Learning College Algebra by Creating Student Experts

by

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ABSTRACT

In any instructional situation, the instructor's goal is to maximize the learning attained by students. Drawing on the adage, 'we learn best what we have taught,' this action research project was conducted to examine whether students, in fact, learned college algebra material better if they taught it to their peers.

The teaching-to-learn process was conducted in the following way. The instructor-researcher met with individual students and taught a college algebra topic to a student who served as the leader of a group of four students. At the next step, the student who originally learned the material from the instructor met with three other students in a small group session and taught the material to them to prepare an in-class presentation. Students in these small group sessions discussed how best to present the material, anticipated questions, and prepared a presentation to be shared with their classmates. The small group then taught the material to classmates during an in-class review session prior to unit examinations.

Quantitative and qualitative data were gathered. Quantitative data consisted of pre- and post-test scores on four college algebra unit examinations. In addition, scores from Likert-scale items on an end-of-semester questionnaire that assessed the effectiveness of the teaching-to-learn process and attitudes toward the process were obtained. Qualitative data consisted of field notes from observations of selected small group sessions and in-class presentations. Additional qualitative data included responses to open-ended questions on the end-of-semester questionnaire and responses to interview items posed to groups of students.

Results showed the quantitative data did not support the hypothesis that material, which was taught, was better learned than other material. Nevertheless, qualitative data indicated students were engaged in the material, had a deeper understanding of the material, and were more confident about it as a result of their participation in the teaching-to-learn process. Students also viewed the teaching-to-learn process as being effective and they had positive attitudes toward the teaching-to-learn process.

Discussion focused on how engagement, deeper understanding and confidence interacted with one another to increase student learning. Lessons learned, implications for practice, and implications for further action research were also discussed.

DEDICATION

I dedicate this work to my wife Cindy, my son Anthony and my daughter Sarah. Their love and support made this work possible.

ACKNOWLEDGMENTS

Published works of research are rarely, if ever, done by one person. The researcher relies on previous work to obtain direction and affirmation of his hypothesis. He also relies on a peer to review the work before it is published to check for everything from spelling and grammar, to legitimacy and honesty in the finished piece. This paper would never have reached this stage had it not been for the help of Ray Buss, Ron Zambo and Phyllis Shaw. Ray has spent tireless hours editing each chapter, and meeting with me for face to face conversations to iron out details. This document wouldn't be what it is without his commitment to this action research project. I was very blessed to have had him as my chair.

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TABLE OF CONTENTS

CHAPTER Page

APPENDIX Page

LIST OF TABLES

Table Page

LIST OF FIGURES

Chapter 1 Introduction and Context

Consistent with the views of many educators, I believe we all are of the opinion that the problems we face in the classroom are unique to us. Yet, every time we go to a conference and listen to others who teach in similar settings, or even those that don't, we walk away saying to each other things like, "That's just what my students are like.", or "I can't believe you have the same problems I do, and you teach at a high school." Nevertheless, there seem to be more commonalities rather than differences in the problems we face as teachers. In fact just the other day one of my colleagues, Sonya, walked by my office and stopped to exchange pleasantries. The conversation quickly turned to one involving problems she was experiencing in her classroom. Sonya teaches a developmental algebra class. A class for students who don't quite have the skills to take college level math classes at the current stage in their math careers. So as the conversation developed, she was telling me about trying to teach her class about domain and range. Understanding these two, related, and very important concepts is needed throughout the mathematics coursework we teach at Paradise Valley Community College, and beyond.

She began to relate what happened in class that morning. "Why are domain and range such difficult concepts for students?" she asked. I told her many of my students have the same problem even in college algebra, and to a slightly lesser extent in calculus. We both discussed how we presented these ideas, and how simple the concepts were to us. As our conversation continued, we were befuddled about why this is such a daunting problem for them. As with most discussions about student learning, we concluded this portion of our discussion recognizing there are those students that do get it and those that don't. I suggested to Sonya that she ask those who understand it to teach it to those who don't. Sonya thought it was great idea. I continued by discussing with her how I taught individual students a concept and asked them to teach it to small groups of four to five other students. What I have found to be interesting was that each of the "teachers" demonstrated the concept in a way that was slightly different than I had taught it, but they taught it in a way that they understood. I have been very pleased with the results of this process. Not only did most of the class now understand better, but I have found new "experts" that I can count on to help explain a variety of topics whenever the class runs into difficulty with one area. This conversation reinforced my desire to conduct my action research project, but with renewed energy and commitment.

Frequently innovative educational leaders choose to employ an innovation that will change their situation for the better. Of course those changes are based on ideas. Where do the ideas come from? Why do the innovators think the idea would be successful? Often, the answer to that question comes from data based on surveys conducted before examining where change is needed. When I began my work in the doctoral program at Arizona State University, I was asked to devise an action research plan and implement an innovation to bring about change and study the results.

Fortunately, some data related to student perceptions about learning and college engagement were already being collected by Paradise Valley Community

College (PVCC), which employs the Community College Survey of Student Engagement (CCSSE, n.d.) to obtain data useful to the College. Why use CSSEE? Because as they say, act on fact, using data to improve student success. The CCSSE survey was administered directly to PVCC students during both spring 2005 (N = 884), and spring 2007 (N = 868).

In the survey, students were asked questions about institutional practices and student behaviors that are highly correlated with student learning and retention, and the researchers used a sampling methodology that is consistent across all participating colleges. More than 310,000 community college students from 525 community and technical colleges in 48 states responded to the 2007 CCSSE (n.d.) survey. One of the questions on the survey involved collaborative learning. The description of the item was that students learn more when they are actively involved in their education and have opportunities to think about and apply what they are learning in different settings. Through collaborating with others to solve problems or master challenging content, students develop valuable skills that prepare them to deal with the kinds of situations and problems they will encounter in the workplace, the community, and their personal lives.

In 2007, just over 68% of the students who answered the survey at PVCC, stated that they often or very often asked questions in class or contributed to a class discussion. Only 36% made a class presentation. Fifty-eight percent worked on projects with others during class, whereas 30% worked outside of class with others to prepare assignments. But the one item that caught my eye was that only 8% of those surveyed tutored or taught others. This question asked them to answer, whether they were paid to teach or tutor, or if they had volunteered to do so. The conclusion from this survey is that students at PVCC want to be more actively involved in their education and this outcome is consistent with the premise of this study.

Another question from the survey that informs the current project was a question regarding student and faculty interaction. In general, according to results from the CCSSE (2007), the more contact students have with their teachers, the more likely they are to learn effectively and persist toward achievement of their educational goals. Through such interactions, faculty members become role models, mentors, and guides for continuous, lifelong learning. Thus, more substantial interaction with instructors is likely to lead to increased learning.

Action research is necessarily based on localized studies that focus on the need to understand *how* things are happening, rather than merely what is happening, and to understand the ways that stakeholders – the different people concerned with the issue – perceive, interpret, and respond to events related to the issue being investigated (Stringer, 2007). Stringer goes on to say that action research requires all participants to engage in styles and forms of communication that facilitate the development of harmonious relationships and the effective attainment of group objectives.

With Stringer's criteria in mind I began to refocus my action research plan. In one of my current college algebra classes, I have observed that students would like to develop a better way to help them to understand material, and ultimately to perform more capably on tests. Frequently students give teachers the impression they are going through the motions of taking the class. Nevertheless, the majority would really like to attain a deeper understanding of the material, including being able to attach more meaning to the concepts being learned. This desire to more thoroughly understand is fundamental to conduct the project. However, what is less clear is which processes and teaching strategies and techniques are effective in aiding students to develop this deeper understanding of mathematics.

Chapter 2 Theoretical Perspectives and Research Guiding the Project

Vygotsky's (1978) socio-cultural theory guided the conduct of this action research project. In addition, the research work on tutor learning as a result of tutoring (Roscoe & Chi, 2007; 2008) and student learning in groups (Jacques & Salmon, 2007) which supports the project was also reviewed.

Vygotsky's Socio-Cultural Theory

Lev Vygotsky contends that social interaction plays a fundamental role in the process of learning. In contrast to Jean Piaget's understanding of development in which development necessarily precedes learning, Vygotsky (1978, p. 57) notes:

> Every function in the child's cultural development appears twice: first, on the social level, and later, on the individual level; first, between people (interpsychological) and then inside the child (intrapsychological). This applies equally to voluntary attention, to logical memory, and to the formation of concepts. All the higher functions originate as actual relationships between individuals.

Thus, for Vygotsky a substantial amount of learning occurs as a result of social interaction. In this social interaction framework for learning, learning is initiated at the interpersonal level and it is consolidated at the individual level. Importantly, the social interaction leading to initial learning may be the result of interacting with an instructor or with a peer.

One other basic tenet of Vygotsky's (1978) theory is crucial in the current study. The concept is the more knowledgeable other (MKO). The MKO refers to anyone who has a better understanding or a higher ability level than the learner, with respect to a particular task, process, or concept. The MKO is normally thought of as being a teacher, coach, or older adult, but the MKO could also be a peer, a younger person, or even a computer. Thus, according to Vygotsky, the MKO plays the critical role of having more knowledge, which the person shares with a less knowledgeable learner through social interactions. These interactions might include formal teaching sessions such as an organized class in a school or university setting. Alternatively, the MKO may share the information in a more informal setting such as small group learning or individual tutoring.

Wertsch (1985) argues that when we examine learning we need to focus on the very process by which higher forms of understanding are established (see also Vygotsky, 1978). Rieber and Robinson (2004) go on to point out Vygotsky's central theme is that higher psychological processes are formed by cultural processes, including fundamental semiotic concepts. Thus, for example, the dialogue, including explanations and questions, which occur in the exchange between the learner and the MKO is essential in the learning process. As a result in this current project, the interaction between the students and the researcher and subsequently between student and student is fundamental to the teaching-to-learn process.

Learning from Tutoring

The belief that tutees benefit academically from tutoring has provided long-standing justification for peer tutoring programs. On the other hand, recent evidence suggests that tutors also benefit greatly by learning as they tutor (Roscoe

& Chi, 2007; 2008). Consistent with the aforementioned benefits of tutoring, Comenius argued that the process of teaching gives a deeper insight into the subject being taught (Nevi, 1983). Pestalozzi wrote that his students "were delighted when they knew something they could teach to others and they learned twice as well by making the younger ones repeat their words" (as cited by Roscoe & Chi, 2007, p. 534). More recently, researchers have found empirical evidence of learning gains for tutors as compared to non-tutors which is referred to as the tutor learning effect (Cohen, Kulik & Kulik, 1982).

The tutor learning effect has been attributed to two processes, which purportedly underlie the tutoring process (Roscoe & Chi, 2007). Roscoe and Chi suggest (a) explaining and (b) questioning are the essential tutoring functions, which lead to increased understanding by the tutor. Further, they suggest explaining and questioning are two critical concepts that affect the tutor and tutee relationship.

Explaining. Tutors use explanations as one of the primary ways to convey information to their tutees with the goal of making the ideas clear and comprehensible. In their explanations, tutors employ various strategies, such as summarizing main ideas, giving examples and analogies to help make sense of new information, (e.g., the definition of the discriminant when working with quadratic functions) or to share known information (e.g., dividing a polynomial by synthetic division). Roscoe and Chi (2007) assert,

> When explaining, tutors must transform their prior knowledge into instructive messages that are relevant, coherent, complete, and accurate …

> However, although peer tutors may be more advanced than their tutees, they are not likely to have expert domain knowledge. True expertise takes time and much practice to devlop …, and so tutors' knowledge is probably novice-like in a number of ways. (p. 545)

When tutors are in the tutoring situation and they begin to explain they may find they have incomplete knowledge or gaps and misconceptions of the topic they are explaining. They may also find that their knowledge of the material may be fragmented or incomplete. Thus, by explaining, they may be able to improve and reorganize their own mental models of a topic by thinking more carefully about it and priortitizing information.

In a similar way, tutors strive to produce complete explanations that include the key ideas. This approach pushes them to generate more accurate and more detailed explanations. Roscoe and Chi (2007) also indicate,

> the tension between the demands of effective explaining and peer tutors' less than perfect knowledge may push tutors to engage in reflective knowledge-building. For example, to generate relevant explanations that address key topics in a meaningful way, tutors may have to think carefully about conceptual relationships and prioritize information. Generating coherent explanations that are internally consistent and follow a natural progression of ideas may require tutors to reorganize their own disjointed mental models by forming or rearranging connections among concepts. Thus, explaining may help tutors improve the organization and accessibility of their knowledge … (p. 545)

Roscoe and Chi (2007) go on to say that in so doing, tutors may find that they lack complete comprehension of the topic. As a result, tutors may evaluate whether their explanations are coherent and meaningful. Moreover, Roscoe and Chi contend these evaluations may lead peer tutors to reflect on their own knowledge as noted below.

> Thus, explaining may help peer tutors to metacognitively recognize and confront their own knowledge gaps and misconceptions. To the extent that peer tutors attempt to repair these problems through elaboration and inferences, their understanding should be enhanced… (p. 545)

The successful tutor will study worked out examples to check her own comprehension and begin to find links between steps, and be able to anticipate future steps. For a math tutor, she may take the tutee through the idea of finding zeros of a function (where a graph crosses the x-axis) by drawing the graph with a graphing calculator, factoring the polynomial, and using long division or synthetic division to demonstrate the remainder theorem to them. To maximize the usefulness of these tools the tutor may need to explain the underlying principles that relate all of these to each other and how these similar ideas have both their own uses as well as constraints. For example, a graph isn't going to show a zero, if the zero is imaginary, but through the process of long division or synthetic division this value may be discovered.

An important consideration related to tutor learning is the distinction between knowledge-telling explanations and knowledge-building explanations (Roscoe & Chi, 2007). Knowledge-telling explanations are represented by explanations that just give answers. Peer tutors, even when trained, focus more on delivering knowledge rather than developing it. As a result, the true potential for tutor learning may rarely be achieved. By comparison, knowledge-building explanations are focused on explaining. These activities are hypothesized to support peer tutors' learning via *reflective knowledge-building*, which includes self-monitoring of comprehension, integration of new and prior knowledge, and elaboration and construction of knowledge (Roscoe & Chi, 2007).

Based on a review of the literature, Roscoe and Chi (2007) concluded those tutors who generated knowledge-building explanations scored higher on tests than those who employed knowledge-telling explanations. Importantly, in their review of the literature, Roscoe and Chi observed that although those who tutored using knowledge-building explanations scored higher, many tutors focused on knowledge-telling unless they received explicit training on explanation strategies.

Roscoe and Chi (2007, p. 550) also advised "Within the confines of the tutors' semi-scripted lessons, however, scaffolding dialogues occurred in which explanations were further developed." They followed this by noting a five-step dialogue frame: tutor asks a question, tutee answers the question, tutor gives feedback, tutor and tutee elaborate upon the tutee's answer, and tutor evaluates the revised answer. When the tutor and tutee elaborate the tutee's answer they say this can be potentially rich in terms of knowledge-building, because the tutors may deviate from their script to revise or generate new explanations, which are more closely connected to ideas discussed in the dialogue. This scaffolding process has the potential to offer tutors the chance to gradually refine their explanations.

In their concluding remarks about explanations, Roscoe and Chi (2007, p. 552) stated, "…this research shows that tutors' explanations, when they incorporate elements of reflective knowledge-building, do support more effective tutor learning." How tutors vary tutoring between knowledge-telling as compared to knowledge-building is something that must be considered very carefully. Most tutors, even with training in knowledge-building, often use knowledge-telling more frequently. The authors noted that knowledge-telling may have benefits because tutors' recall might improve by rehearsing, and knowledge-telling may be the necessary precursor to knowledge-building explanations. As has been posited, tutors benefit by explaining using knowledge-building explanations, which provide for richer, deeper processing of the material, which is being shared with others. In addition to explaining, Roscoe and Chi have seen evidence that asking and answering questions might support tutor learning and reflective knowledge-building.

Questioning. Questioning, which includes both asking and answering questions, is another tutoring activity that may lead to deeper understanding of the material, which a tutor is sharing. Tutors ask questions to guide tutee thinking, as well as to assess their thinking. Tutors ask review-type questions to get at prior knowledge that the tutees might have, but they may also ask questions that provide a subtle hint, such as "If the graph doesn't cross the x-axis, are the zeros real or imaginary?" These questioning techniques may not be of the information-seeking type but rather they are often of the yes-or-no type and the tutor may be seeking assurance the tutee already knows the answer. Roscoe and Chi (2007, p. 554) note “However, questioning is most beneficial when students ask deeper questions that require integration of new and prior knowledge, reorganization of mental models, generation of inferences, and metacognitive self-monitoring.” Additionally, they add,

> Tutors do not ask true information-seeking questions … because they already know the answers. However, peer tutors may benefit from constructing questions to help tutees think deeply about the material. For example, tutors may devise questions that contrast concepts ("How are these two kinds of problems different from each other?"), apply concepts ("Could you use Newton’s Third Law to solve this problem?"), unpack causal relationships ("What would happen if this force were zero?"), and so on. To generate integration and reasoning questions, tutors may have to also reflect upon the fundamental ideas, relationships, and principles needed to produce a correct answer. Thus, question-asking may help tutors further reinforce and organize their own understanding… . (p. 554)

Occasionally, when a tutor poses a question to a tutee, the tutor may not know the answer or have an incorrect answer due to their lack of knowledge of the subject or because their knowledge contains gaps or misconceptions because they have just learned the material themselves. Roscoe and Chi (2007) maintain,

> This may often happen when tutors try to ask deeper questions that go beyond the source materials. In this case, the tutor has inadvertently posed

> an information-seeking question. To the extent that tutors attempt to identify or construct a correct answer to such questions, similar to self-questioning …, they may experience learning benefits. (p. 554)

During this questioning-response dialogue, tutees might be confused by the tutor's explanation. It might be incomplete, or contradictory. The tutees' questions may lead the tutors to revise their own understanding and knowledge, all to provide better explanations for their tutees. Answering questions that lead to a discovery of either the answer or a new way of thinking provides a rewarding sense of efficacy that can improve the confidence of the tutor or even the tutee. The Socratic method allows an individual to think for herself, rather than simply being told how or what to think. This unique ability to find one's own way may be gratifying and fulfilling, more importantly, it may be lasting.

Roscoe and Chi (2007) further suggest educators have hypothesized tutor learning is a direct result of tutors' engagement in instructional activities inherent in the tutoring process, such as explaining, answering questions, correcting tutee errors, manipulating different representations, and so forth. Tutors ask questions to introduce topics and to guide tutee thinking. They must also respond to requests for clarification. This may also lead to learning. Students who have taught others may learn as a result of the process. Students, who serve as the tutors, review the material, organize, prepare, illustrate the material to present it to others, and may try to reshape it to enable the others to learn it and thus they also see it in new ways. They may need to seek out the basic character of the subject, its structure, to teach it more effectively, and may thereby themselves understand it better. By striving to produce complete explanations and appropriate questions that integrate key concepts and principles, students might be pushed to reassess the depth and breadth of their own knowledge. They may also have to assess whether their explanations and questions make sense and are logical (Roscoe & Chi, 2007).

Other Evidence on Tutoring

Similarly, Rick Dollieslager, an English faculty member at Thomas Nelson Community College in Virginia, cogently argues that we learn and retain material most effectively by preparing to teach it to others (Dollieslager, n.d.). For example, when he asked fellow writing instructors, 'When, exactly, did you learn the rules of punctuation and grammar?' they all answered, 'When I had to start teaching the rules to students.' Isn't this true of your own experience? Didn't you learn your discipline most deeply when you began teaching it to others? Dollieslager made these remarks in the *On Course Newsletter*, a publication for community college instructors.

Dollieslager (n.d.) asked his students to become experts in a certain area related to the writing of papers for an English class. First, Dollieslager assessed students' writing weaknesses over the first several weeks of the semester and then asked students to conduct research on their writing weaknesses, say the use of semicolons or the correct form for preparing references for the bibliography section of their papers. He grouped students based on their weaknesses and these groups became the experts on the topic. After students conducted their research, they presented on the specific topic, say the correct reference form, to the class.

Then they served as the experts on that topic for the remainder of the semester. Other students would consult with them when they had a question about the specific editing issue.

Dollieslager (n.d.) found that as a result of expert groups, students' retention of learning was high. By mid-semester the student experts had made their presentations and had become knowledgeable about a major editing error that had been problematic for them earlier. In the course of a semester, students moved from being an uncertain novice to being a polished expert on at least one aspect of editing. As a result, he spent very little time explaining or editing corrections during workshop days in his English class.

One of his students came to talk to him two semesters after she had taken his class to say that what she learned in English was helping her to do well in biology (Dollieslager, n.d.). She said, "The experts project made me realize that hands-on is a better way for me to learn, and that when I learn something well enough to teach it, I really know it." Additionally, this strategy helped students develop interdependence since they are relying on the expertise of their classroom colleagues, and they freely and willingly shared their information with others, both during class and outside of it. Some had even included email information in their teaching supplements for contacting them outside of class. Because they kept working on their teaching presentations and supplementary teaching materials until their projects were worthy of an A grade, each student achieved a measure of success in the course, which enhanced self-esteem. Dollieslager's students have said of the project that it was fun and creative and gave them more confidence. Being able to do something and being able to answer other people's questions about it are two very different things. This project makes students responsible for their own learning. Each student learns that an academic difficulty can be overcome by research and collaboration.

Dollieslager's (n.d.) insights ultimately provided the initial impetus for this action research project. Nevertheless, in the current project, his ideas have been modified based on the review of the tutoring-to-learn research, particularly the research reviewed and conducted by Roscoe and Chi (2007, 2008). It should be noted that Dollieslager's students conducted independent research, which informed their learning, subsequent presentation to their peers, and their continued efforts of serving in the role of expert to other students in his English classes. By comparison, in the current action research project, students will initially be tutored by me, tutor their own group and develop a presentation on a math topic for the rest of the class, provide a demonstration of their understanding of the topic, and continue to serve as experts on the topic throughout the remainder of the semester.

Learning in Groups

As we consider tutoring in the current context, one aspect that needs to be examined is the effect of learning in groups, because the tutoring will occur in a group setting. The value from learning in groups is illustrated in the following guidelines (Jacques & Salmon, 2007):

- Minimize/simplify the structure

- Use intergroup as well as interpersonal communication - in order to enable people to explore structural as well as individual similarities
- Import (selected?) bits of the real world into the laboratory environment
- In designing laboratories, keep in mind at all times how things work in 'real life'
- Encourage intervention/confrontation (e.g. through the asking of questions as well as self-disclosure)
- Remember that past and future are experienced in the present.
- Use metaphors to explore interpersonal behavior

Drawing on these seven guidelines, the most relevant one for the project is encouraging intervention/confrontation because it is related to questioning. Asking questions in the group setting allows for repairing gaps in the tutors' own knowledge, which can be facilitated through the exchange of ideas based on the questions (Roscoe & Chi, 2007).

Jacques and Salmon (2007) also suggest six categories to facilitate group work. These six categories are: directing, informing, confronting, releasing tension, supporting, and eliciting. In particular the two categories, *eliciting* and *informing*, are of special importance for group work because they are related to tutoring. The six categories are summarized as follows. Under the authoritative mode the tutor can be directing, for example, by raising an issue for discussion, re-routing the discussion or suggesting that further work might need to be done.

The tutor may be *informing***,** summarizing key points regarding the topic being discussed and giving knowledge and information that is required by the rest of the group to prepare the topic to present to the rest of the class. Confronting may be another trait that the lead tutor may employ. This is demonstrated by challenging with direct questions, or by disagreeing with the others, correcting them, or critically evaluating a student statement as well as by giving direct feedback.

Under the facilitative mode, the tutor can release tension as well as arouse laughter, or allow students to discharge unpleasant emotions such as embarrassment, irritation, confusion and sometimes even anger. The lead tutor exhibits support by approving or reinforcing and agreeing with or affirming the value of student contributions. Tutors will also *elicit* responses by drawing out student opinions or their knowledge and problem-solving ability. Eliciting also includes posing questions for which a response is required.

The student, who has been instructed by the researcher, the lead tutor in this case, will generally start the group discussions by bringing to the group the topic to be discussed. The lead tutor will inform the group by summarizing, but others will interrelate by giving their knowledge about the topic and add information of their own. This can be facilitated as well by the lead tutor, by drawing out opinions, knowledge and problem solving approaches from the other group members.

Implications for the Study

What are the implications to this study? With respect to Vygotsky's MKO, the researcher and the lead tutor will both serve in those roles. Initially the researcher serves as the MKO when the topic is first discussed by the instructor with the lead tutor. Subsequently, the lead tutor will assume the MKO role when that individual meets with the group to tutor and to plan the activity for teaching it to the class.

Action research is necessarily based on localized studies that focus on the need to understand how things are happening, rather than merely what is happening, and to understand the ways that stakeholders – the different people concerned with the issue – perceive, interpret, and respond to events related to the issue being investigated (Stringer, 2007). The proposed action research project adheres to this perspective and is based on the CCSSE (n.d.) student survey responses, especially the one about tutoring or teaching others. Stringer (2007) goes on to say that action research requires all participants to engage in styles and forms of communication that facilitate the development of harmonious relationships and the effective attainment of group objectives. The group characteristics outlined previously, informing and eliciting support this as well.

Roscoe and Chi's (2007) findings about tutors' engagement in instructional activities inherent to the tutoring process, such as explaining, answering questions, correcting tutee errors, manipulating different representations, and so forth also support the conduct of this study. It is through this deeper engagement process that students will begin to understand the material better as they function as the tutor. As noted previously, according to Roscoe and Chi (2007), tutoring can benefit students academically. Richard Morales, who is the interim director of the Learning Support Center (LSC) at PVCC, tells students that not only will tutoring help other students in the center when they are there to tutor them, but they themselves will learn the subject better by being a tutor. This along with much of the other research already noted is critical in why this process for improving learning is what this action research project will be conducted to examine. The Community College Survey of Student Engagement (CCSSE, n.d.) has shown that the best indicator of student success is the degree to which they are actively engaged as a learner. This action research project is designed to provide for more active engagement of students in their own learning.

Students in past college algebra classes have struggled with understanding material that is needed to help them with subsequent coursework. Traditional lecture doesn't seem to work for everyone, as a result, the literature suggests that students may learn better if they teach the material to others (Dollieslager, n.d.; Roscoe & Chi, 2007, 2008). The innovation is based on the idea that teaching something to another leads to deeper and better understanding. The researcher will work with selected students in a one-on-one basis. One student from the group will meet with the researcher outside of the regular class time, and then go back to the group and teach the topic to a small set of peers who will, as a group, teach it to the whole class.

Previous Action Research Relevant to the Project

The premise of the project, we learn best what we teach, has been examined in earlier rounds of action research. During a previous round of action research, a student who had just been tutored by me was asked to tutor a student on the same material that we had worked on together. It was an interesting coincidence, and it came at a very good time. The initial student, Sam, with whom I worked, was left with Jennifer to go over how to graph a logarithmic function. This was going to be the topic that Sam and his group would present for the next class review as part of this particular round of action research. Jennifer had actually come by to see me, but the opportunity to see how tutoring can help students learn needed to be seized. Sam worked with Jennifer, and what was evident was that both Sam and Jennifer were more engaged in class during our discussion of graphing the next day than they had been previously. Not only that, but when I gave the class an assignment to do in groups on this topic, the two of them were now the more knowledgeable others. Their understanding of the topic was evident as I walked among the groups. Students from other groups were now asking for help from Sam and Jennifer, and also from other members in their groups.

Over and over again we ask ourselves ‘You are passionate about learning, but are your students passionate about learning?’ The outcomes from previous action research projects have shed some light on this question. Students felt better about the experience, they felt that they learned the topic better as a result of my innovation, and in some cases they showed signs of being more passionate about their learning.

Can such efforts make a contribution to the idea of improving learning? When I asked one of my colleagues, she stated an emphatic “Yes.” I believe this story is worthy of being shared, especially with those in similar professional situations. Her comments were like others that I spoke with in my division. She went on to add, that we don't think like students do, and it's good to have them help other students because students base their teaching efforts on their own understandings. I shared this with people who are proponents of cooperative and active learning and this fits nicely into their thinking on these pedagogies as well. As noted by Roscoe and Chi (2007) when students are engaged more actively in the learning process, it helps them learn and retain more material.

One of the problems groups face is that of commitment, engagement and collaboration by all involved. Moreover, they also face the additional problem of staying in communication with each other in the group. In previous action research on this matter, although they would meet as a group at specified times, not all members could attend those meetings, due to work, or class scheduling conflicts. At community colleges across the country there is a mold that needs to be broken, or at least cracked, and that's the "car–to class–to car" syndrome into which many community college students fall. As the instructor, I have learned that I will need to require that each member of the group participate, as they will be graded as a group, but they will also get individual grades, based on input from the other members, and their ability to answer random questions from the class, as part of the follow up to their presentation.

Previous findings. The results showed not every student scored four out of four on the test questions, but if the data are separated and analyzed only for students who were active participants in the whole process, all of these selected students did in fact make perfect scores. Results from an interview also supported the premise that teaching-to-learn improved student learning. Five such statements from the group supported this claim:

“It was better to be the teacher. We worked hard to make sure we could present it, and that helped us understand it. It was hard to learn from others.”

“The small group setting made it easier to learn the topic, and it was nice to have just one item to learn and teach.”

“Things fell into place better in the small group.”

“Confidence level was increased.”

“Participation level increased.”

Suggestions for improvement included among others, the following two comments:

“The groups need to know there are resources at the Learning Support Center (LSC) and that they can come to the instructor.”

“As the instructor, assign a time that the group needs to come together. Make a schedule for them.”

When I asked them “What is one question I didn’t ask that you wanted me to ask?” The individuals didn’t ask a question but instead made the following comments, which again provided support for the teaching-to-learn approach.

“It was good to have guidance on what to focus on, and why.”

“Scheduling was difficult.”

“Using one person to learn and take that back to teach the group was good.” “Assign the groups and discuss the importance of this project to them in this small group. They need to meet together as a group. Their presentation affects others, and if they are not prepared it won't be helpful."

Implications. Giuliodori, Lujan, and DiCarlo (2006) convincingly argue,

> It is now clear that concept construction requires processing of information. That is, we understand and remember the information we think about. However, processing information requires time. Faculty members must be realistic about the amount of time required to learn complex concepts and provide the time needed to achieve the goal. Students need time to explore the underlying concepts and to generate connections to other information. (p. 168)

This statement has as a 'read between the lines' aspect to it, the idea that students need time to learn complex concepts, and math has many of those.

The action research conducted this spring, did just that, it allowed students to spend more time on a concept, through the conversations with me as the MKO as Vygotsky suggests, and also while the tutors were working with their group when they were the MKO to prepare the lesson for the review session. Instead of hearing about it in class, and doing some homework, these students now spent time working on a problem, teaching it to their group mates, and then teaching it to the class. In this tutoring process, the tutor used the two ideas of Roscoe and Chi (2007), explaining and questioning. The tutors initially used statements that have the characteristic of knowledge-telling when they were in the tutoring setting. Although there is improved learning using this method, the student will benefit more by using knowledge-building explanations instead (Roscoe & Chi, 2007).

In this setting as well, tutors asked questions to guide and assess tutor thinking, but this technique also has the added effect of the tutor having to answer questions from the tutee. This requires the tutor to more thoughtfully process information to provide clarification for the tutee. Both of these questioning activities involve making inquiries of the material that may lead to learning (Roscoe & Chi, 2007). All of this occurred in groups where the students were engaged in informing and eliciting, group processes discussed by Jacques and Salmon (2007), which may lead to deeper understanding.

The innovation appears to be appropriate, but there are still problems with getting full participation by the students. During spring 2010 as well as during the previous action research project, one prevalent problem was the group not being able to always get together at the same time. Students have very different schedules. To help alleviate this issue, the students will use the hour before class to meet, which has the added benefit that I will be there as well,

Taken together, the evidence from the research literature and the information from previous rounds of action research suggest learning may be enhanced as a result of tutoring—learning by teaching. Nevertheless, there appears to be much that can be learned from examining more fully the affect of tutoring on learning of college algebra. As a result, the present action research project will be conducted to discover answers to the following research questions:

How does tutoring increase mathematical understanding to college algebra?

How can tutoring be more effectively implemented to increase mathematical understanding of college algebra?

Chapter 3 Method

Setting and Participants

The study took place during the fall 2010 semester at Paradise Valley Community College (PVCC). PVCC is one of ten colleges in the Maricopa Community College District. PVCC is the seventh largest with an annual enrollment of approximately 18,000 students**.** Although students may come from any ethnic background, they are primarily Caucasian, about 69 percent, with 11 percent being Hispanic, 2 percent American Indian, 3 percent being African American, and 4 percent being Asian. All others round out the balance at 11 percent. Typically, demographics in this class are very close to the demographics of the school as a whole.

The participants were the thirty-two members of my college algebra class who range in age from 18 to 50 years. Females constituted approximately 60 percent of the class and males 40 percent. The participants were divided into eight groups of four students, each. From each of the groups, individual students were asked to become the expert in some topic related to college algebra. After meeting with me on the specific algebra topic, they were asked to serve as a tutor to the other three members of their group, collaboratively prepare with their group a presentation on the particular topic to be offered on a review day prior to a chapter exam, present the material prepared by the group to the class on a review day, and serve as the content expert about the topic for the remainder of the semester along with their group members.

Instruments

Quantitative and qualitative data were collected in this action research project. As Johnson and Onwuegbuzie (2004) define mixed methods research, it is the class of research where the researcher combines qualitative and quantitative research techniques, approaches, concepts or language into a single study. This type of analysis can be called between-method triangulation which involves contrasting research methods, such as a questionnaire and observation (Bryman, 2010).

Four instruments were used to collect data for this study. First, questionnaire data were collected. The first instrument was a questionnaire of attitudes regarding teaching to learn. To measure student attitudes toward the process, the questionnaire was given after implementation of the intervention. The measure included six items that were assessed using a four-point Likert scale from 1 = *Strongly Agree* to 4 = *Strongly Disagree*. Two examples of the items were: "Learning by teaching helps me understand material better." and "Being taught by my peers is a good way to learn material." These six items were followed by three open-ended questions. An example of an open-ended item is "What did you find to be the most beneficial part of the teaching-to-learn process?" The complete survey is provided in Appendix B. Responses to Likert items were analyzed using quantitative procedures. By comparison, responses to open-ended items were coded to determine emerging themes.

The second instrument used to collect data was an interview consisting of seven questions. The purpose of the interview items was to assess the students' perceptions of the effectiveness and the perceived benefits of the learning by teaching process. Two items illustrative of those included on the interview were: "Did your participation in learning by teaching help you better learn college algebra? If so, how? If not, why not?" and "Was the tutoring you performed in your group beneficial to your learning? If so, how? If not, why not?" The complete set of questions can be found in Appendix A. The responses to the questions were recorded, and transcribed. Subsequently, the results were coded to determine emerging themes in the data.

Third, descriptive field notes based on observations of eight small group sessions were conducted to collect data on the interactions that occurred between the tutor and the other group members as they prepared their group presentation. These sessions were recorded, transcribed, and analyzed for emerging themes.

The fourth instrument was a set of four unit tests. Scores from various exams given to the entire class throughout the semester were collected. The term was fifteen weeks long and there were five unit tests during the term. I used data from the last four of the tests in the action research project. The data were gathered in such a way to allow comparison of results on the items that the groups presented to the class to see how the presenters scored on the item that they taught as compared to the other members of the class. Students were tested individually. The test items came from the publisher's test bank. They were items that everyone in the class had been taught throughout the weeks before the test by the instructor as well as by the groups when they presented their material on the review day.

Intervention

The innovation in the project was to create student experts by having students teach others after having been taught by the instructor. The question I'm trying to answer is "With instructor assistance in a college algebra class, how will peer teaching by students affect their learning?" Students in the class were divided into groups of four. One member of each group met with me for 30 minutes one-on-one outside of the regular class time. During this meeting, I facilitated their knowledge acquisition enabling them to become an expert at a concept by providing both direct instruction and guided practice. The student also learned to use appropriate explaining and questioning strategies (see Roscoe & Chi, 2007).

The researcher decided the content on which the students became experts. I met with one member of each group outside of class so that they became fully familiar with the information that they taught to their group mates during the week following that meeting. Subsequently, the student expert taught the content to the other members of his or her group. The role of student expert rotated across the four units so that each member would become the expert on a different topic or concept.

The process rotated during the term so that each member of the group went through the same process once during the semester. The topic was chosen from the topics that were covered during class and from the ones that were used on the exams. This was done for each unit test. After getting instruction from me, the lead student went back to the group and taught the same topic to the group.

Next, each group taught the class about this topic during an in-class review session.

During this instructional time, I taught the student and allowed for exchange of ideas and questions so that each time they felt comfortable with the material before they went to the group to teach it to their group mates. I modeled the explaining and questioning procedures of Roscoe and Chi (2007). In particular, I taught the tutors to use knowledge-building and questioning strategies, which they employed in working with their group.

Each of the groups was encouraged to include supplements or overhead work, and to make arrangements for the presentations (who was going to speak, what each person's role was, etc.). If questions had not been satisfactorily answered by the presenters, time would be taken to clarify the material for the class either by me or more importantly by someone else in the group.

Throughout the rest of the semester, these experts were to act as a consulting service. Whenever the topic they presented came up in class, they were asked to answer questions from their classmates both during class and on occasion, outside of class.

Data Collection

As noted previously, four instruments were used to collect data. Data were collected at various points throughout the intervention. Tests were given on a recurring basis during the semester. The tests were administered by the teacher in class, but they were taken by the students on an individual basis. The questionnaire was administered following the intervention. The questionnaire was administered by the researcher to the class and students responded on an individual basis. The students read each item and circled the rating that reflected their level of agreement. They also answered the open-ended questions at the end of the survey. The interview questions were given in two focus group settings. The responses were recorded and then transcribed. Additionally, descriptive field notes were obtained from eight small group sessions as they prepared their presentation for the class. These descriptive field notes were transcribed and coded and analyzed using the methods described in the data analysis section.

Procedure

Students were assigned randomly to eight groups of four students each. As noted earlier, individual students met with me on one-on-one basis for one-half hour to learn more about an algebra topic. Subsequently, these individuals met with their groups to prepare for a presentation to the class about the topic. I observed and tape recorded the sessions and developed field notes based on the recordings for eight of these small group meetings to learn more about the effectiveness of the tutoring offered by the tutor. I also took notes during the in-class presentations. Throughout the course of the semester, unit test data were collected in such a way that information about the material which students presented to the class was kept separate from that which they merely learned from others. This procedure was used to determine whether teaching increased understanding of that specific content. Moreover, at the end of the project, questionnaire data and interview data were collected. As described in detail in the next section, quantitative data and qualitative data were analyzed to determine the influence of teaching to learn on the development of understanding in a college algebra class. Finally, member checks were conducted with students to ensure the themes derived were consistent with the intended meaning of the student.

Data Analysis

Quantitative data analysis. Quantitative data were analyzed in the following way. Test score results from unit tests on material that was not taught were compared to scores on the material that was taught. These data were examined to determine whether there were differential increases in the scores for those who taught the material as compared to the remainder of the class. Questionnaire results were also analyzed using quantitative procedures and descriptive statistics are presented.

Qualitative data analysis. Qualitative data including responses to the open-ended items on the questionnaire, transcriptions of the interviews, and descriptive field notes based on the observations were analyzed to determine emerging themes using the constant comparative method (Corbin & Strauss, 2008). In this procedure, open and axial coding was used to initially identify concepts and then develop subsequent categories that represent phenomena related to the data. After a theme was identified, quotes from the interviews were used to substantiate and support the theme. These qualitative data were used to augment and support the quantitative data.

Role of Researcher

My role as the researcher was as a participant-observer. I was the participant because I implemented the intervention. Meetings with the lead tutor from each group took place in my office. Additionally, I was an observer when I observed the small groups preparing for their presentation, when groups conducted their in-class presentations, when I conducted the interview sessions, and when I tabulated the surveys and test results.

Conclusion

The present action research project was conducted to determine whether teaching-to-learn increases mathematics understanding in a college algebra course. The research questions being examined were:

How does tutoring increase mathematical understanding of college algebra?

How can tutoring be more effectively implemented to increase mathematical understanding of college algebra?

Evidence from the research literature and the information from previous rounds of action research suggested learning may be enhanced as a result of learning by teaching. Nevertheless, there appears to be much that can be learned from examining more fully the affect of teaching on learning of college algebra. As a result, the present action research project was conducted to discover answers to the research questions outlined above.

Chapter 4 Data Analysis and Results

Results from the study are presented in two sections. In the first section, results from the quantitative data are presented. Following the results for the quantitative data, results for qualitative data are presented. For the qualitative data, assertions are presented and supported through theme-related components and quotes from participants. Prior to presenting the results, a brief section outlining the data sources and data collection procedures is presented to provide some context for the presentation of the results.

Quantitative data were collected with a series of four pre- and post-unit tests over the course of the study. This pre- and post-instructional assessment process allowed for the examination of changes in performance during the unit. Data were also specified with regard to whether a specific item was taught or was not taught by the student. Quantitative data from these unit tests were analyzed using repeated measures analyses of variance (ANOVA) procedures. Additional quantitative data were gathered with an end-of-semester instrument that assessed the effectiveness of and students' attitudes toward the teaching-to-learn process. These data were collected only at the end of the semester and are presented descriptively.

Qualitative data were gathered via (a) field notes from small group preparation sessions, (b) field notes from in class presentations, (c) open-ended items on the end-of-semester questionnaire, and (d) digitally recorded and transcribed focus group interviews. The qualitative data were analyzed using the constant comparative method (Corbin & Strauss, 2008). In that procedure, open coding was initially conducted to identify ideas and concepts from the two sets of field notes, open-ended responses, and transcripts of the focus groups. Subsequently, those open codes were gathered into larger categories using axial coding. Those larger categories led to theme-related concepts that suggested themes, which emerged from the data. The themes and theme-related components were examined and assertions were developed. Thus, the results should provide evidence to answer the following research question, Does teaching-to-learn affect student learning in a college algebra class?

Results from Quantitative Data

Performance in mathematics. To answer the research question about whether teaching a topic facilitated greater understanding of that topic as compared to other not-taught topics, repeated measures ANOVA was employed. In fact, the measures were doubly repeated because each student had pre-test scores for each of the two topic areas, those which were not taught and those which were taught, as well as having post-test scores for these same two variables. The results from the repeated measures ANOVA for arcsine transformed proportion data showed there was a statistically significant effect for time of testing, $F(1, 26) = 103.85$, $p < .001$. The pre-test M = 0.24 was significantly different than the post-test M = 0.60 (see the marginal means in Table 1). The effect size for this measure was $\eta^2 = .800$, which is an extraordinarily large effect size for a within-subjects design based on Cohen's criteria (Olejnik & Algina, 2000). Pre- and post-test means and standard deviations for the pre- and post-test scores and for the taught as compared to not-taught scores based on total performance on the four unit examinations are presented in Table 1.

Table 1

Total Performance Scores on the Mathematics Unit Examinations

	Pre-test		Post-test		Mean
Taught vs. Non-taught	*M*	*SD**	*M*	*SD*	
Taught	0.25	(0.21)	0.50	(0.34)	0.38
Not-taught	0.22	(0.16)	0.70	(0.21)	0.46
Mean	0.24		0.60		

*Note: Standard deviations are presented in parentheses.

The repeated measures ANOVA for the taught as compared to not-taught material was statistically significant, $F(1, 26) = 9.66$, $p < .005$. The taught M = 0.38 was significantly different than the not-taught M = 0.46 (see the marginal means in Table 1). The effect size was $\eta^2 = .271$, which is a large effect size for a within-subjects design based on Cohen's criteria. Nevertheless, it should be noted the not-taught mean was higher than the taught mean, which is contrary to the anticipated effect. This contraindicative information as compared to the anticipated effect will be discussed in the next chapter. Finally, the repeated measures ANOVA for the interaction of time of testing (pre- vs. post-test) x teaching category (taught vs. not-taught) was statistically significant, $F(1, 26) = 17.24$, $p < .001$. The not-taught mean showed a greater increase from pre- to post-test, 0.22 to 0.70, i.e. 0.48, than the taught mean 0.25 to 0.50, i.e., 0.25, (see the non-marginal means in Table 1). The effect size for this interaction effect was $\eta^2 = .399$, which is a very large effect size for a within- subjects design based on Cohen's criteria.

Questionnaire data. Before the questionnaire data were analyzed, reliability analyses were conducted on each of the two subscales from the questionnaire. Recall the subscales assessed areas related to perceived effectiveness of the teaching-to-learn method and how much they enjoyed/liked the teaching-to-learn method. For each subscale, Cronbach's α was computed using SPSS to determine the reliability of the subscale. Based on the students' responses, the reliabilities for the subscales were: .93 and .92. The reliability coefficients were substantial and attested to the reliability of these two subscales. With respect to the questionnaire data, it appeared that students thought the teaching-to-learn process was effective, M = 3.33 out of 4 points with a SD = 0.68. Similarly, it seemed students liked the teaching-to-learn method, M = 3.24 out of 4 points with a SD = 0.70.

Results from Qualitative Data

Results for the qualitative data are presented in this section. The themes, theme-related components and assertions from the qualitative data are presented in Table 2. This information provides a summary of the qualitative data obtained in the action research project.

Table 2

Themes, Theme-Related Components and Assertions

Themes	Theme-related Components	Assertions
Deep processing and understanding	Deep thinking Deep questioning to elicit understanding Elaborate explanations Elaborate responses to questions	Students showed a deeper understanding of the material.
Engagement	Elaborate questioning Increased class participation Presenters and participants discussed problems as they arose	Levels of engagement in class discussions and during presentations improved during the study.
Confidence in their skill and performance	Presentations showed newly developed skills Presenters were confident in answering students' questions Students showed leadership in the small groups Everyone participated in the small groups	Confidence of the participants improved and was evident during presentations and preparation.
Effectiveness of the Intervention	Peer teaching seen as effective More elaborate in-class demonstrations Group interaction seen as effective Leadership offered by instructor	Participants felt the intervention was effective because it increased their level of learning.
Affective	Enjoyment Desire to continue the process Beneficial to learning	The teaching-to-learn process was viewed in a positive way by students.

Depth of processing and understanding--Assertion 1. Students showed a deeper understanding of the material. Results from the two types of descriptive field notes, responses to the open-ended items, and responses during the focus groups showed students had a deeper understanding of the class material. Theme-related components that supported deep processing and understanding of the material included: (a) deep thinking; (b) deep questioning to elicit understanding; (c) elaborate explanations; and (d) elaborate responses to questions. In the sections that follow each of these will be explored in more detail.

Deep thinking was illustrated when students expanded their efforts to understand a problem. Instead of merely exhibiting awareness of the basic concepts of a problem, students brought prior learning to bear or analyzed the problem to understand it in a more insightful manner. This also referred to their ability to ask and answer questions and to elicit in-depth conversations regarding the problem at hand. The exemplars came from student responses to open-ended items, interviews and observations from my field notes.

During an observation of a small group preparation session, student #1 asked for input from the group instead of just giving them the answer. She let them discover the answer and the process. Then student #1 graphed the equation to tie the problem together. During the same session student #2, 3 and 4 discovered an alternate way to do the problem that was different than the way student #1 had demonstrated. Student #1 offered, ". . . that it doesn't come down to which way is faster, it comes down to which way you understand it" (Field notes, Small group preparation session, October 14).

During an in-class presentation student #9 explained to the class how to set the viewing window correctly on the graphing calculator to display a regression problem the group was presenting. This was a critical piece of the problem because if the viewing window was set incorrectly, the wrong regression model may be chosen in error. Prior to this discussion, most students struggled with this situation because they lacked deeper understanding of all the components that were required to select the correct model.

Another theme-related component that was evident during this project was that students asked questions more often of their peers. In addition to greater frequency, questions were of a deeper nature, that is the questions asked, by both the group members who were presenting and by class members who were learning, elicited more thorough understanding of the material. This was most obvious when students asked thoughtful questions during the class presentations. Nevertheless, a more subtle, but compelling situation with respect to asking questions arose during the small group preparation sessions when students anticipated they were going to be asked questions during the presentations, and as a consequence they prepared more deeply to be better able to respond to the anticipated questions. When asked if the teaching-to-learn project changed the way she behaved in the classroom student #18 responded, "I asked more questions" (Interview, December 7). During the same interview, student #17 declared, "I didn't want someone to ask a question and me (sic) not know when I'm the one teaching it." After the follow up question that asked if he had prepared for this, he followed with "Absolutely. And [I] prepared additional questions. You know, you went the extra step to make sure you knew every single thing about it in case you got all those questions, really" (Interview, December 7). During an in-class presentation of a lesson, one of the groups was asked to clarify what some of the numbers meant in a standard form of the equation of the parabola. Both students #17 and #18 were able to answer that question and in addition they went further to explain how those values affected the graph of the parabola (Field Notes, In-class presentation, September 30).

Elaborate explanations were the third theme-related component that emerged for this theme. This component was evident primarily during the class presentations. Often, the presenters explained a problem by using the whiteboard and carefully demonstrated the steps for solving the problem by hand. Then someone else in the group showed how the problem could be solved a different way or they would solicit input from the class on alternate ways to do the problem. This typically led to showing how to do the problem on the graphing calculator. The presenters knew that even if the problem required that it be solved by hand, it could be checked with the calculator and they wanted to share this additional information with the class. For example, during a presentation of solving an absolute value equation a group was asked if the problem could be solved in a different way. Student #25 showed how it could be solved simply by a numeric method. He said, "Just plug in a number to see if it works. Be sure to check for more than one solution though, as absolute value equations typically have two solutions" (Field Notes, In-class presentation, September 30). Student #26 illustrated how this problem could be done graphically using the graphing calculator. She added, “Put the left hand side in the calculator under y_1 and the right hand side under y_2. Once you set the appropriate window, look at where the two graphs intersect. Those x values will be the solution” (Field Notes, In-class presentation, September 30).

The fourth theme-related component was elaborate responses to questions. When asked during the interview what was found to be the most beneficial part of the teaching-to-learn process, student #3 acknowledged,

> They bring not only your perspective, but also bring their perspective. And when they explain it to the group, they explain across (sic) to each other [using] their own perspectives on the problem and you can have by the time you’re done five or six different ways to look at a single problem and you can show that [there are] three different ways to solve it quite easily” (Interview, December 7).

One respondent on the end-of-the-semester questionnaire indicated that one of the most beneficial parts of the process was that, “… we went through every specific detail of our topic … it instills explanations of the process in your mind which definitely helped me to remember it” (Questionnaire response, December 7).

When asked for clarification of an in-class presentation by one of the groups, group members first offered an explanation using a graph drawn by hand. They also provided a numerical representation of how the graph can be drawn. Subsequently, they suggested how function transformations can be determined from the equation, which was related to prior knowledge. Finally, they asked questions of the class to be sure that class members understood (Field notes, In-class presentation, September 30).

Engagement--Assertion 2. Levels of engagement in class discussions and during presentations improved during the study. Engagement refers to being occupied or involved *in the learning process.* Thus, instead of just being casual participants in the classroom or in the studying process, students were more fully engaged in discussions and learning. Theme-related components that supported engagement included (a) elaborate questioning, (b) increased class participation, and (c) presenters and participants discussing problems as they arose. In the sections that follow each of these will be explored in more detail.

The first theme-related component for engagement was elaborate questioning. This component referred to both questioning by members of the group and the presenters themselves, or from the class during presentations and discussion. By questioning, students solicit responses that help their understanding as well as the students in the class or group. The exemplars come from student quotes, interviews and observations from my field notes.

During one small group preparation session, student #12 was leading the session when he allowed student #15 to ask, "… can synthetic division be done with any polynomial divisor?" (Field notes, Small group preparation session, October 13). Based on this question, student #14 responded, "No, it can only be done when the divisor is a linear binomial divisor" (Field notes, Small group preparation session, October 13). Student #12 affirmed that response, but it led to a deeper conversation regarding what other type of division problems might come up, how they would solicit input and questions from the class regarding this important concept, and how they would best answer those questions. In a second group preparation session, student #1 was discussing imaginary zeros of a polynomial and how an individual could determine a second zero if she knew the first. During this explanation, the other members of the group asked about how to go about finding the other zeros, and how many there would be, and what might happen if all of them or all but one were imaginary? They all soon realized graphing wasn't going to help them. They concluded they would have to either find the solution using synthetic division with the imaginary zeros or multiply the imaginary factors together and use long division and factoring to find the remaining solutions. This discussion, which involved elaborate questioning, led them to discover and reaffirm the process. For some it was a discovery, whereas for others it was a reaffirmation. The group also realized that these questions might come up during the presentation of the lesson and they discussed how it would be presented. During the class presentation a student in class asked about which method was the best. Student #3 offered, "There are two ways to do the problem, and that (sic) either way works, but choose the one that works best for you" (Field notes, In-class presentation, October 21).

Class participation also increased during this project, which was a second theme-related component. Increased class participation can be attributed in part to the fact students felt more comfortable presenting in front of their peers. This outcome was evidenced in the interviews when one student confirmed, "… it's easier to understand your peer than your professor. … you can talk more freely about it” (Interview, Student #2, December 7). In another interview, a student acknowledged “I think it’s easier to open up to another student because I guess like when I look at another student and I still see someone in college that’s struggling when he asks a question to you specific (sic) it’s more of like you know it” (Interview, Student #17, December 7).

The third theme-related component, presenters and participants discussed problems as they arose, was evident in small group preparation sessions and during the in-class presentations. During the interview, one student made an observation about the in-class presentation when he offered, “… it was like the third time through it. I was ready. I didn’t have any questions” (Interview, Student #20, December 7). During an in-class presentation, Student #26 was being asked a question by one student, while another student answered the question for her. This led to a small discussion about how the center of an ellipse can be found and how it was related to the concept of transformations from a previous presentation (Field notes, In-class presentation, December 2).

Confidence in their skill and performance--Assertion 3. Confidence of the participants improved and was evident during presentations and preparation. Theme-related components that support confidence in their skill and performance include: (a) presentations showed newly developed skills; (b) presenters were confident in answering students’ questions; (c) students showed leadership in the small groups; and (d) everyone participated in the small groups. In the sections that follow each of these theme-related components will be examined in more detail.

The first theme-related component for confidence in their skill and performance was evident in the presentations when students demonstrated their newly developed skills. Students who presented were able to connect ideas from previous lessons to the lesson being presented, as well as show how important it was to know how to look at a problem from different perspectives. The exemplars that supported this contention come from student quotes, interviews and observations based on field notes.

Student #2 affirmed, “I remember even down to the first one that we did and every successive lesson when that format came up of movement (sic) on a graph … We could still refer back to that as a group” (Interview, December 7). During an in-class presentation, student # 3 began when he declared, “We’re going to show you how to solve a system of equations” (In-class presentation, December 2). When he made this comment, it was with confidence. His group was ready to present and the members were confident of what they were presenting and as well as believing that students should be able to learn the material from them. The confidence of the group was further evidenced when they did the problem by hand, on the graphing calculator, and on the white board graphically.

Presenters were confident in answering students’ questions. This particular theme-related component took time to become evident and was more obvious later in the semester. Students #12, 14 and 15 demonstrated confidence in their skill when they offered an in-class presentation about synthetic division. During their small group preparation session they decided to get the class more involved by asking more questions. To achieve this goal, they were going to reward students who responded correctly by giving them a piece of candy. Student #12 demonstrated confidence in his skills when he discussed the importance of questioning during their preparation for the lesson as he affirmed, “It made me discuss questions I had with my fellow students,” and “It was good when … asked tough questions about the topic.” These two quotes were offered during the interview when students were asked to describe how useful the group part of the teaching-to-learn process was for them. Student #3 showed his confidence during an in-class presentation when he was asked about how to factor a polynomial. Student #4 offered the solution, but student #3 said “No, I have this one” (In-class presentation, October 14).

Another piece of evidence that demonstrated students newly developed confidence was the leadership skills exhibited by students in the small group preparation sessions. Generally, field notes showed the person who had previously met with the instructor led the discussion and preparation of the presentation during the small group preparation session. Nevertheless, during the in-class presentation, other members of the group demonstrated leadership. Because each of them took part in the presentation, each had a leadership role. For example, during one small group preparation session, student #1 reassured the group, asked for input and showed them how it tied together when they had completed their first steps of a problem on which they were working (Field notes, Small group preparation session, October 13). Additionally, student #12 corrected student #15 when she asked about doing a problem by synthetic division. Student

#12 pointed out "No, that problem can't be done that way because it's a quadratic factor. You can only do synthetic division with linear factors" (Field notes, Small group preparation session, October 13).

Further evidence to support the theme of confidence was demonstrated in the theme-related component that everyone participated in the small groups. On the open-ended items of the questionnaire where students were asked what the most beneficial part of the teaching-to-learn process was, one student acknowledged, "It was not hard on one person because everyone participated" (Questionnaire, December. 7). During the interview, a student offered, "Groups always helped in the learning process" (Interview, Student #3, December 7). And another student confirmed, "The most beneficial part was teaching and learning the material with peers" (Interview, Student #1, December 7). With a few exceptions due to illness or other occurrences, all members of the group were present during the small group preparation sessions for the in-class presentation.

This extensive participation in the small group preparation sessions demonstrated students' commitment to the teaching-to-learn process. Again, with few exceptions, students were present and participated fully during the in-class presentations. One final quote demonstrated the high level of commitment students made to teaching-to-learn when a student wrote, "…we stayed until everyone in the group knows exactly what our subject was (sic). If we didn't know, then we got help" (Questionnaire, December 7).

Effectiveness of the intervention--Assertion 4. Participants believed the intervention was effective because it increased their level of learning. Theme-related components that support the perception that the intervention was effective include: (a) peer teaching was seen as effective; (b) more elaborate in-class demonstrations were provided; (c) group interaction was seen as effective; and (d) leadership offered by the instructor was viewed as essential. In the sections that follow each of these will be examined in more detail.

With respect to effectiveness, the first theme-related component for effectiveness of the intervention indicated peer teaching was seen as effective. Twenty-two of 23 respondents on the end-of-the-semester questionnaire responded strongly agree or agree when they rated teaching the material in college algebra helped me to better learn the material. Similarly, when rating that being taught by my peers was a good way to learn the material 21 of the 23 students responded strongly agree or agree. Additionally, open-ended responses supported this contention as observed when one student wrote, "I thought that teaching it was most helpful because in order to teach it you really had to know the material" (Questionnaire, December 7). Another student recorded, "Teaching the class [the material] because it made me fully understand the problem by fully teaching it in front of the class" (Questionnaire, December 7). These statements clearly attested to students' perceptions of the effectiveness of the teaching-to-learn process.

A second theme-related concept that supported effectiveness of the intervention was that more elaborate in-class demonstrations were evident as the semester went forward. As noted previously, students did not just lecture on or demonstrate one method for solving a problem; instead they used the whiteboard and graphing calculator, led in-class discussions, and lectured to teach their particular concept. Not only did they use different methods, but they brought into the discussion prior knowledge from earlier lessons. During a presentation on ellipses, student #3 reminded student #26 that the center of an ellipse can be found using the idea of transformations that student #3's group taught the class in an earlier lesson. The rest of his group agreed and the class also concurred (Field notes, In-class presentation, December 2). Another in-class presentation illustrated this as well when one of the groups was explaining how to graph an exponential function. Early in the semester students would only use the calculator to graph, but during this presentation, the group took the time to start with the basic graph, then remind students how transformations could be used to graph the problem they were presenting. The group took the time to find the horizontal asymptotes for the curve, the correct shift, and a few points on the curve. Then they showed the class how to check their graph on the calculator. This group used numerical, algebraic and graphical representations to do the problem and to check their results. During the interview at the end of the semester student # 2 quipped, "…there's two ways to look at it and that's just one part of the problem" (Interview, December 7).

During a small group preparation session for an in-class presentation, student #9 was working through the process of explaining how to do a regression problem. As he did this, he carefully explained the importance of the viewing window for looking at the scatter plot and how important it would be to know what the correlation coefficient would be for this example. The concepts from this discussion were incorporated during the in-class presentation. Not only did this group do the problem on the calculator, they also showed the problem on the white board (Field Notes, In-class presentation, November 16).

Group interaction was seen as effective, which was the third component for this theme. One of the most telling quotes to substantiate this claim was offered by student #3 when he affirmed,

> They [members of the group] bring not only your perspective, but also [they] bring their perspective[s]. And when they explain it to the group, they explain across to each other (sic) their own perspectives on the problem and you can have (sic) by the time you're done five or six different ways to look at a single problem and you can show that [there are] three different ways to solve it quite easily (Interview, December 7).

When student #3 was asked if that helped you learn it better, he responded, "Oh definitely, definitely." In the same interview, student #2 added "And if you don't [understand] and if you try to explain it to someone then you start understanding it more, so that they understand it then they explain it to you, too" (Interview, December 7). One compelling quote with respect to the importance of group interaction on learning was elicited when the group was asked "Was my assistance helpful to your preparation?" Student # 2 responded in the affirmative, but emphasized the value of group interaction when he declared, "Yeah it was helpful, but to be honest the group was way more helpful" (Interview, December 7).

The final, effective theme-related component was the leadership offered by the instructor. Student #1 affirmed, "Well, because when the group doesn't understand it they we (sic) go [to] you as the supervisor and you explain it to us so we can understand the problem and then we can think about it and then teach someone else too" (Interview, December 7). One respondent on the questionnaire wrote, "For me meeting with the instructor was very beneficial. Having one-on-one time with the instructor made the topic much more understandable . . ." (Questionnaire, December 7). Another student recorded, "I liked meeting with [the instructor] cuz (sic) then we got one on one on each subject and it helped me learn it better" (Questionnaire, Student #16, December 7).

Affective--Assertion 5. The teaching-to-learn process was viewed in a positive way by students. The affective perspective refers to how the students felt about the project. Did they enjoy it? Did they want to continue it? Did they see it as beneficial to learning? Theme-related components that support the evidence of an affective response from students include: (a) enjoyment; (b) desire to continue the process; and (c) perceived as beneficial to learning. In the sections that follow each of these will be explored in more detail.

The first theme-related component, enjoyment, was evident, for example in students' responses to interview questions and to the questionnaire. Student #20 affirmed, "Now I get 25 perspectives when I'm teaching to [the] class with any questions that get shot at me. Like, I'm almost hoping that they'll shoot a question at me that I don't know" (Interview, December 7). On the end-of-the-semester questionnaire, 19 of 23 respondents agreed or strongly agreed that the teaching-to-learn process was enjoyable. During the interview, the question was posed "Did you have fun?" Student # 1 agreed he did have fun when he confirmed, "I did, I enjoyed it" (Interview, December 7). Another comment reflected enjoyment when a student allowed, "We're all best friends now. Best friends to the end" (Interview, Student #18, December 7). Other final comments from the interview also suggested students were pleased with the teaching-to-learn process as illustrated when one student offered, "This is awesome. I'm glad to be part of your research" (Interview, Student #3, December 7). Another added, "This is very cool" (Interview, Student #2, December 7). And, a third, student #4, averred, "Yeah, me too. This is cool. I'm really glad" (Interview, December 7).

With respect to continuing to use teaching-to-learn, a question was asked whether students wanted to continue the project? "Yes," said student #2 who added, "… because a peer can show you how he or she thinks and is the same age category (sic) it's probably easier to relate to that, understand it" (Interview, Student #2, December 7). Student # 3 agreed and added, "And it's not really the way humans learn and if you take it to where the teacher isn't the only person teaching to where the students teach" (Interview, December 7). Student # 2 quickly confirmed, "Yeah, because the main point is that it's easier to understand your peer than your professor" (Interview, December 7).

In regard to perceptions of teaching-to-learn being beneficial, one student acknowledged, "I thought it was very beneficial" (Interview, Student #18, December 7). Student #2 added,

> You don't have to do it yourself. You didn't have to go and make your own study group when you are panicking just before a test. I know that is

> one of the biggest assets I have is these guys (sic). We already know we can go to each other" (Interview, December 7).

Student # 4 agreed with him when he pointed out "Yeah it was helpful, … the group was way more helpful" (Interview, December 7).

When asked did the process help you learn it better because you were the teacher, student #17 responded, "Yeah, cuz (sic) I felt like if I was teaching it, I wanted to know it like in and out (sic) rather than just kinda (sic) grasp it" (Interview, December 7). Student #18 added that "I didn't want someone to ask a question and me not know when I'm the one teaching it. I prepared for this with additional questions" (Interview, December 7). Student #20 pointed out that he thought the process helped him learn better when he affirmed, "You wanted to make sure you were right on" (Interview, December 7).

Chapter 5 Discussion

The discussion includes three major sections: lessons learned from the action research project, implications for practice, and implications for research.

Lessons Learned

To begin the discussion on lessons learned, it is instructive to consider the relations among three themes emerging from the qualitative data: engagement, deep understanding, and confidence. The relations among these constructs are illustrated in the EDUCate model, which is presented in Figure 1. In the model, E denotes engagement, DU represents deep understanding, and C signifies confidence.

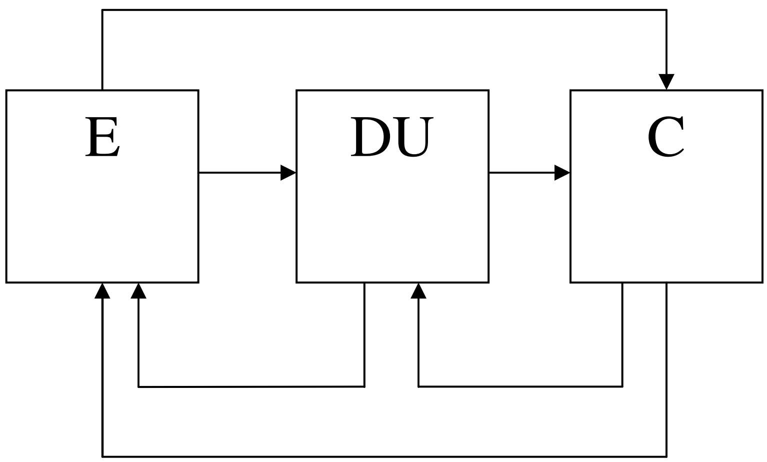

Figure 1. The EDUCate model shows the relations among and between student engagement, deep understanding, and confidence, themes that emerged from the qualitative data. E denotes engagement, DU represents deep understanding, and C signifies confidence. Each of the constructs in the figure is mutually influential on each of the others.

The model indicates that engagement leads to deeper understanding. Data show students clearly are engaged in class. For example, students who are leading the presentation suggest problems, pose questions, and offer explanations or demonstrations that are meaningful and capture the attention of their classmates. The classmates then become active participants in the presentations, rather than being mere passive recipients. On the other side, active recipients ask for clarification, further explanation, or elaboration from the presenters. Both sets of actions of the presenters and of the recipients indicate their engagement with the material. These discussions and interactions between presenters and recipients provide the basis for students developing a deeper understanding of the material. A deeper understanding is more than just memorizing a definition or a process, it is also being able to understand a problem fully. Many students think that because they can recite a definition or mimic a lesson when doing homework that they understand a topic. However, understanding includes the ability to explain to someone how a problem can be solved, an action that results in deeper understanding of the material. This is the deeper understanding that is a result of engagement.

As noted in Figure 1, Deeper Understanding leads to Confidence. This interrelation is evident during small group preparation for the presentations as well as during the actual in-class presentations. When students are presenting, deeper understanding of the material allows them to be more confident in themselves. Thus, they are not afraid to answer questions and offer additional explanations of the problem on which they are working. During the small group preparation for these presentations, it is evident that deeper understanding of the material leads to greater confidence. Students would begin the session without waiting for someone else to lead the group. They freely offer suggestions about how a problem could be solved. They know that they are correct and would very confidently demonstrate their understanding of the material.

Engagement fosters confidence. As the students engage in the conversations during the presentations, their confidence levels increase. They are not afraid to answer questions, and more importantly to ask questions. More learning occurs when questions are asked by students. In this project, questions asked by members of the class prompt answers by the presenters. These findings are consistent with the results obtained by Roscoe and Chi who suggest that asking and answering questions might support tutor learning and reflective knowledge-building. Roscoe and Chi (2007, p. 554) also note, "… questioning is most beneficial when students ask deeper questions that require integration of new and prior knowledge, reorganization of mental models, generation of inferences, and metacognitive self-monitoring."

Confidence leads to engagement. Students are engaged in the lessons that are presented by their peers because they are confident in themselves. When students feel that they are the only ones that do not know the answer to a question, they are less likely to ask during class discussion. Students who have confidence, are more likely to ask questions which leads to engagement in the lesson and the presentation. This confidence is also evident in the small groups as they were preparing to present. Everyone in the groups that I observed contributes to the planning of the lessons, and each of them took part in the presentations.

Confidence influences deeper understanding. Because students are more confident of the learning taking place in the small group preparation meetings, a deeper understanding of the material results. This is evident when students in their groups begin to discuss the way a problem should be solved. Because they were confident in what they are doing, they began to discuss with each other alternative solution methods. They formulate questions they anticipate their classmates might ask during the in-class presentation and develop elaborate responses to those potential questions. All of these actions lead to a deeper understanding of the material.

Deeper understanding facilitates engagement. This is evident in the following example. I was leading a review session with a few students, when all but one had left. He had a question regarding the solution to a logarithmic equation. After he (I will call him Sam) and I went through the problem and he was satisfied that he understood, another student came in (I will call her Jennifer) to the review and asked the same question. This was a great opportunity to test my hypothesis regarding teaching-to-learn. So I gave an excuse that I had to leave, and I asked Sam to show Jennifer how to do the problem. The next day I began class with a review sheet that all the students could work on in groups. Sam immediately started going around to the rest of the groups to show them how to do a similar problem on the worksheet (solving a logarithmic equation) like the one that he had taught to Jennifer. Not only was he more engaged in the class, more than he had been in any previous class, but so was Jennifer.

A second lesson learned involves the quantitative scores on the unit exams. When the quantitative results are considered, the outcome of the study is not what was expected. Originally, for unit exams, I predicted that students would perform better on mathematics content that they taught (taught topics) as compared to content that they did not teach (not-taught topics). In fact, as noted in the results, the scores for not-taught topics were higher than for taught topics. The mean on the pre-test for not-taught topics was 0.22 and the mean on topics taught was 0.25. But the mean on the post-test for not-taught topics was 0.70 and the mean for topics taught was 0.50. This outcome is perplexing until a closer examination of the unit exams is undertaken. On each unit exam for the not-taught topics, there are nine items from which the score is derived. By comparison, only one item is involved in the calculation of the taught topic score. Thus, the student either got the taught topic item correct or incorrect. Now, if the item difficulty is greater for the one item than for the pool of nine items for the not-taught topics, students would attain lower scores on the single taught topic item than across the nine not-taught topic items. In fact, it appears this may be the case. It seems that the best way to deal with this measurement dilemma would be to add a few more items in the taught area, so that item difficulty of one item is not suppressing the mean scores for the taught topic.

A third lesson learned is related to students' perceptions of teaching-to-learn. Students find teaching-to-learn to be effective for helping them learn. They also like participating in the project. The fact that they like it and find it to be effective bodes well for sustainability. I have talked to a number of different students after they have left my class at the end of the semester. Typically, they tell me how much they appreciate the connection that is made through the group interaction. As a result, they attempt to initiate and maintain contact with other students in the next class they are taking. In addition, they are more apt to form their own group in the new classes they are taking. The effectiveness is evident to them on how they perform in the class and on how they perform on the final exam. Our division conducts course level assessments and we track classes by instructor as well as semester. This class has a higher mean than in previous semesters. This could be the result of my student's deeper understanding of the material. Learning how to study in groups by questioning and explaining is something they thought is very effective for learning.

A fourth lesson learned is a focus on leadership. The teaching-to-learn process can only occur with good leadership. Leadership is critical in initiating the teaching-to-learn process. The leader must develop the blueprint and the processes by which teaching-to-learn is implemented. First, a student representative from each group meets with the course instructor, the leader of the teaching-to-learn process. Then that student takes the lesson learned from the one-on-one meeting with the instructor to the small group session. This material is shared with the small group, which manipulates, elaborates, and clarifies the material in preparation for the in-class presentation to all students. Subsequently, the members of the small group lead an in-class review of material in preparation for a test.

Notably, the leader sets up the process. The leader provides content and processes to the student with whom he meets. Thus, for example, the student takes content and processes, including the questioning and explaining skills, to the small group. The leader also provides guidance to the students about group dynamics by providing them with ground rules. Small group preparation is a critical part of the teaching-to-learn process. The leader serves an important role in developing skills for use in the small group sessions. Leadership will also be important in implementing teaching-to-learn in the future. Students carry out the teaching-to-learn process, but it will take a leader to initiate the process and to continue teaching-to-learn on an on-going basis.

Implications for Practice

Teaching-to-learn with modifications will be implemented in my classroom in subsequent semesters. The one-on-one tutoring with the group leaders will continue. The learning in those sessions was critical to the learning that occurred among the groups of students who presented mathematics material. The influence of the small group preparation sessions is in part due to the questioning and explaining that occurs during those sessions. These same questioning techniques need to be developed more fully for the in-class presentations as well. Engaging students in meaningful discussions during the in-class presentations builds confidence and deeper understanding and this process needs to continue.

Hargreaves and Fink (2004) say that sustainable leadership matters, spreads and lasts. It is a shared responsibility. So who shares in this responsibility? I believe all of us as teachers have a major role in this responsibility. The students we teach also share in it as well as administrators. If we only concentrate on the teacher and student, we might not be able to make a change that is sustainable due to this shared responsibility. Community College Survey of Student Engagement (CCSSE, n.d.) results show that 88% of the surveyed students sometimes or never worked with their instructor on activities other than coursework. I make it a point to have my students come to my office where we talk about anything but school work. It is part of my first day request of them. Once they have made that office visit, all other visits are easier, or at least more frequent.

As the leader of the class, I needed to reflect on my role as leader. Based on the literature, I offer the following observations. "Great leaders are not mythological composites of every dimension of leadership. Instead they have self-confidence, and without hubris they acknowledge their deficiencies and fill their subordinate ranks not with lackeys but with exceptional leaders who bring complementary strengths to the organization" (Reeves, 2006, p. 33). He notes that these qualities made the difference when guiding good leaders to become great. Having students teach to make a connection to a fellow student is just one way teaching-to-learn can help students learn. All students do not learn the same way, so hearing how to approach a problem from a different view point is just one way that teaching-to-learn can complement the instruction of the teacher. These new student leaders bring added strength to the classroom. Students' strengths include (a) knowledge, (b) enthusiasm, and (c) their status as a student. Recall that some of the students mentioned that it is easier to learn from their peers than from the instructor. It was leadership that initially instigated the project, but it is the benefits to the students that will make it sustainable. Those benefits are more engagement in learning and deeper understanding of the material and how those are related to the students' perceptions of achievement and better performance on tests. The depth of understanding manifested itself in better descriptions and explanations, as well as better questioning and answers to questions.

Implications for Research

What is the next research question that I should ask? One question might be: 'With a more sophisticated measurement instrument using more than one item on the taught topic, would I see that teaching-to-learn leads to better results in learning of the taught-topic?' Another might include: 'How does structuring the dialogue during the small group session preparation influence the depth of understanding and the in-class presentation of material?' Or, 'How would teaching dialogue skills in the small group preparation sessions assist students to attain deeper understanding of material, better teaching, and enhance learning?' Subsequently the anticipated deeper understanding generated in this session would influence the teaching and learning session of the whole class during the presentations.

As I reflect on the literature and the different theories from the courses I have taken and the reading I have done, I envision all kinds of ideas and connections that I have not considered previously. I know there are other research studies and theories that can inform my efforts on teaching-to-learn and my quest to facilitate student learning. All of this leads me to appreciate that there are good reasons to continue to examine the teaching-to-learn process.

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APPENDIX A

INTERVIEW PROTOCOL

Semester in School: ____________________________
Major or Field of Study: _________________________
Participation in Teaching-to-Learn: ____________________________

Interview Questions

How did your participation in learning by teaching help you better learn college algebra?

How was it different from learning in other classes?

If it wasn't different, why not?

Was my assistance helpful to your preparation?

If so, how? If not, why not?

Was my assistance helpful to your learning?

If so, how? If not, why not?

Was the tutoring you performed in your group beneficial to your learning?

If so, how? If not, why not?

What was the most beneficial part of learning by teaching?

Did you find that you were more engaged in class?

If so, how? If not, why not?

Did you find that you were more involved in class discussions?

If so, how? If not, why not?

Would you recommend learning by teaching as a technique for learning math to future students?

If yes, why? If no, why not?

What questions do you have?

APPENDIX B

SURVEY

On a scale of 1 – 4 where 1 = strongly agree (SA), 2 = agree (A), 3 = disagree (D), and 4 = strongly disagree (SD). Please rate your responses to these questions.

	SA 1	A 2	D 3	SD 4
1. Teaching the material in College Algebra helped me to better learn the material.				
2. I enjoyed teaching the material I learned.				
3. Being taught by my peers was a good way to learn the course material.				
4. I liked being taught by my peers.				
5. I enjoyed working in the peer tutoring groups.				
6. Working in groups helped me learn the material for this class.				
7. The teaching-to-learn process was an effective way to learn material in College Algebra.				
8. The teaching-to-learn process was enjoyable.				
9. I learned the material better because I had to think about it more deeply in order to teach it.				
10. I would like to take other classes that used the teaching-to-learn method.				

APPENDIX C

SAMPLE TEST QUESTIONS

1) Find **all** of the solutions to the polynomial equation: $2x^3 - x^2 + x - 2 = 0$.

2) Find the domain and range of the function $f(x) = \sqrt{1-2x}$

3) Find all asymptotes for $f(x) = \dfrac{6x^2 + x + 7}{2x^2 - 8}$. (Remember, asymptotes can be horizontal, vertical or oblique).

4) Find the inverse of the function $f(x) = x^3 + 8$.

5) Solve the following equation: $3^{5x+1} = 5$

6) Solve the following equation: $\log(x-5) + \log(7x-2) = 1$

7) For $f(x) = 2x - 5$ and $g(x) = \sqrt{x+8}$, find $(g \circ f)(x)$

APPENDIX D

RECRUITMENT LETTER

My name is Stephen Nicoloff and I am a professor at Paradise Valley Community College. I will be conducting a research study to examine the effectiveness of peer group teaching in a College Algebra class. I will be recruiting students in the current class, Fall 2010, to complete surveys, and to participate in interviews to describe how effective this program is in helping them succeed in the college algebra class.

Your participation in this study is voluntary. If you choose not to participate or to withdraw from the study at any time, there will be no penalty; it will not affect your work or your grade in this course. Additionally, your participation in this study will be completely confidential.

I do hope that you will agree to fill out the information requested in the surveys and participate in the interviews. The responses to the surveys and interviews will be used to help me to improve the College Algebra class. In addition, the results of this study may help to inform others about an effective method to improve learning.

If you have any questions concerning the research study, please contact the research team at: (Principal Investigator Dr. Ray Buss **602-543-6343**) or e-mail: ray.buss@asu.edu or co-investigator: stephen.nicoloff@pvmail.maricopa.edu.

If you have any questions about your rights as a subject/participant in this research, or if you feel you have been placed at risk, you may contact the Chair of the Human Subjects Institutional Review Board, through the ASU Office of Research Integrity and Assurance at (480) 965-6788.
Thank you for your consideration in this matter.

Sincerely,

Stephen J. Nicoloff, MA.

APPENDIX E

INFORMATION LETTER

Learning College Algebra by Creating Student Experts

Date______________________:

Dear ______________________:

I am a graduate student under the direction of Professor Ray Buss in the Mary Lou Fulton Teachers College at Arizona State University. I am conducting a research study to examine the effect of how becoming an expert on a particular topic in a College Algebra class and teaching it to others will increase student learning.

I am inviting your participation, which will involve interviews that will take approximately 40 minutes. The interviews will be audio taped. You have the right not to answer any question, and to stop participation at any time.

Your participation in this study is voluntary. You must be 18 years of age or older to participate. If you choose not to participate or to withdraw from the study at any time, there will be no penalty, and it will not affect your grade.

The possible benefits to your participation are a greater understanding of the mathematics material. There are no foreseeable risks or discomforts to your participation.

Your responses will be anonymous. Results from the interviews will only be shared in the aggregate form. The results of this study may be used in reports, presentations, or publications but your name will not be known.

I would like to audiotape this interview. You will not be recorded, unless you give permission. If you give permission to be taped, you have the right to ask for the recording to be stopped. The tapes will be kept in a locked drawer in Dr. Ray Buss' office at the ASU West campus. They will be destroyed at the end of the research project, or within one year, whichever comes first.

If you have any questions concerning the research study, please contact the research team at: (Principal Investigator Dr. Ray Buss **602-543-6343**) or e-mail: ray.buss@asu.edu or co-investigator: stephen.nicoloff@pvmail.maricopa.edu.

If you have any questions about your rights as a subject/participant in this research, or if you feel you have been placed at risk, you can contact the Chair of the Human Subjects Institutional Review Board, through the ASU Office of Research Integrity and Assurance, at (480) 965-6788.

APPENDIX F

COVER LETTER

Learning College Algebra by Creating Student Experts

Date ______________________:

Dear ______________________:

I am a graduate student under the direction of Professor Ray Buss in the Mary Lou Fulton Teachers College at Arizona State University. I am conducting a research study to examine the effect of how becoming an expert on a particular topic in a College Algebra class and teaching it to others will increase student learning.

I am inviting your participation, which will involve completion of a survey that will take no more than 10 minutes to fill out.

Your participation in this study is voluntary. You must be 18 years of age or older to participate. You can skip questions if you wish. If you choose not to participate or to withdraw from the study at any time, there will be no penalty and it will not affect your grade.

The possible benefits to your participation are a greater understanding of the mathematics material. There are no foreseeable risks or discomforts to your participation.

Your responses will be anonymous. Results from the interviews will only be shared in the aggregate form. The results of this study may be used in reports, presentations, or publications but your name will not be known.

If you have any questions concerning the research study, please contact the research team at: (Principal Investigator Dr. Ray Buss **602-543-6343**) e-mail: ray.buss@asu.edu or co-investigator: stephen.nicoloff@pvmail.maricopa.edu.

If you have any questions about your rights as a subject/participant in this research, or if you feel you have been placed at risk, you can contact the Chair of the Human Subjects Institutional Review Board, through the ASU Office of Research Integrity and Assurance, at (480) 965-6788.

Return of the questionnaire will be considered your consent to participate.

Sincerely,

Stephen J. Nicoloff, MA.

APPENDIX G

INSTITUTIONAL REVIEW BOARD APPROVAL

ASU Knowledge Enterprise Development

Office of Research Integrity and Assurance

To:	Ray Buss FAB
From:	Mark Roosa, Chair Soc Beh IRB
Date:	08/13/2010
Committee Action:	**Exemption Granted**
IRB Action Date:	08/13/2010
IRB Protocol #:	1008005391
Study Title:	Learning College Algebra by Creating Student Experts

The above-referenced protocol is considered exempt after review by the Institutional Review Board pursuant to Federal regulations, 45 CFR Part 46.101(b)(1) (2) .

This part of the federal regulations requires that the information be recorded by investigators in such a manner that subjects cannot be identified, directly or through identifiers linked to the subjects. It is necessary that the information obtained not be such that if disclosed outside the research, it could reasonably place the subjects at risk of criminal or civil liability, or be damaging to the subjects' financial standing, employability, or reputation.

You should retain a copy of this letter for your records.