THE EFFECTS ON STUDENT ACADEMIC ACHIEVEMENT AND STUDENT SELF-CONFIDENCE OF A COURSE-SPECIFIC TEXTBOOK WRITTEN FOR APPLIED ELECTRONICS MATH 2

by

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ABSTRACT

This research project was developed from the need for a good, affordable textbook for Applied Electronics Math 2 at Madison Area Technical College. When no suitable textbook was found, I chose to write a one specifically designed for that course. This study was motivated by two major research questions in relation to that text: (1) what is the effect on student achievement of using this text? (2) Does the additional emphasis on basic concepts enhance student self-confidence in field-related applications?

Data for this project was collected over a period of three semesters. This included not only student grades for homework, quizzes, and exams but information on students' self-confidence levels with respect to mathematics in math and related electronics classes collected at the beginning and end of each semester. Student opinions of the textbook were collected and evaluated using surveys and interviews.

Academic scores of the three test classes as compared to a baseline of previous classes taught without a textbook showed expected improvement. However, the greatest improvement was in the self-confidence levels of a majority of the students. Math anxiety was greatly reduced and students declared themselves more prepared to take on the mathematics in their other electronics classes. Student comments about the textbook itself were very favorable.

The findings from this research suggest that an affordable book written for a particular course can have a positive effect on both students' academic success in that course and their self-confidence in related areas.

INTRODUCTION AND BACKGROUND

This research project was developed to answer the need for a good, affordable textbook for Applied Electronics Math 2 (Math 2) at the Madison Area Technical College (MATC). When no suitable text could be found, a textbook was written specifically for the course. This project consisted of two major parts: the creation of the textbook and the testing of the book during three terms of Math 2 with three separate classes. The data collected included students grades for homework, quizzes and exams, survey information on student self-confidence with respect to mathematics in math and electronics classes, and student opinions of the textbook itself.

Madison Area Technical College (MATC), founded in 1912 as a vocational school, is located in Wisconsin's capital city. It serves a twelve county area with eight locations within the city and four regional campuses. Approximately 43,000 commuter students attend the college, with 24,000 in degree programs and another 19,000 taking courses outside of degree programs. One of sixteen schools in the Wisconsin Technical College System, MATC consists of 98% in-state and 2% out-of-state students. Female students outnumber male students 55% to 45% although more male students graduate (57.3%) than female students (42.7%). The diversity of the school is similar to the diversity of the Madison area itself. The majority of students are White Non-Hispanic (76.6%) with the remainder being Hispanic (7.4%), Black Non-Hispanic (7.2%), Asian or Pacific Islanders (4.0%), American Indian or Alaskan natives (1.7%), non-resident aliens (1.3%) and unknown or other (1.8%). The student to faculty ratio is 11:1. (Retrieved from http://www.stateuniversity.com/ universities/WI/Madison_Area_ Technical College.html).

I am currently teaching in the Electronics Department in the School of Applied Science, Engineering, and Technology, at the Truax campus in Madison. My research involved three classes of Applied Electronics Math 2 students over the course of three semesters. In order to clarify discussion, I have labeled these classes F14 (fall, 2014), S15 (spring, 2015) and F15 (fall, 2015). Class F14 had fifteen students, including fourteen white non-Hispanic males and one female student from Thailand. Class S15 consisted of nine male students: seven white non-Hispanics, one black non-Hispanic, and one from the Middle East. Class F15 had eighteen students, including fourteen white non-Hispanic males; one black non-Hispanic male from Africa, one Asian male, and two white, non-Hispanic female students. In addition to my three research classes, I am using a comparison class composed of weighted averages from all of the preceding Math 2 classes since the class was created. This class was designated Baseline.

Most students in these classes were in the age range of early twenties to mid-thirties, while one of the students in F14 was in his fifties. My students have displayed a wide range of academic abilities from students who plan to transfer to a four-year electronics engineering program to students who hope to improve their current job prospects. Several of our electronics students have bachelor's degrees from four-year colleges. Most students will complete the two-year program within two to five years. Many of our students work half to full time, often while attending school full time. Approximately half of the students are married, many with young children.

In 2011, I was asked by the Electronics Department at MATC, where I have taught for nearly twenty years, to create two new courses in applied electronics mathematics. Each of these courses would be eight weeks long and would meet for three hours, twice a week, or for five hours one night a week. Each of these condensed short courses would cover much of the material that had formerly been covered in a full semester. After extensive consultation with the other electronics instructors, I created the initial versions of the two courses. Since then I have worked to fine tune these courses.

Over the years, the general electronics math textbook that we used for both Math 1 and Math 2 had become unaffordable for many of our students. After teaching for several years using only course handouts which I wrote and gave to my classes, I came to realize that I could combine my handouts, add some practice problems with answers, and write a book specifically for these courses.

Writing my own textbook would have several advantages. I could include everything that we covered in class, omit non-essentials, and keep the cost down for the students. I could emphasize the methods of problem solving that we are currently teaching and omit some of the dated methods still shown in some current textbooks. In addition, I could combine sections of the text with specific computer programs and use these to teach relevant modern problem-solving techniques. The textbook would enable students to learn some of the material on their own. It would provide reference material to supplement inadequate or missing class notes. It would also help to unify all sections of the course and ensure that all instructors cover the same material.

Together these ideas led to my capstone proposal: the development, writing and testing of a textbook specifically designed for Applied Electronics Math 2, containing both the mathematical background and the applications to electronics that we emphasize. Three chapters, covering the topics of imaginary and complex numbers, voltage and current as sine waves, and the Thevenin, Norton and Superposition circuit theorems, were printed and given to the class during the fall of 2014. I added a fourth chapter on logarithms during the spring semester. The completed textbook was computer-printed, bound and sold in the college bookstore during fall 2015 as the official textbook for Applied Electronics Math 2.

The book contains eight chapters, one for each of the seven units covered during the course plus an additional chapter on parallel RLC circuits. (Appendix B). Each chapter begins with an introduction to the subject including a brief discussion of new terms and units. Whenever possible, the mathematics of the chapter is linked to electronics topics, obtained through working with other electronics instructors, in order to maintain student interest. Instructors' requests for specific mathematical topics were added to the chapters whenever possible.

Each chapter contains a series of course-related problems. For each type of problem, the first example contains detailed, step-by-step directions for working toward a solution with an explanation for each step. At the conclusion of the problem, a method for checking the answer is given. The second example in each set shows the step-by-step solution without the detailed explanation. Each chapter contains a variety of practice problems with answers for students to work independently.

This research study contains two major focuses. The first issue, involving the writing of the textbook and my use of it as class teacher, will be discussed in the values and claims section. The second, requiring an evaluation of the utility of the text for the students, led to my research focus question: what is the effect on student achievement in Applied Electronics Math 2 of using a textbook specifically written for the course that emphasizes student understanding of the basic mathematical concepts underlying all of electronics? Two related sub-questions were also identified: does the additional emphasis on basic concepts increase student self-confidence in field-related applications and do the computer simulations performed in class relate well to and enhance the material contained in the text? A third sub-question dealt with student opinions about the textbook itself and whether or not my students thought that using this book enhanced their confidence in their ability to understand electronics-related mathematics. Data was collected on these three topics concurrent with the focus question.

CONCEPTUAL FRAMEWORK

Mathematics is said to have arisen from our human need to organize and explain the phenomena we observe and experience in the course of our lifetimes (Bell, 1993). For some areas of study, mathematics may be rather unimportant. However, for the fields of science, technology, engineering, and mathematics (STEM), math serves as a scaffold that both anchors and supports them.

Flegg, Mallet and Lupton (2012) define engineering as “the application of mathematics and sciences to the building and design of projects for the use of society” (p. 717). In today’s world, and especially in the United States, the need for trained engineers is constantly increasing. Unfortunately, the number of students in college-level engineering programs is not keeping up with the demand. The popularity of engineering degrees is declining among undergraduates. The attrition rate is high in these programs, with many students either dropping out of college or simply changing to a different, less demanding major. Retention rates in the engineering programs are particularly low for women and ethnic minorities. Much of the growth in numbers of freshman engineering students today is likely to come from students with lower academic achievement levels (Smaill, Rowe, Godfrey, & Paton, 2012).

Nowhere is this problem more obvious than in the area of mathematical preparation. Studies show a strong relationship between students' performance in math and their ability to succeed in their engineering courses (Tolley, Blat, McDaniel, Blackmon, & Royster, 2012). The problem begins well before college. Students planning to major in engineering in college should spend their high school years taking advanced courses in the sciences and mathematics. These courses will better prepare them for rigorous college courses in the STEM fields than the standard college preparatory courses (Moses et al., 2011). Students who enter college without this background may start at a disadvantage and will have to struggle to catch up. Because both high school students and their advisors are often unaware of how important math is to engineering, students often make poor choices of coursework during these important years (Bowen, Prior, Lloyd, Thomas, & Newman-Ford, 2007). Poor performance in math and science classes may eliminate many bright students from the fields of science and engineering (Norman, Moore, & Kern, 2010) while grade inflation and non-challenging courses may wrongly persuade others that they can succeed in STEM majors.

Problems with mathematics for engineering students do not all arise from lack of high school course work alone. Often the problems result from the simple inability to manipulate numbers, judge the "correctness" of an answer, rearrange a mathematical equation, or transfer knowledge used in solving one category of problem to another. Frequently, unrealized deficiencies in middle and high school math, combined with lack of retention of studied material, may lead to the inability to adequately compete in required courses on the college level. Brannan and Wankat (2005, in Tolley et al., 2012) found that nearly three quarters of the college institutions studied considered math to be a serious area of weakness for incoming engineering students. Colleges have been forced to require remedial math courses for many of their students.

Many of these same problems have developed at the level of community or technical colleges. Many students in the electronics, science and math-related fields plan, after completion of their two-year associate's degrees, to continue their studies at a four-year college. Even those students who plan to leave after the completion of a two-year course often find that their time in school must be increased by a series of remedial math courses.

Once students are in the college-level math courses, they will find that there is no real agreement on how the course should be taught. Some schools and some instructors support the need for formality and rigor in their math courses. Others oppose such rigidity. Some support teaching math as theorems and proofs while others prefer to model problems that relate to engineering. Math departments usually have the responsibility of teaching math to all students, including to engineering students. However, according to Flegg et al. (2012), there is a growing belief among engineering faculties that math for engineers should be taught by engineers, that it is preferable for engineering departments to integrate the necessary math into engineering classes so that students are better able to understand its relevance.

Undergraduate STEM classes generally feature instruction transmitted to the student by the expert teacher using the lecture format. Stage and Kinzie (2009) found that this type of focus, usually coupled with a series of cookbook laboratory experiments, and an emphasis on teaching scientific concepts first, leads to a “fragmented view of science” (p. 87). Theoretical math is similarly taught. Lectures are generally followed by exams containing questions dealing with memorized facts. Qualters, Sheahan, Mason, Navick, and Dixon (2008) claimed that these exams are not really measuring knowledge gained or knowledge retained but rather what the student memorized to prepare for the test. They further maintained that current research shows universities are not as successful at educating their students as once thought.

Traditionally, engineering faculties have demanded expert computational skills and algorithmic knowledge from their students while engineers in the work force are additionally expected to show analytical and creative design abilities. This leads to the question of how to produce engineering and electronics students who are capable of demonstrating all of these abilities. In order to teach or learn engineering math in a form that will lead to “life-long learning in the knowledge society,” Booth (2008) recommended a form of understanding that "goes beyond facts, theorems and algorithms" (p. 381). Knowledge is characterized as *relational*, between a person who knows and an object that is known, and learning as *experiential*. Learning is intentional and active; it is demanded of the learner and requires a shift by the teacher from actively teaching to creating the appropriate conditions for learning.

Engelbrecht, Bergsten, and Kagesten (2012) investigated the question of whether students in undergraduate engineering mathematics courses would benefit more from an emphasis on a conceptual orientation or a procedural orientation to teaching. Using definitions from cognitive psychology, they described conceptual knowledge as a connected web of knowledge. The more traditional procedural knowledge had two components, the step-by-step procedures used to perform mathematical tasks and the symbolic representations used in these solutions. Students beginning their university careers have frequently experienced learning math with a focus on computational or procedural skills. They begin with little training in deeper conceptual thinking and must be taught to do so. The existence of these two different types of knowledge leads to the problem of whether it is better to teach concepts or procedures first. Each method has its supporters while other engineering instructors believe that the two should be integrated into each lesson. Engelbrecht et al. learned that engineering students found both forms of math knowledge relevant to their engineering studies but were uncertain about the relevance of the two categories of knowledge in fields outside of math and engineering.

Learning can be characterized as deep learning and surface learning. Litzinger et al. (2011) studied engineering education and how it led to the development of expertise.

They described those learning experiences that would lead to developing expertise in a field as *effective learning experiences*. *Deep approaches to learning* lead to increased depth of understanding, higher-level cognitive skills, and the ability to make connections across disciplines (Litzinger et al., 2011; Qualters et al., 2008). As with conceptual skills, students must be taught the skills necessary for deep approaches to learning and the integrated application of knowledge across disciplines. These place higher cognitive demands on students than do surface approaches. Students must therefore be motivated to attempt more complicated approaches to learning and to value these efforts.

There are many problems inherent in traditional math education. Bell (1993) described traditional math lessons as consisting of the demonstration by the teacher of a single method of solving a particular problem, followed by practice using a series of different numbers. The emphasis, as he put it, is "on learning to use tools and not on making furniture; and when the latter is attempted, it demands strategic capabilities – concerning planning, designing, costing, choosing materials, and selecting tools – which have not been developed" (p. 7).

Students often prefer this way of learning and are not ready to abandon the surface learning approach, in large part because it is the method they have used most often in their primary and secondary school years (Smaill et al., 2012). Their math courses have emphasized procedural knowledge, with the result that many students arrive at their first college math courses with no previous knowledge of the concepts underlying math. They can often solve a problem when given an equation, but if the problem is put into words, they have no idea how or where to begin. Students often have more confidence in their ability to solve procedural problems than conceptual ones because they have seen so many more procedural questions in their math careers (Engebrecht et al., 2012).

At least part of the blame for the problems that students experience in their math and science courses can be divided among the students themselves, their teachers and schools, and their textbooks. Students often come to math and science courses with poor attitudes, expecting that the courses will be too hard or boring. Often this arises from a rather fallacious view that all learning should be painless and entertaining (Dutch, 2005). Students do not expect to have to work hard to learn. Teachers may be at fault due to poor attitudes or lack of knowledge in the field in which they find themselves teaching. Schools may be at fault for any number of reasons.

An important area in which schools fail their students lies in the selection of the textbooks to be used. Research has shown that textbooks have a great influence on student learning, perhaps even more than the teacher does (McKeachie, 2002, in Wolfe, 2004). At the secondary level, textbooks are considered an integral part of both teaching and learning math. Many schools use the textbook to plan the math curriculum. For this reason, textbooks are sometimes described as “de facto curriculum” (Budiansky, 2001, in Shield & Dole, 2012) and are seen as “the most important tools in guiding teachers’ teaching” (Van den Heuvel-Panhuizen, 2000, in Shield & Dole, 2012, p. 184). In spite of the great respect that schools seem to have for textbooks, many of them have been found to fall far short of what is needed.

One cause for this problem is the serious disconnect that seems to exist between what teachers and other academics say that they want in a textbook and the type of textbook that they will choose. According to Dutch (2005), many academics claim that they want a logically arranged, unified text. However, they will repeatedly choose texts that follow a traditional, highly compartmentalized format that confuses rather than enlightens. These texts often have no logical overall structure and no links between topics (Shield & Dole, 2012). Teachers in the United States and other technologically advanced countries tend to use textbooks that provide standardized assignments and tests, contain many vocabulary words that seem to have no purpose other than to appear on a test, and feature sample problems with no relation to real-life situations. According to Bloom (1984), textbooks such as these have not had any significant positive effect on student achievement.

Students have somewhat different requirements for their textbooks. They want a book that can serve as an outline and as reference material for a course, one that they can consult when they miss a class (Wolfe, 2004). They want to be able to easily identify major issues and themes throughout the book and they appreciate organizers placed at the beginning and ends of chapters and units (Bloom, 1984). They want to be able to rent the book or to purchase it at a reasonable price. Math and engineering students generally do not want to derive deep meaning from their textbooks. According to Kuhlenschmidt (2007), many students do not like to read or even are unable to read at the college level. Some students actually read very little or none of the textual material in a textbook (Nicely, 1985). Instead of extensive verbal explanations, they would prefer to have a series of worked examples that they could follow, step by step, in order to complete homework exercises (Rezat, 2009, in Shield & Dole, 2012). They would like the examples to be of varying difficulty, not just easy examples that they could have figured out themselves, nor do they want the first example of a new procedure to be too difficult. They would like their textbooks, regardless of the course, to be up to date and to relate to real life experiences, both current and future.

This brings up the question of textbook design and, in particular, the content and arrangement of a textbook that is to be specifically designed for an introductory class in electronics and engineering math. Within the engineering curriculum, there will naturally be a strong emphasis on problem-solving skills. Engineering students will learn math as a subject of study in itself, as a tool for using with other subjects of study, and as a tool for dealing with real world problems (Booth, 2004, in Flegg et al., 2012). However, students should also develop a deep conceptual understanding of the mathematical basis of electronics and engineering and a sense of the connectedness of the information. The problem lies in achieving the right balance of theory and practice.

The textbook for an introductory course in applied electronics mathematics should be logically organized so that topics develop naturally from those that preceded them. It should be readable, reasonably priced, relevant and current. Bloom (1984) recommended organizers at the beginning of each chapter, organizational aids during a chapter, and summaries and appropriate questions at the end of each chapter. Dutch (2005), on the other hand, believed that these promote poor study habits. He found chapter summaries to be worthless and recommended leaving out of the textbook anything that "fosters the illusion that learning is entertainment" (p. 44). Dutch also recommended against catering to math and science anxiety. To do so, he believed, lowers the number of students who become science and math majors and reduces the quality of those who do.

If helping students to truly understand the math they will be studying is important to the textbook writer, then the text and the resulting curriculum must be designed for this understanding, beginning with the language content. Czegledy and Kovacs (2008) found that "the simple, clear, concise and precise wording of definitions, theorems, proofs or other rules" is significant in the field of mathematics (p. 17). Long, complex sentences should be avoided whenever possible. The language itself should not be at too elementary or too advanced a level. The writing should be aimed primarily at the average to better student, not the poorer student or the teacher. Clarity of language will facilitate learning in all fields, but especially in mathematics and science.

Presentation of new information in a textbook is particularly important. By building on existing knowledge and connecting it to new material being presented, a writer can help students to see the bigger picture. Learned material that consists of well-connected pieces of knowledge can be more easily retrieved from memory than isolated bits (Bell, 1993). The more interconnected links there are to stored bits of knowledge, the easier its retrieval will be. One implication of this in mathematics is that if a certain relationship is known, all of its logical consequences should also be known. Unfortunately, this is not necessarily true for students, who may not see beyond the immediate problem. In writing a textbook, the author should encourage students to stretch each small piece of knowledge as far as they can. This can be done by guiding the students into exploring the implications of what they have learned. Stein and Lane (2006) found that the greatest gains in mathematical performance are closely related to instructional tasks that engage students in high levels of cognitive processing. Students learn and understand more when the tasks they are given are both longer and more focused on mathematical ideas than on simple mechanical, algorithmic procedures. Tasks that encourage students to use multiple strategies for the solution of multifaceted problems help them to develop greater understanding of the basic theoretical background to what they are learning. Bell (1993) further suggested offering appropriately challenging tasks in areas that students can see as part of their future careers. He recommended minimal intervention by the teacher as students work on these tasks, followed by a period of reflection and discussion to help connect this new knowledge firmly to the old.

Along with fostering a deep understanding of the conceptual bases for mathematical knowledge, however, it is equally important not to ignore the procedural component. Within the engineering curriculum, there will always be a strong emphasis on problem-solving skills. Students must learn to identify problems, carry out the required mathematical analysis or calculations, and interpret the results within an engineering context (Flegg et al., 2012). Appropriate examples must be chosen to illustrate each type of problem solution. Clarity is absolutely essential in explaining these examples (Ginsberg, 2012). Vincent and Stacey argued in favor of a range of problems to help students "make connections and recognize mathematical concepts, as well as stimulating mathematic reasoning and reflection" (Vincent & Stacy, 2008, in Shield &

Dole, 2012, p. 185). They found that some of the best-selling textbooks contained far too many repetitive examples of problems requiring little more than simple routine procedures.

For class explanation and homework problems, choosing context-rich multifaceted problems will support both procedural skills and knowledge development (Litzinger et al., 2011). It will also help students to bridge the gap between textbook problems and real-life problems. Students will need help at first, both from their textbook and from their teacher, because they will initially have little experience with problems involving multiple concepts. It is important to challenge students at the appropriate level, neither too high nor too low, to maintain interest in learning (Litzinger, 2011). As students realize that they are developing analysis skills that they will use in later professional practice and see themselves developing expertise in their math skills, they will be more motivated to learn. They will be able to solve increasingly complex problems, both in engineering and mathematics and in all their other subjects (Qualters et al., 2008).

Finally, Ginsberg (2012) offered some suggestions for the actual writing of a textbook. When creating and explaining a sample problem, he recommended first choosing an example that has elements of previous examples integrated into it and using this to help students to build on previous knowledge. An interesting example that applies to student concerns now, or professional concerns in the future, will keep students motivated. Textbook writers should choose examples that are not too complex, at least at first, and explain in detail what they are trying to show. It is important to explain why a particular procedure or method of solution is being used. Graphs and figures should be included where helpful and the degree of detail of an explanation kept at the level of the intended students. However, according to Kuhlenschmidt (2007), students frequently do not look at graphs and images and often ignore captions. References to the graphs, tables, and pictures in the text should therefore be included in the solutions to problems, to encourage student use of these images. At the conclusion of the explanation of a problem, the writer should attempt to use the problem to connect the application of principles to the principles themselves. The next problem should be a little different, not simply a repetition of the same problem with different numbers. Finally, when creating homework assignments or practice problems, the writer should always include the answers to a selection of the problems or, even better, to all of the problems. Students who make the effort to work additional problems appreciate knowing that they have achieved the correct answers. They likewise appreciate knowing if their answers are incorrect so that they may attempt to find the cause of their errors.

Financial issues are rarely mentioned when discussing a textbook. However it is important to point out the fact that many students are financially stressed during their college years. As Kuhlenschmidt (2007) reminds us, when students must spend a great deal of money on textbooks that are rarely used, their confidence in their teachers is undermined. In addition, some students may be unable to obtain textbooks until after their financial aid arrives, requiring them to start the term without the necessary books. Costs of textbooks have risen at twice the rate of inflation according to the Government Accountability Office (Kuhlenschmidt, 2007), causing some students to try to get by without a textbook. A further problem for students is the current practice of "bundling," adding solution manuals, workbooks, or CDs to the textbook, increasing the cost and generally requiring students to buy new books. All of these factors should be taken into account when selecting or writing a textbook, whether for engineering and mathematics or any other subject.

METHODOLOGY

Data for this capstone project was collected at Madison Area Technical College in the Applied Electronics Mathematics 2 courses during three semesters: fall of 2014, spring of 2015, and fall of 2015. Each of these classes was a half-semester (eight-week) class. The fall 2014 class was a five-hour evening class with fifteen students. The spring semester class met for three hours twice a week and had nine students. During the fall of 2015, the day classes were shortened to five hours, two hours on one day and three hours on a second day, in order to match the time-frame of the evening classes. The class for the fall semester of 2015, with eighteen students, followed this new schedule. All three classes covered the same topics, although not always in the same order. The research methodology for this project received an exemption by Montana State University's Institutional Review Board and compliance for working with human subjects was maintained (Appendix A).

For the first semester of this research project (fall 2014), three chapters of a teacher-written, course specific textbook were used as treatment units while four units were taught without a text. The three treatment units consisted of Chapter 4: Introduction to Imaginary and Complex Numbers, Chapter 6: Circuit Theorems and Chapter 8: AC

Current and Voltage as Sine Waves, (Appendix B). The remaining units, covering the topics of vector and phasor addition, series AC circuit analysis, circuit analysis using complex numbers, and exponential functions and logarithms, were considered non-treatment units.

A fourth unit, Chapter 7: Exponential Functions and Logarithms, was added as a treatment unit during the spring semester of 2015. The completed book, containing seven chapters plus the added chapter on parallel RLC circuits, was used for all treatment units during the fall of 2015.

A baseline for comparison for these classes (called Baseline) was obtained using the averages, weighted according to the number of students in each class, for the quizzes, homework assignments, final exams, and final grade percentages for the following classes: fall 2011, spring 2012, fall 2012 (day), fall 2012 (evening), spring 2013, fall 2013 (day), fall 2013 (evening), and spring 2014. The homework assignments, quizzes, and final exams were the normal ones for Math 2. No new data collection instruments were required.

In order to answer the primary focus question of this study, summative assessments were gathered for each of the six major units in Applied Electronics Math 2 in the form of graded homework, unit quizzes, and a cumulative final exam. Each of these assessment tools was teacher-created and closely related to the material covered in class and the contents of the textbook chapters. Homework assignments and quizzes for the three semesters were compared by topic. The final exam has traditionally been an open-book, take-home exam due to the length of some of the circuit problems. This practice was continued during these semesters. While exams and quizzes were necessarily different for each class, an effort was made to keep the level of difficulty the same for all classes.

Homework and quizzes for the three classes plus the baseline weighted average of previous terms were compared numerically and graphically as course totals and as individual homework and quiz topics. Average scores for the final exam including extra credit were compared numerically and graphically for the four class groups. The midterm exam was not compared since the material covered varied with the timing of semester breaks. The class average scores for homework, quizzes, final exams, and course totals were compared for the four groups using Analysis of Variance (ANOVA).

The Self-Confidence Survey, a balanced Likert style survey with equal numbers of positive responses on the left and the right, was given to each class during the second class period and during the final class period, giving both pre- and post-treatment values (Appendix C). The survey contained five response alternatives: *Never* (1), *Seldom* (2), *Sometimes* (3), *Often* (4) and *Usually* (5). The responses were averaged, tabulated, and graphed to give an indication of any changes in the students' self-confidence, as a group. It was decided not to use identifying marks on the Self-Confidence Survey for student privacy.

The circuit theorem unit included a graded assignment using *Multisim*, National Instruments' electronics simulation program, which allows students to model circuits on a computer (ni.com). Students used the computer to study and manipulate Thevenin Equivalent voltages and resistances.

Student opinion data relating to the utility and difficulty of the computer work was obtained using the open-ended Computer Assignment Questionnaire (Appendix D). Additionally, five students from each class, including two A or AB students, two B or BC students, and one C or lower student, were individually interviewed using several questions from the computer questionnaire. The results from the questionnaires and the interviews were tabulated and analyzed for trends and suggestions for improvements.

At the end of each treatment unit, the Chapter Evaluation Questionnaire, a Likert style questionnaire with five response alternatives, was used to determine student opinions of the teacher-created textbook chapters (Appendix E). Response choices were *Disagree* (1), *Tend to Disagree* (2), *No Opinion or Undecided* (3), *Tend to Agree* (4), and *Agree* (5). A second part of the questionnaire, also in Likert form with the same response choices, sought information on how students used the chapter while a third part consisted of several open-ended questions. The totals for the two Likert parts of the questionnaire were summed for the treatment chapters for each of the three test classes and compared either graphically (Part I) or as percentages (Part II). The answers for the open-ended questions were listed and compared for trends.

A final survey, the End of Course Questionnaire, used open-ended questions to gather student opinion on the contents of the treatment chapters and how they could be improved (Appendix F). Data from this survey was tabulated and analyzed for trends and suggestions for improvement.

The four questionnaires developed for this project were then additionally used to look more closely at several of my focus questions. The primary focus question, relating to student achievement, was studied using graphical and statistical methods to evaluate academic grades. I looked more closely into the sub-question dealing with an emphasis on basic concepts and student self-confidence in electronics-related applications through the Self-Confidence Survey, both pre- and post-treatment. In this survey, I was particularly interested in student responses to several specific questions (6, 9, 12), relating our math course to other electronics courses. On this same topic, I looked at responses to questions 4, 5 and 6 from the End of Course Questionnaire, which dealt with whether students found material from our class to be useful in other electronics classes. The sub-question related to computer work was investigated using several questions from the Computer Assignment Questionnaire (3, 4, 5) and through student interviews. Data relating to the final sub-question on student opinions of the textbook itself was obtained though the Chapter Evaluation Questionnaires, three questions (1, 2, 3,) from the End of Course Questionnaire and a classroom discussion on the inclusion of printed homework assignments in the text. For each of the questionnaires student responses were listed and compared for trends and, where applicable, percentages were calculated.

The triangulation matrix shown in Table 1 summarizes the sources of data for my research questions.

Table 1
Data Triangulation Matrix

Focus Question	Data Source 1	Data Source 2	Data Source 3
Primary Question: 1. What is the effect on student achievement of using a course-specific textbook for Math 2?	Unit homework (graded)	Unit quiz (graded)	Final Exam (graded)

Sub-questions: 2. Does the additional emphasis on understanding basic concepts enhance self-confidence in field-related applications?	Self-Confidence Survey Pretreatment	Self-Confidence Survey Posttreatment	End of Course Questionnaire
3. Do the computer simulations relate to and enhance text material?	Thevenin computer assignment (graded)	Computer Assignment Questionnaire	Interviews
4. Do students believe this text has contributed to their mastery of course content?	Chapter Evaluation Questionnaire	End of Course Questionnaire	Class Discussion

DATA AND ANALYSIS

The results of the Self-Confidence Survey administered at the end of each of the three treatment semesters indicated that 89% of the Math 2 students felt *confident* that they could apply a variety of mathematical perspectives in solving electronics problems in their math and future electronics courses (*N*=42). Only one student still worried that math would hold him back in his future electronics courses as compared to eleven with this worry at the beginning of the semesters.

Prior to the addition of the course-specific chapters used as treatment units, 40% of the students felt *confident* of their ability to complete the Math 2 class successfully. Twenty-three percent felt *little or no confidence* that they would pass the course. Twenty-seven percent of the students suffered from some form of math anxiety, including a fear of taking a math test (30%), fear of speaking up or asking questions during a math class (24%), or stress while working on math homework (29%). Several students worried because they had been out of school for a number of years. They were afraid that they had forgotten most or all of the math that they had learned. Other students had more specific worries. Logarithms and complex numbers were mentioned by nearly a third of the students. The biggest fear, mentioned by nearly 75% of the students, was "the short time we have to learn so much material."

After the treatment units, but before the final exam, 74% of the students were *confident* that they could successfully complete the course. Only eight percent were still uncertain of success. Eighty percent of students felt *confident* that they could do well on any Math 2 exam compared with 41% prior to using the text for treatment units. Math anxiety was reduced in all three classes from 27% of students answering *often* or *usually* to statements of feeling nervous or worried in relation to math classes, homework, or tests to nine percent. Nearly half of the students commented once again on the time factor: "too much to learn in too short a time." Twenty percent of the students suggested an additional term or half term to better enable them to learn all they needed to know. A third of the students felt that the "speed is just right." Three students mentioned their fear that "nothing I learned will stick with me to next semester." These students too felt that a slower pace would be more beneficial.

Posttreatment, many students spoke of their own responsibility with respect to learning. Almost every student mentioned the need for taking better notes and studying them between classes. During the fall 2014 and spring 2015 classes, many of the students requested that I try to get the whole book out as soon as possible. The posttreatment Self-Confidence Survey was given on the last day of class in the week before final exams.

Within the three classes, abilities, fears and anxieties, and confidence levels varied. Using weighted averages with the Likert statements on the Self-Confidence Survey, these differences were observed and recorded. The values for statements 2, 5, 7, 8, 9, and 11 were reversed in this calculation.

A comparison of pretreatment and posttreatment values illustrates some differences among the three classes (Figure 1). The class designated F14, the first in this research project, showed substantial differences between pre- and posttreatment surveys, with differences of greater than a full point on nine of the twelve statements. The largest differences were on the statements which dealt with some forms of math anxiety and the final statement which indicated that they were *more confident* at the end of the term than at the beginning that they could make use of the information from this course in other electronics courses. Class S15 started with higher averages and only showed gains greater than one point for two statements dealing with confidence that they could do well in Math 2. Class F15 started with the highest average for all statements but only changed by about half a point on most statements. On one statement their average went down, indicating a slightly higher degree of tension about taking math tests at the end of the term.

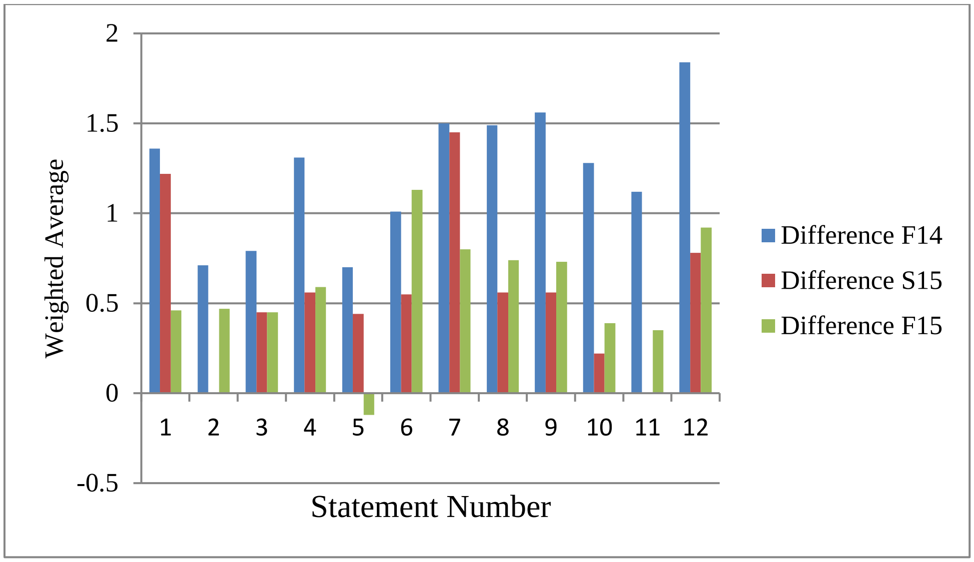

Figure 1. Difference in self-confidence, between pre- and posttreatment.
Note: 1=Never, 2=Seldom, 3=Sometimes, 4=Often, 5=Usually. (*N*=42).

Note: Explanation of Statement Numbers 1 – 12.
1. I feel confident that I can do well on a Math 2 test.
2. Working a math-related homework is stressful for me.
3. I believe I am a person who is good at math.
4. I believe that I can complete all of the assignments in my Math 2 course.
5. I get tense when preparing for a math test.
6. I believe that I can apply a variety of perspectives in solving math and electronics problems.
7. I worry that I will not be able to pass my Math 2 class.
8. I feel nervous when asking a question in class.
9. I worry that I do not know enough math to do well in future electronics courses.
10. I believe that I can do well on the computer based math problems.
11. I get nervous taking a math test.
12. I am confident that I can integrate the math from this course into my other electronics courses.

A comparison of student responses pre- and posttreatment for all three classes added together and averaged showed a general increase in student self-confidence over the period of this research (Figure 2).

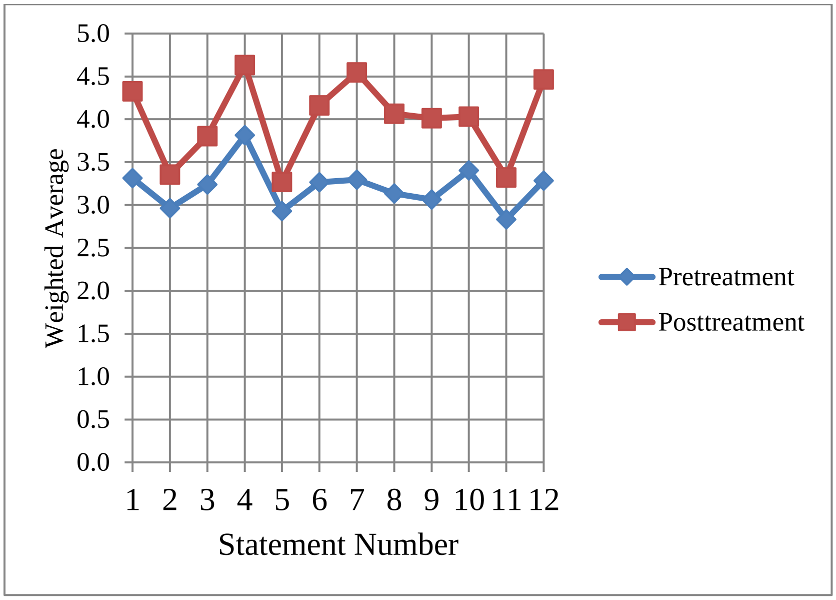

Figure 2. Comparison of self-confidence levels, pre- and posttreatment.
Note: 1=Never, 2=Seldom, 3=Sometimes, 4=Often, 5=Usually. (*N*=42).

Note: Explanation of Statement Numbers 1 – 12.

1. I feel confident that I can do well on a Math 2 test.
2. Working a math-related homework is stressful for me.
3. I believe I am a person who is good at math.
4. I believe that I can complete all of the assignments in my Math 2 course.
5. I get tense when preparing for a math test.
6. I believe that I can apply a variety of perspectives in solving math and electronics problems.
7. I worry that I will not be able to pass my Math 2 class.
8. I feel nervous when asking a question in class.
9. I worry that I do not know enough math to do well in future electronics courses.
10. I believe that I can do well on the computer based math problems.
11. I get nervous taking a math test.
12. I am confident that I can integrate the math from this course into my other electronics courses.

Students showed the largest changes in self-confidence for three statements (7, 9, 12) relating to their math and electronics courses at MATC. All three started in the S*ometimes* range and progressed to feeling confident at the *Often* to *Usually* range. The areas in which students felt less confident involved mathematics and their abilities in math itself (2, 3, 5).

Further information relating to changes in student confidence levels was found using the Chapter Evaluation Questionnaire and the End of Course Questionnaire. Many of these will be discussed in relation to student opinions about the textbook itself. However, several areas are related to student confidence in general, including a question at the end of the course as to whether students felt *more confident* about their ability to handle the math required in their electronics courses than they did at the beginning of the term. One student spoke for many, saying, “Math has always been a struggle for me but going through Math 2, I am *confident* about the rest of the courses that require math.” Another added, “Because of all the notes, examples, homework and quizzes, it’s pretty well nailed down.” Nearly every student mentioned how useful the math was for their AC/DC and Analog courses. As one student said, “I have used everything from Math 1 and 2 in other classes.” Students who had been out of school for several years spoke of no longer being afraid of the math in their other classes. A few students mentioned specific areas where they had formerly had trouble. “I feel good about vectors, which in the past were something I had a little trouble with.” “We started some Thevenin circuits in AC/DC. Seeing them in math first helped.” Eleven students added to their comments similar versions of “this course was fun. I enjoyed it. I never thought I would like math but I really liked your course. And I learned a lot. I’m ready for my other courses now,” In order to evaluate changes in student grades, four baselines were created to cover specific parts of the course: homework grades, quiz grades, final exam grades, and course grades.

Six homework assignments, each worth 100 points, were compared, as shown in Table 2. The scores shown are class averages for each assignment. Cells marked in light grey are treatment units.

Table 2
Comparison of Homework Scores as Percentages, (*N*=144)

Homework	Baseline	Fall 2014	Spring 2015	Fall 2015
Vectors	87.6	91.9	93.2	85.8
Series RLC	87.4	91.4	93.0	89.2
Complex Numbers	86.2	89.2	85.4	86.6
Sine Waves	80.9	93.9	94.1	86.6
Circuit Theorems	83.5	88.8	90.1	88.9
Logarithms	83.0	98.6	94.6	96.5

The vectors unit and the series RLC circuits unit were planned to be treatment units for the Fall 2015 class. However, until the end of the second week of classes, only one-third of the students were able to purchase the book. Therefore, these two units were considered non-treatment units for all classes.

Each treatment class and the Baseline group did better in some units than in others. The homework scores of the F14 class were higher in each instance than the Baseline group. Because of the loss of a class period during the final week of the half-semester course, the non-treatment logarithm homework assignment was done as a class activity with extensive teacher guidance. This led to a much higher score than would normally have been obtained.

The S15 class exceeded the Baseline scores in five of the six units. The complex numbers unit score was less than one percentage point lower than the Baseline. The F15 class exceeded the Baseline scores in all but the non-treatment vector unit. All class average scores were in the 80 to high 90% range (Figure 3).

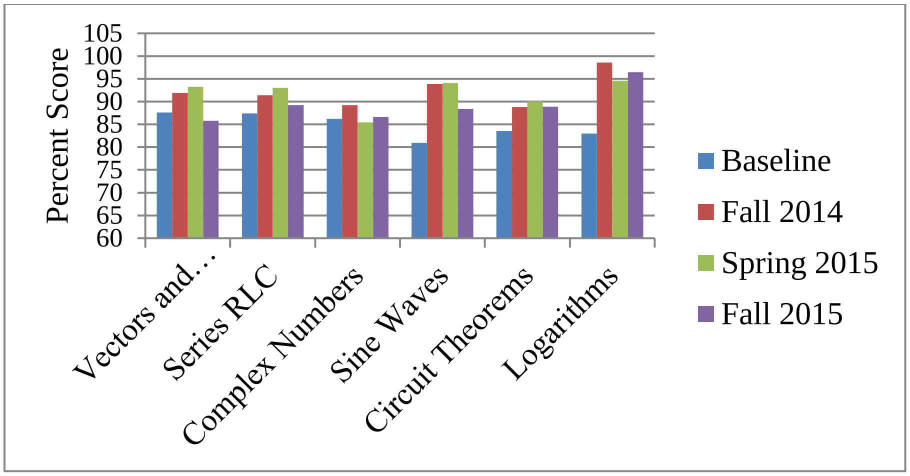

Figure 3. Comparison of homework scores, (*N*=144).

Figure 4 shows the average homework scores given as percentages for the Baseline and the combined treatment classes over the course of the term.

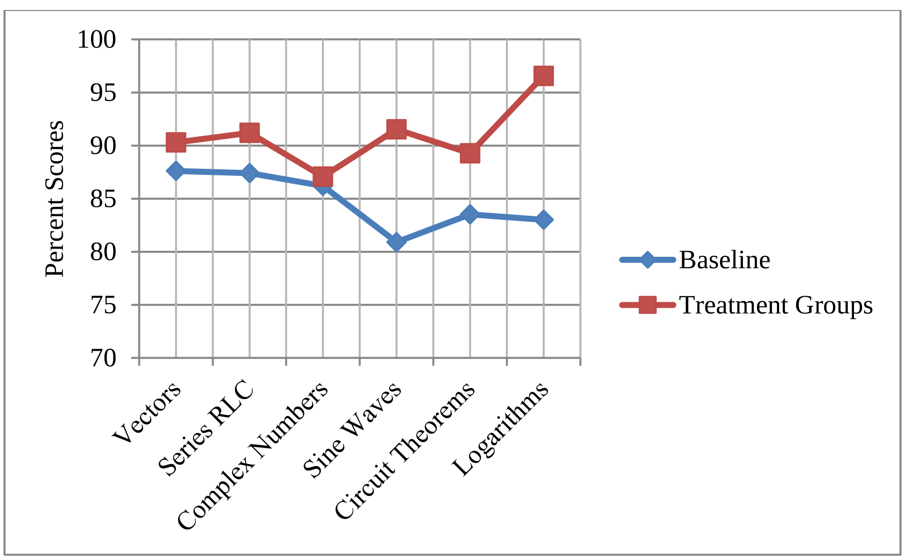

Figure 4. Comparison of homework scores over the course of the term, (*N*=144).

The greatest improvement for the treatment groups was on the sine wave unit and the logarithm unit. There was little improvement for the complex number unit. When asked what might be the reason for problems with the complex number unit, students had two answers: “too much to learn in too short a time” and “I should have tried more practice problems.”

Each Math 2 class had five or six quizzes, depending on scheduling due to exams, vacations, snow days and other unexpected situations. In addition, each student was allowed to drop one quiz. Frequently students who had done well on previous quizzes simply skipped the final quiz. For the purpose of this study, all quizzes that were taken, including any quiz on which a student’s score was zero, were counted in the average. Whenever a student skipped one quiz, as allowed, that quiz was not counted. Quizzes were worth 30 points each. Scores are shown as percentages to make comparison easier in a later table. Table 3 shows the class averages for each quiz. Treatment units are shown in light grey**.** Quizzes which were not given during a particular term are marked n/a.

Table 3
Comparison of Quiz Scores as Percentages, (*N*=144)

Quiz	Baseline	Fall 2014	Spring 2015	Fall 2015
Vectors	88.0	87.7	90.0	87.4
Series RLC	83.3	80.0	89.7	88.3
Complex Numbers	80.7	91.7	96.7	85.7
Sine Waves	83.3	89.0	86.7	84.0
Circuit Theorems	80.0	93.0	88.7	84.0
Logarithms	76.3	n/a	89.3	n/a

Classes for the two fall half-semesters each had only five quizzes while the Baseline classes and the spring class had six quizzes. The two non-treatment units at the beginning of the term had varying results. This is typical for most semesters. All three classes had improved grades for the treatment units as compared to the Baseline group although the sine wave quiz for F15 class was well within any margin of error. Each treatment class showed substantial improvement over the Baseline in complex numbers, sine waves, and circuit theorems. The S15 class, the only one to take a quiz over logarithms as a treatment unit, showed substantial improvement over the non-treatment Baseline (Figure 5). Averages for the series of quizzes were Baseline 81.9%, F14 88.3%, S15 90.2%, and F15 85.9%.

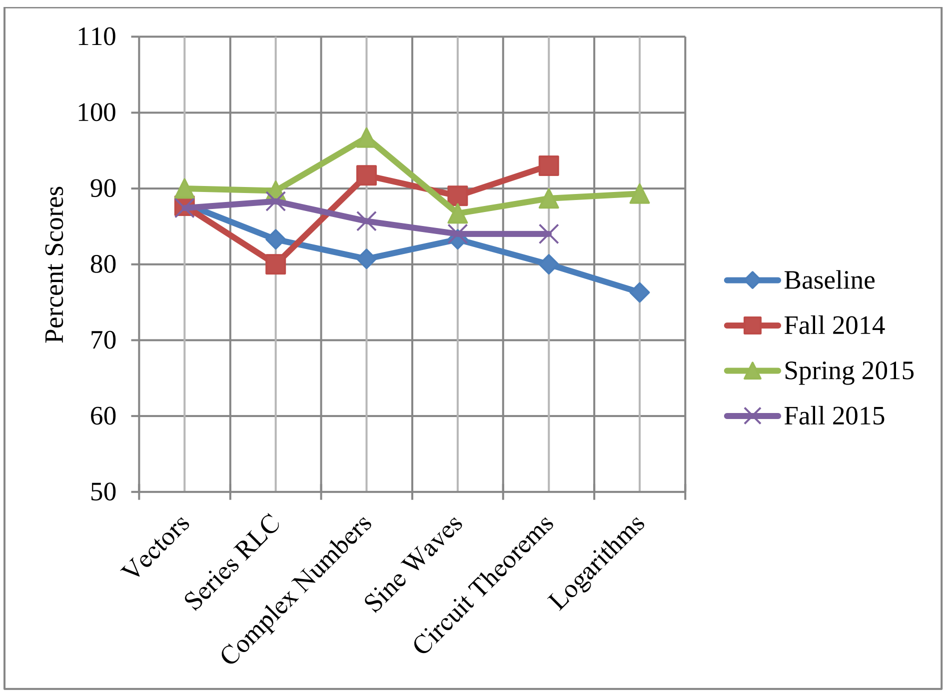

Figure 5. Comparison of quiz scores, (*N*=144).

Midterm exam topics varied according to scheduling so the midterm exams did not become part of this study. Final exams, however, have always been cumulative and traditionally have been take-home exams due to the length of some types of problems. They are also open-book and open-notes. This made the final exam especially important for this study. It should be noted that the groups that made up the Baseline did not have a textbook. They had only the notes that they took in class plus their corrected homework assignments, quizzes, computer assignment and the midterm exam. They were, however, permitted to use any textbooks from other classes. In addition to those aids, the F14 class had the three treatment chapters that they received in class. The S15 class had an additional chapter on logarithms. The F15 class had the textbook covering the entire course. It should be noted that an undisclosed number of students during any term choose not to buy a textbook. This was undoubtedly true during the fall of 2015. This question was not asked of the students.

Each student's grade on the final exam included extra credit points. Since only total scores were available for the Baseline classes, total scores will be used for all comparisons. The scores are shown as both points out of 150 and as a percent (Table 4).

Table 4
Final Exam Scores, (*N*=144)

Class	Score Out of 150 Points	Percent Score
Baseline	126	84.0
Fall 2014	134	89.3
Spring 2015	147	98.0
Fall	137	91.3

Figure 6 shows these values in relation to one another.

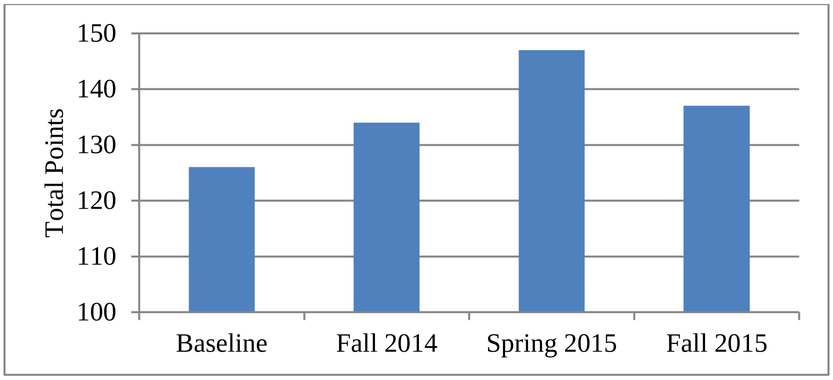

Figure 6. Final exam scores including extra credit, (*N*=144).

Final Exam scores were additionally studied using the mean, median, range, and standard deviation for the average total scores as shown in Table 5.

Table 5
Final Exam Score Statistics, (*N*=144)

Class	Mean Score	Median Score	Range (Low – High)	Range (points)	Standard Deviation
Baseline	126.4	131.5	42 - 159	117.0	24.1
Fall 2014	133.9	138.5	87 - 156	69.0	20.2
Spring 2015	146.8	149.0	124 - 160	36.0	13.1
Fall 2015	135.6	133.0	115 - 159	44.0	13.8

Comparison of the final exam scores as a box plot shows graphically that the S15 class average was substantially higher than any of the other averages. Both other treatment classes scored somewhat higher than the baseline class (Figure 7).

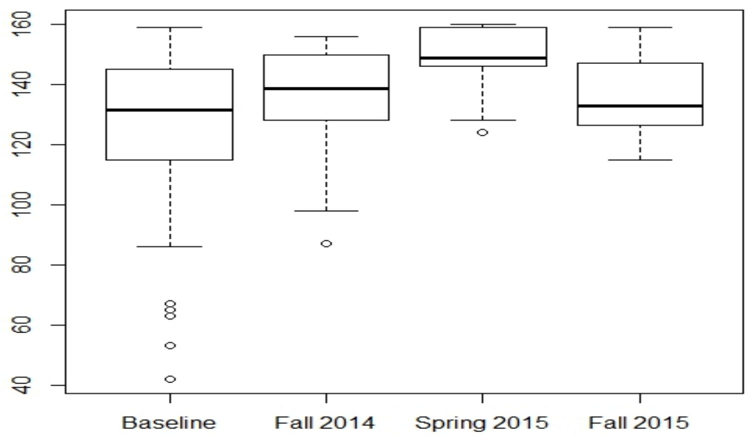

Figure 7. Box plot of final exam scores, (*N*=144).

Student course grades were determined using the following point distribution: homework 25%, quizzes 12%, computer work 8%, midterm exam 25%, and final exam 30%. Extra credit points were included in these scores, leading to scores higher than 100% in some cases. Class scores were calculated according to this formula and are shown in Table 6.

Table 6
Final Course Score Statistics, (*N*=144)

Class	Mean Score	Median Score	Range (Low – High)	Range (points)	Standard Deviation
Baseline	85.0	88.5	33.4 – 105.7	73.0	14.4
Fall 2014	87.0	90.6	63.1 – 103.2	40.1	12.4
Spring 2015	90.0	91.8	72.3 – 100.5	28.2	10.4
Fall 2015	86.4	83.1	65.8 – 103.8	38.0	12.0

A box plot of the final grade scores shows the median scores of the Baseline, F14 and S15 classes to be fairly close to the same value while the F15 class has a lower median score (Figure 8).

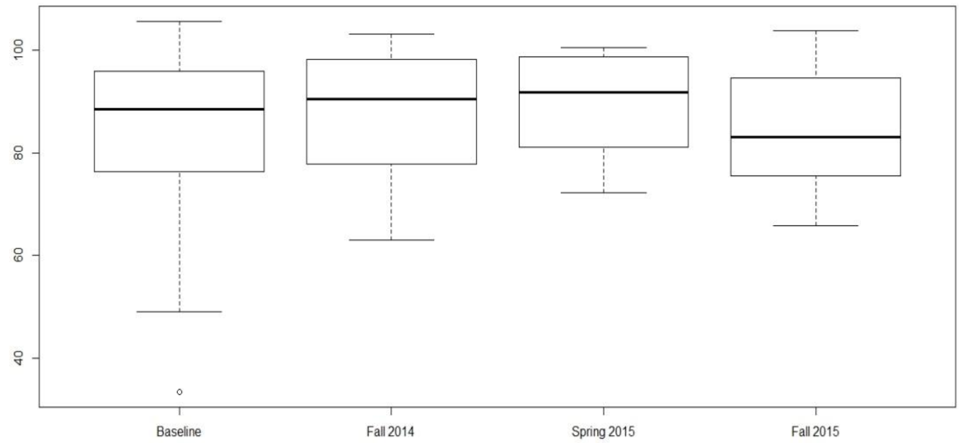

Figure 8. Box plot of final course scores, (*N*=144).

Comparing the four classes by topic in the following table and graph illustrates the different results obtained during the course of the relevant semesters. The Baseline classes with no textbook had the lowest average scores in each category. The F14 class had three treatment units and showed somewhat higher scores in all areas. The S15 class added one further unit and had the highest total average score. The F15 class had the entire textbook, in theory for the whole term, but actually had the same number of treatment units as the Spring 2015 class. This class, which had a lower median grade, still scored higher than the Baseline in all four areas (Table 7 and Figure 9).

Table 7
Comparison of Course Scores by Topic, (*N*=144)

Class	Homework	Quizzes	Final Exam	Total Course Score
Baseline	85.1	81.9	83.4	85.0
Fall 2014	88.2	88.3	85.4	87.0
Spring 2015	87.2	90.2	92.4	90.0
Fall 2015	85.4	90.5	87.4	86.4

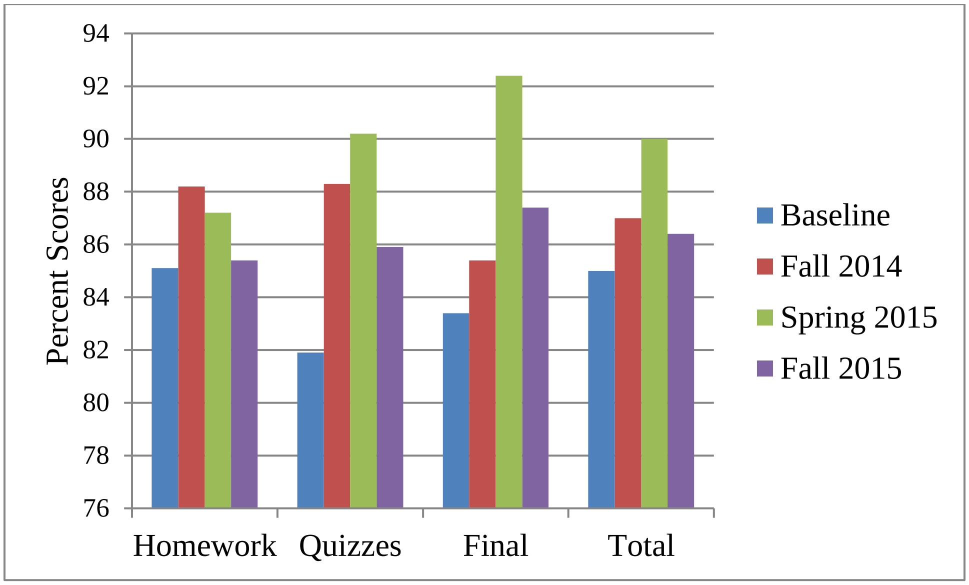

Figure 9. Comparison of course scores by topic, (*N*=144).

A one-way between subjects ANOVA was conducted using these values to determine whether there were significant differences between the four class groups. The null hypothesis was that there was no difference. There was a significant difference in groups observed at the $p < 0.05$ level [$F(3,12) = 7.408$, $p = 0.00455$]. The Tukey HSD test indicated that a significant difference existed between the Baseline and S15 groups ($p = 0.0025447$) and slight differences between the Baseline and the other two classes. There were no appreciable differences among the three treatment groups. A Bonferroni pairwise test confirmed these results. However it should be noted that these comparisons with the Baseline group were made after the treatments for the other classes. Insufficient data was available for a pretreatment comparison.

Student evaluation of the four treatment chapters constituted a major part of this project. Two Likert survey questionnaires were given as part of the Chapter Evaluation Questionnaires. One survey looked at how students actually used the chapters and the other collected their opinions of the chapters. Three chapters were used by all three classes. One third of the students stated that they read the chapter before it was discussed in class. One third did not read the chapter prior to discussion. Approximately 60% tried some of the practice problems. Ninety-five percent of the students used the chapter to help with their homework problems while 72% made use of the text when absent. Ninety percent of the students said that they felt more confident having the chapter as a reference.

The logarithm chapter was only used in the S15 and F15 classes. Sixty percent of these students stated that they read the text prior to lecture. Half of the students tried practice problems while 70% used the text to assist with their homework. Eighty percent of these students felt more confident with the chapter as reference material. Several students commented that the chapter helped but they still did not really understand logarithms.

Student opinions were collected for each of the four treatment chapters using a five-point Likert scale with ten statements. Weighted averages were calculated using the following responses to the statements: *Disagree* (1), *Tend to Disagree* (2), *No Opinion/Undecided* (3), *Tend to Agree* (4), *Agree* (5). Student opinions on the three original chapters plus the opinions on the logarithm chapter are displayed in Figure 10. No weighted averages fell below 4.0 on this scale. Standard deviations were calculated for each chapter. All values for each statement in each chapter were less than two standard deviations from the mean value for each chapter.

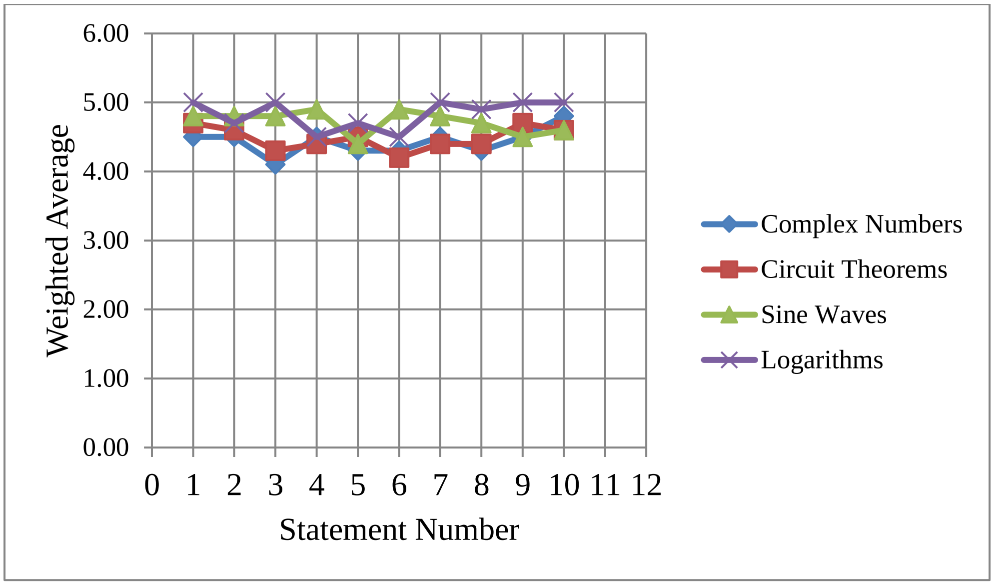

Figure 10. Student opinions on the complex number, circuit theorem, sine wave chapters, (*N*=42), and the logarithm chapter, (*N*=27).
Note: 1 = Disagree, 2 = Tend to Disagree, 3 = No Opinion/Undecided, 4 = Tend to Agree, 5 = Agree.

Note: Explanations of Statement Numbers 1 – 10.
1. The chapter relates well to the material we are studying.
2. The material is well arranged.
3. The terms are well defined.
4. The examples are clear and easy to follow.
5. There are sufficient examples to illustrate each major type of problem.
6. The explanations are clear and well-illustrated.
7. The figures are clearly labeled and related to the material being discussed in each section.
8. There is a wide variety of practice problems.
9. All of the answers to the practice problems are easily found.
10. The material is relevant to my electronics courses.

Data analysis of the student chapter evaluations was complicated by the unnaturally high values given by the students. When the percentages of students responding in the categories of *Agree* and *Tend to Agree* were combined for each statement, most totals fell into the 90 – 100% category. No question for the Circuit Theorem chapter had an *Agree plus Tend to Agree* total of less than 90%. The Sine Wave and Logarithms chapters had similar totals with 100% of the answers to many questions falling into that combined category. The lowest value obtained for any one question was 78.6% for the question involving the variety of practice problems in the Complex Number chapter. The *Agree plus Tend to Agree* totals for the four treatment chapters were: Complex Numbers 90.2%, Circuit Theorems 96.6%, Sine Waves 98.3% and Logarithms 97.4%.

In this case, the student comment portion of the Chapter Evaluation Questionnaire proved more valuable. Students were asked which part of each chapter they found most difficult. Most students wrote thoughtful answers to these questions. Many students found the idea of complex and imaginary numbers to be a difficult concept. Those who had some familiarity with complex numbers from previous math classes found the use of the letter "j" instead of the more usual "i" for the square root of minus one to be extremely confusing. Approximately half of the students had never heard of imaginary numbers. For some students this made the chapter more difficult while for others it was easier because, as one student remarked, "I didn't have anything to unlearn." All students agreed that more sample problems and practice problems would be helpful.

Students wrote that they found the Circuit Theorem chapter to be more interesting because it looked more like electronics. For most groups this unit in math came before it was covered in various electronics classes. Students reported that this was very helpful. "By the time we got to Thevenin in my other classes, we had already covered it in math. I didn't have to worry about the math so I could concentrate on the electronics part."

Students asked for a little more information on determining circuit polarities in the textbook but felt that in most cases the book explained most things very well.

Half of the students said the chapter on currents and voltages as sine waves was one of the easiest chapters. The other half claimed that it was one of the most difficult. Several students mentioned that they enjoyed the simpler equations at the beginning of the chapter but found writing their own sine wave equations to be more difficult. They asked for a few more specific examples in the textbook. Other students found the idea of angular period to be difficult and asked for a little more help with this. Several students mentioned the many examples and one especially liked the "visual stimulants" which he said "aids in the ease of understanding."

The logarithm chapter was added for the second and third classes. Students reported finding this chapter to be particularly difficult since most of them had no background in the subject. Several students commented that the chapter was very well organized and they appreciated the many examples of different types of problems. The most difficult part of the chapter for many of the students was solving logarithmic equations when the exponent contained the unknown variable. One student wrote, "I have trouble figuring out if I want to use log base 10 or natural logs. I really appreciated how you showed us how to do it. It really helped." Several students mentioned how much they enjoyed seeing the way that this type of math applied to electronics. "I learned how to use the capacitor charging and discharging equations and they really weren't so hard after all," wrote another student.

Textbook evaluation was also done via the End of Course Questionnaire. Twenty-seven percent of students found the text explanations (choice A) to be the most helpful in understanding new material while 44% found the step-by-step examples (B) most useful. Seventeen percent preferred working the practice problems (C). Another 12% felt they learned best using the circuits and charts in the chapters (D) (Figure 11).

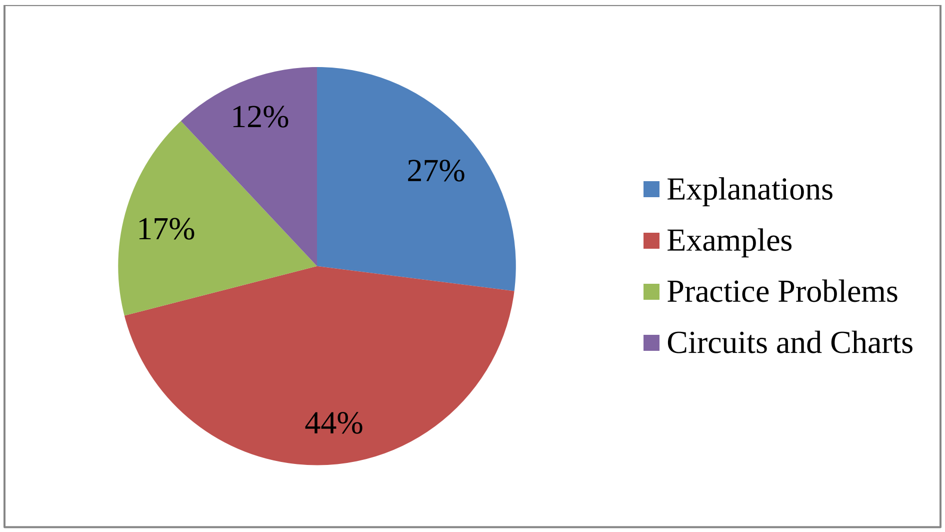

Figure 11. Student choices for most useful part of chapters, (*N*=42).

The largest group of students chose B, the examples. Reasons for this choice included, “I’m a very visual learner. Seeing the process helps a lot.” “They are good templates for solving future problems.” “I was able to follow along through a problem and was able to convert it to a problem of my own.” Several students liked “having a reference as to where to place components of each formula.”

One student who chose the explanations (A) wrote, “It was in an easy to read format that got its point across easily,” while another student commented, “If I didn’t get something in class I was able to read the explanations in the chapters which helped a lot.” A few students chose both A and B, saying, “With examples I have the steps to work through a problem. I really find this useful." Another found that "I could model other problems on the examples and grasp concepts from the explanations."

Students who chose option C liked working practice problems. One student remarked that "math is repetition. The more problems and variety, the more ingrained it becomes." Another simply said, "This is how I learn." Those who chose the circuits and charts option felt that they helped them to "visually see the way things worked together." "It linked the words to what the equations say visually and helped with analysis."

Ninety percent of students found the material in this text to be useful in other electronics classes, in particular AC/DC 1 and Analog 1. "It reinforced concepts we learn in AC/DC 1 and helps with the math for both courses," several students commented. "The vector stuff helped me in physics," another student remarked. "We learned different ways to analyze circuits which helped in all of my courses," said another. Several students said the book helped clarify things that had been taught in their other classes. "It made more sense the way you showed us and it really helped to have the math explained in detail," another student said in class. Several other students agreed that having the math explained was helpful because "my other instructors assume I already know the math."

No new suggestions as to other topics that could be included were offered by the students on this questionnaire. In class discussions, about half of the students wanted the homework assignments to be placed in the book while the other half did not want to have to remove sections of the book, making it less valuable for keeping as a reference or for future resale.

Eighty-five percent of students thought that the computer assignment that accompanied the circuit theorem chapter definitely contributed to their understanding of the chapter. "It was very helpful and time-saving and it gave me a way to check my homework calculations," said one student. Another remarked that it "puts into perspective how you could use tools instead of your head." "Building circuits helped work out in my head how things worked together," another student commented. Many students found that "I could make my Thevenin circuit and see if the values that I calculated really worked." All students enjoyed the fact that they could "let the computer do the work of finding the Thevenin values."

Ten percent of the students had not used MultiSim before and found entering the data to be somewhat difficult. However, all of them stated that they were happy to have learned how to use the computer program. No one found the computer assignment too difficult. One person found it too easy but most students felt that the degree of difficulty was just right. As shown on the Self-Confidence Survey, by the end of the semester 78% of students answered *usually* or *often* to the statement, "I believe that I can do well on the computer based math problems."

INTERPRETATION AND CONCLUSION

The data collected over the course of three semesters of Applied Electronics Math 2 has confirmed my belief in the importance of a class textbook to both the students and the teacher. I began writing the textbook out of a need for an affordable text and reference book for my students. I believed that the most important thing that it would do would be to enhance my students' academic performances. This became my primary focus question. I hoped to see improvement in homework grades and in grades on the take-home final exam. I did not expect to see as much improvement on quizzes since students could not use the book on quizzes.

As shown by the data, students in the three treatment classes generally performed better academically than the pre-textbook Baseline group. While a few homework and quiz scores fell below those of the Baseline group, most treatment class scores were higher by five or more percentage points. Unexpectedly, quiz scores for the three treatment groups were also better for most topics. An interesting effect was shown in Figure 4, the graph comparing homework grades across the course of the term. The grades for the three treatment classes generally rose during the term; all finished at or near the high point for the term. Conversely the Baseline grades gradually sank over the course of the term. Insufficient data exists on the Baseline classes to fully account for this. A comparison of the homework, quiz, final exam and course grades for the four groups showed that all three treatment groups had higher grades in each category than the Baseline group. The Spring 2015 class in most instances had the highest grades. ANOVA confirmed that a significant difference existed between the Baseline and S15 groups and a slight difference between the Baseline and the other two groups. While these differences probably contributed to some of the improvement shown, I am pleased to have seen improvement in all areas of Math 2. However, at this point, it is too soon to credit the book as the main source of this improvement.

One factor that I did not take adequately into account when planning the class comparison part of my research was the actual differences between classes. As a teacher

I am aware that within any given class there are students who are mathematically oriented and others who are not. The relative proportion of A and C or D students within a class will have an effect, sometimes an extreme effect, on the class averages and thus where the class falls on a continuum of academic success. Each of my three test classes had a few truly excellent students. Both fall classes had several students who were much less capable; the spring class had only one such student. All of these students have affected the means and medians for the parts of the courses that I studied. The box plot of the four groups' course scores clearly shows that the Fall 2015 class had a distinctly lower median score even though the class average fell within the mean scores for the four classes. The differences between classes posed a slight problem when comparing results for this research problem and could probably be corrected using statistical methods. This is not a problem outside the scope of this research.

Most technical college students come into our department hoping to jump right into classes involving hands-on projects. They see no reason why they should have to take math classes. Many of these students come to our Math 1 and Math 2 classes with negative attitudes and low self-confidence. This is one of the major challenges faced by those of us who teach these beginning courses. My second focus question dealt with student self-confidence. I had thought that this would be an interesting side issue, not as important as the academic achievement, but still something to look into. However, over the course of my three semester study I came to believe that this was the most important part of my research.

Math anxiety is a far greater problem than I had formerly believed. Twenty-seven percent of my students in these classes admitted on anonymous questionnaires that they were "worried" or "nervous" or even "scared" during math tests. Many students were afraid to speak up in class, even to ask a question. They were afraid of "looking or sounding stupid." I have tried to help these students through a combination of verbal encouragement and presenting course information in a clear and understandable way in lecturing to the class, in working problems on the blackboard and in the textbook itself. One successful method for working with anxious students was to give them a problem to work at their desks. After they had worked for a while, I worked through the same problem on the board, explaining each step. Because students knew that they would not have to go to the board themselves, they were able to relax and learn. The improvement in student self-confidence in each of the three test classes was amazing and gratifying to see. Many students who thought they hated math, couldn't do math, or didn't see why they had to learn math were surprised to learn that they could actually enjoy it. Over the years I have had literally dozens of students tell me how much they enjoyed the class and how surprised they were to find they could "do math."

In the past few years, I have seen a somewhat different problem with self-confidence, especially among students who are recent high school graduates. Many of these students have too much self-confidence. They believe, and often tell me, that they are good at math. Actually many of them are not very good at math at all. The Fall 2015 class was a good example of students who thought they were better at math than they actually were. That class showed very little change in self-confidence from the pretreatment to the posttreatment survey. Overly self-confident students are often harder to work with than the less confident students who have been out of school for a few years. I have found that these slightly older students work harder and usually do quite well. The overly confident younger students often do not. I am currently working on ways to help these students to understand that there is both need for and room for improvement without destroying the good part of their self-confidence.

Keeping students engaged during a class they have no real desire to take can be a challenge. The results of this study have confirmed my belief that our students are most engaged when the topics are closely related to the field of electronics. Even though math was involved in all of the units, students particularly enjoyed the parts where they could clearly see the relationships with their other classes. The Circuit Theorem unit was a particular favorite for several reasons. The students saw the value of learning to create Thevenin models of more complicated circuits and they especially enjoyed working with these models using computers. By using as many electronics examples as possible both in lecture and in the textbook, I gave them visible reasons for learning these mathematical procedures. Once they saw the need to learn a process, most students were eager to learn. As several students commented on questionnaires and in class, they also became aware of the benefits of learning the necessary math first and then, confident in their ability to do the math, learning the electronics later.

VALUE

I believe, from talking to my students, evaluating their work, and receiving feedback from other electronics instructors, that the entire research project has been a success. I found it invaluable to me as the writer for the ways it forced me to learn more about my subject and my teaching methods, for me as the teacher making use of what I had learned, and for my students as a class using the book and hopefully benefitting from all that I learned while doing my research. Three terms are too short a time to prove that the book will solve all of our problems in the classroom, as of course it will not, but I know that many of the students are glad to have it, for the Math 2 course itself, as a source of increasing self-confidence and as a future reference book. These were the reasons that I wrote the book in the first place.

The process of writing this textbook was a fascinating experience. I began writing the book in a formal, textbook style but soon realized that wasn't working. Eventually I developed a format, based mostly on my lecture notes, that matched my teaching style, friendly yet precise and logical. I had to think at every stage of how I could best describe math procedures in ways that would make them clear to all types of students. As I wrote the step-wise methods for solving problems, I tried to include the reason for each step. I included circuit diagrams, charts, and practice problems with answers for each type of problem. As I wrote the sections of the text that were more electronics-related than simple mathematical operations, I found to my surprise that, instead of being less able to write them because my field is not electronics, I was actually better able to explain these parts to beginning students because I had had to learn them as a beginner myself.

Math textbooks have a lot of equations and this book is no exception. I spent many hours working with the Word Perfect Equation Editor. Showing every step of the procedure for solving algebraic, logarithmic and other complex equations takes an incredible number of steps, many of them quite complicated to type. This has definitely been a learning experience for me.

Judging by the students' comments, this has been a successful project. Part of the reason for the book's success is that it is specific to our course. It covers everything that we cover during the course as precisely and logically as I could make it. It does not have a lot of unnecessary extras that my students have to pay for. The same edition will be used each semester unless the course itself is changed, keeping the price down and allowing for resale.

There have been several unexpected benefits for me over the course of this research project, both as the writer of the book and as the teacher using it. Writing the text required me to focus on logic and clarity. During a lecture there can be a little "hand waving" during parts that are more difficult to explain. A good textbook cannot permit this to occur. Although my students have always said that I explain things well, I found that the mental discipline required to explain problem solving in a clear, logical written order has benefitted me in my two technical calculus courses as well as Math 1 and 2.

Although I have always enjoyed math and have tried to pass on to my students at least an appreciation of math, I believe that as a result of this project I have developed a much clearer understanding of the anxiety that many students feel whenever they must deal with mathematics. I hope that this increased empathy and understanding will help to make me a better teacher. I know that this project has sharpened my perception of many aspects of teaching and learning and I expect the benefits to be seen and felt by both my students and myself.

One final unexpected result of writing the textbook for Math 2 is that I enjoyed the whole process so much that I am currently working on a companion textbook for Math 1. I plan to take all that I have learned in this research project and use it to improve whatever classes I may teach in the future.

Over the years that I have taught the math courses for our electronics and electronics technology students, I have found there to be two major goals for the mathematical component of engineering education. Students need to understand and use mathematical concepts, models and procedures in both engineering classes and their other related classes. They also need a sound mathematical background for their future lives as engineers. Unfortunately, here at MATC as well as in most institutions of higher learning, math is more often used as a "gatekeeper" guarding the entrance to engineering and the sciences and keeping out the unworthy. As a teacher of Applied Electronics Math 1 and 2 and Technical Calculus 1 and 2, it is up to me to ensure that our students who want to successfully pass through this gate will have the mathematical background to do so.

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APPENDICES

APPENDIX A

IRB APPROVAL

INSTITUTIONAL REVIEW BOARD

For the Protection of Human Subjects
FWA 00000165

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MEMORANDUM

TO: JoAnne Phillips and John Graves

FROM: Mark Quinn, Chair *Mark Quinn CJ*

DATE: October 27, 2014

RE: *"Assessment of the Effects on Student Academic Achievement and Student Self-Confidence of Four Chapters Written as Part of a Proposed Textbook for Applied Electronics Math 2"* [JP102714-EX]

The above research, described in your submission of October 27, 2014, is exempt from the requirement of review by the Institutional Review Board in accordance with the Code of Federal regulations, Part 46, section 101. The specific paragraph which applies to your research is:

_X_ (b) (1) Research conducted in established or commonly accepted educational settings, involving normal educational practices such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.

_X_ (b) (2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: (i) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability, or be damaging to the subjects' financial standing, employability, or reputation.

____ (b) (3) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior that is not exempt under paragraph (b)(2) of this section, if: (i) the human subjects are elected or appointed public officials or candidates for public office; or (ii) federal statute(s) without exception that the confidentiality of the personally identifiable information will be maintained throughout the research and thereafter.

____ (b) (4) Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available, or if the information is recorded by the investigator in such a manner that the subjects cannot be identified, directly or through identifiers linked to the subjects.

____ (b) (5) Research and demonstration projects, which are conducted by or subject to the approval of department or agency heads, and which are designed to study, evaluate, or otherwise examine: (i) public benefit or service programs; (ii) procedures for obtaining benefits or services under those programs; (iii) possible changes in or alternatives to those programs or procedures; or (iv) possible changes in methods or levels of payment for benefits or services under those programs.

____ (b) (6) Taste and food quality evaluation and consumer acceptance studies, (i) if wholesome foods without additives are consumed, or (ii) if a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the FDA, or approved by the EPA, or the Food Safety and Inspection Service of the USDA.

Although review by the Institutional Review Board is not required for the above research, the Committee will be glad to review it. If you wish a review and committee approval, please submit 3 copies of the usual application form and it will be processed by expedited review.

APPENDIX B

APPLIED ELECTRONICS MATHEMATICS 2 CHAPTER CONTENT

APPENDIX C

SELF-CONFIDENCE SURVEY

Participation in this research is voluntary and participation or non-participation will not affect a student's grades of class standing in any way.
The following is a list of statements relating to your feelings about Math 2. Please place an X in the box that best represents how you feel about the following statements.

Statement	Never	Seldom	Sometimes	Often	Usually
1. I feel confident that I can do well on a Math 2 test.					
2. Working on math-related homework is stressful for me.					
3. I believe I am a person who is good at math.					
4. I believe that I can complete all of the assignments in my Math 2 course.					
5. I get tense when preparing for a math test.					
6. I believe that I can apply a variety of perspectives in solving math and electronics problems.					
7. I worry that I will not be able to pass my Math 2 class.					
8. I feel nervous when asking a question in class.					
9. I worry that I do not know enough math to do well in future electronics courses.					
10. I believe that I can do well on the computer-based math problems.					
11. I get nervous taking a math test.					
12. I am confident that I can integrate the math from this course into my other electronics courses.					

Please turn the page over and briefly answer a few questions.

1. Is there anything about Math 2 that worries you in particular?

2. What do you think would help to improve the situation?

3. Is there anything else that you would like me to know?

APPENDIX D

COMPUTER ASSIGNMENT QUESTIONNAIRE

Participation in this research is voluntary and participation or non-participation will not affect a student's grades of class standing in any way.
Please briefly answer the following questions relating to your computer assignments.

1. Which computer assignment did you just complete – Sine Waves or Thevenin Equivalent Circuits?

2. Do you think that this computer assignment contributed to your knowledge of the current topic (either sine waves or Thevenin Equivalent circuits)?

   Why or why not?

3. Did you find entering the proper data into the computer to be difficult?
   If yes, was this due to your unfamiliarity with the computer program (Excel or Multisim)?

4. Was this computer assignment too hard just right too easy?

5. Would you prefer a more challenging computer assignment?
   If yes, suggest an idea for one.

6. Is there anything else that you would like me to know?

APPENDIX E

CHAPTER EVALUATION QUESTIONNAIRE

Participation in this research is voluntary and participation or non-participation will not affect a student's grades of class standing in any way.
The following is a list of statements about the chapter that you have just completed. Please place an X in the box that best represents how you feel about the following statements.

Statement	Disagree	Tend to Dis-Agree	No opinion / Undecided	Tend to Agree	Agree
1. The chapter relates well to the material we are studying.					
2. The material is well arranged.					
3. The terms used are well defined.					
4. The examples are clear and easy to follow.					
5. There are sufficient examples to illustrate each major type of problem.					
6. The explanations are clear and well-illustrated.					
7. The figures are clearly labeled and related to the material being discussed in each section.					
8. There is a wide variety of practice problems.					
9. All of the answers to the practice problems are easily found.					
10. The material is relevant to my electronics courses.					

The following is a list of statements about your use of the chapter that you have just completed. Please place an X in the box that best represents how you feel about the following statements.

Statement	Disagree	Tend to Dis-Agree	No opinion / Undecided	Tend to Agree	Agree
1. I read the assigned material in the chapter before class.					
2. I try at least some of the practice problems.					
3. I use the chapter to help me with my homework problems.					
4. When I am absent, I study the chapter before asking for help.					
5. I feel more confident having the chapter as a reference.					

Please turn this page over and briefly answer a few questions.

1. What part of this chapter was the most difficult for you?

2. Why do you think this part was more difficult?

3. What do you think might have helped you to better understand this topic?

4. Is there anything else that you would like me to know?

APPENDIX F

END OF COURSE QUESTIONNAIRE

Participation in this research is voluntary and participation or non-participation will not affect a student's grades of class standing in any way.

Looking back over the four chapters that we used in Math 2, please answer the following questions.

1. What part of the chapters did you consider the most helpful?
   A. The explanations? C. The practice problems? E. Other?
   B. The examples? D. The circuits and charts?
2. Why did this seem to be the most helpful for you?

3. Is there anything that I could have included in the text that I left out?

4. Have you found any of this material to be useful in any of your other classes? If so, what material and which class(es)?

5. Is there any material in your other classes that you think should be included in these chapters? If so, what material would you like included?

6. Do you feel more confident about your ability to handle the math required in your electronics courses than you did at the beginning of Math 2?
   Why or why not?

7. Is there anything else that you would like me to know?