computers should be in mathematics learning? Why?

What do you feel the role of calculators should be in mathematical applications on the job? Why?

What do you feel the role of computers should be in mathematical applications on the job? Why?

Are there any other mathematical experiences or comments you would like to share with me and the readers of this research?