

MAKING CONNECTIONS: TEACHING AND USING CONCEPT MAPS
IN A FOURTH GRADE MATHEMATICS CLASS

by

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ABSTRACT

Mathematics requires a vast foundational knowledge in order for students to be successful as they advance through the years. Often times, it is common for teachers to teach these foundational skills over and over to ensure mastery prior to students' advancement. Given this fact, my capstone project was dedicated to increasing students' conceptual knowledge of mathematics through the use of concept mapping in the classroom. This project spanned a total of four math investigations, with two of the investigations taught using concept mapping in addition to the regular curriculum. Data collected to identify the effects of mapping on conceptual understanding, long-term memory, motivation and teacher professionalism included; preunit, postunit, and delayed assessments, interviews, journal entries, surveys, and the concept maps themselves. The results of the study were mixed. Concept mapping had positive impact on conceptual understanding in general. Data also indicate that mapping within the classroom increased student motivation. Finally, the results indicate that concept mapping had a positive impact on my goals as a teacher and my professionalism within the community.

INTRODUCTION AND BACKGROUND

Over the course of the past few years, I routinely observed the struggles my students faced in learning new mathematics concepts. I began to gather both formal and informal data, including tests as well as holding question and answer sessions within the class. I realized that my students' background and knowledge of math concepts did not transfer from year to year or across new content. Four years ago, my school adopted a constructivist mathematics curriculum in which the students are supposed to continually build on prior knowledge and previous years' lessons. Upon reflection, I noticed that only the high-achieving students remembered the specific details of lessons taught in the previous years. I found myself faced with the need to teach concepts again more often than not. As a result, I decided to complement the math curriculum by implementing concept maps into the classroom. A concept map is a graphical way to display knowledge and can be used to teach, as well as assess the level of understanding a student has on a particular subject.

After much research and reflection, I decided to try using concept maps during mathematics. I wanted to implement a visual representation of new concepts, as well as adhere to the human constructivist approach of learning. Literature suggested that the use of concept maps would allow me to assess my students' knowledge of new concepts, help students construct new meaning in math, and add to already established knowledge. The focus question of my project was: what are the effects of concept mapping on the students' conceptual knowledge of mathematics? To support this project, I also posed the following subquestions: what are the effects of concept mapping on the students' long-term memory of math concepts; and what are the effects of concept mapping on the

students' attitudes and motivation towards mathematics. In addition to the questions focusing on student achievement, I also wanted to know: what are the effects of using concept mapping on my goals set forth in the Teaching Goals Inventory and the building of professionalism within my teaching community.

I teach fourth grade at Rooney Ranch Elementary School, which is located in Lakewood, Colorado. Lakewood is located just outside of Denver and Rooney Ranch serves middle class families that commute to the city on a daily basis. The school serves 416 students with 83.4% of students identified as white and 16.6% identified as a minority. Although the student body is relatively homogenous, the classroom dynamics and learning styles are varied. The class of focus contained children between 8 and 10 years of age, and totaled 23 students. This cohort contained special education and ESL students, as well as general education students that varied from high to low- achieving, as based upon previous years' standardized test scores.

My project posed a great benefit to my students and school because it adhered to the need to reach all students by implementing new teaching practices. It also addressed the national concern that many educators, parents, and some politicians have in regards to the rapidly declining mathematics scores throughout the country. Teachers and researchers alike have stated the importance of math education for today's youth. In order to thrive in tomorrow's society and workforce, students must be adept at mathematics, science, and technology. I felt that the use of concept maps, in conjunction with a constructivist teaching policy would benefit my students and increase their conceptual knowledge of mathematics.

The members of my MSSE Capstone Committee provided important feedback both in their ideas and insight throughout the research and writing process. Magali Saez-Cox, Pamala Wimberly, Albert Lago, and Terrill Paterson served as editors, critics and supporters of my project, and their knowledge and feedback was invaluable. Jewel Reuter, Ph.D., was my Montana State University instructor and advisor. Along the way, Jewel provided guidance, direction, and support for every aspect of the project. David Lageson, Ph.D., professor of Structural Geology at Montana State University, served as reader on my committee and provided constructive criticism and feedback in the final stages of the project.

CONCEPTUAL FRAMEWORK

The creation and use of concept mapping dates back almost 40 years and can be attributed to the work of Ausubel, Novak, and Gowin in the early 1970's (Rice, Ryan, & Sampson, 1998). This conceptual framework addresses the use of concept mapping in terms of aiding in the construction of conceptual knowledge. It then discusses the effects that concept maps may have on students' long-term memory and motivation towards the subject in question. The latter part of this conceptual framework focuses on ways in which concept mapping benefits the teacher in terms of professionalism and goal accomplishment. However, before these subjects are addressed, I will first focus on what the constructivist theory of learning is, the definition of a concept map and how concept mapping fits into the theory of constructivism.

Over the past several decades, education has been based upon the ideas of rote learning. The basis of rote learning is one of memorization and regurgitation of facts in

the different subjects. Due to the premise of rote learning, the facts are quickly lost by a student because the information learned is not applied. Today's educational system is witnessing a shift to the theory of learning termed constructivism. The foundation of the constructivist theory is based on the idea that learners construct knowledge for themselves and, thus, each individual develops and constructs their own meaning of a concept as he or she learns (Jonassen, 1991). The basic nature of constructivism leads to the idea that teachers need to take on a more facilitative role in constructing a student's knowledge. The student is then responsible and required to become an active participant in the learning process.

The idea of concept mapping is built on the foundations of the constructivist theory of learning and is coupled with the cognitive psychologists' belief that human knowledge is stored as a network of ideas or webs (Williams, 1998). According to Novak and Canas (2006) for learning to be meaningful, three conditions must be met. The first of these is that the material to be learned must fit into the learner's prior knowledge. The second idea is that material to be learned must be presented in a conceptually clear way that is relatable to the learner's knowledge. The third and final idea is that the learner must choose to learn in a meaningful way. The use of concept maps is a way to *marry* these ideas and create a visual representation depicting the structure of knowledge given a particular subject.

The use of concept mapping is a technique that involves students creating a hierarchical structure that represents a certain concept with the more inclusive ideas at the bottom and the more generalized topics at the top of the map. Concept maps are designed to depict the relationships one forms by developing a series of linking lines,

called propositions, to indicate how one concept is related to another (Novak & Canas, 2006). When used appropriately, these maps become a valuable tool to the student because they require active participation in one's learning.

In order to address my primary focus question, I researched the use of concept maps in general terms and the influence they have on learning. Although concept maps were not originally designed for use in the mathematics classroom, they potentially held great benefits for students and teachers of math in the area of assessment and construction of new knowledge. In studies conducted on secondary students by Gerstner and Bogner (2009), Karakuyu (2010), and Gerstner and Bogner (2010) it was determined that students who constructed concept maps performed better on assessments than those that did not construct a map. In addition, as stated by Novak and Gowin (1984), for teachers, the use of maps helps to determine misconceptions and determine meaning of prior knowledge. Thus, one can ascertain that the maps would also allow for the students to visualize and construct their knowledge as well as realize any misconceptions they may have regarding a topic. Huerta, Galan, and Granell (2006), state that, "a mathematics concept map is an important tool in order to obtain additional knowledge about what a person know[s] about a mathematics topic," (p. 7). Huerta et al. (2006) go on to point out that concept mapping is a difficult process that requires time and reflection and several revisions throughout the learning process. In order for me to assess whether the use of concept maps had an effect on my students' conceptual knowledge of mathematics, I needed to assess the students' knowledge at the onset of a unit, track the growing information throughout the unit, and finalize the research by conducting an assessment at the culmination of the unit. In a study conducted on high schools students,

Kern and Crippen (2008) point out that when maps are compared over a period of time and students are given chances for revision, the changes evident on the maps may provide teachers with insight into the conceptual growth of each student. I suspected that choosing to follow a construct, reflect, and revise structure of concept mapping in the math classroom would provide me very important insight and assess the conceptual knowledge of my students, including their prior knowledge.

My primary subquestion referenced the student's long-term memory. A person's memory is composed of a short-term and long-term memory. The short-term memory can hold approximately seven plus or minus two bits of information at any given time. The long-term memory is considered to be a more permanent fixture in a person's brain. However, in order to move information from short-term to long-term memory one must act on the information. Once the information is moved to the long-term memory, it can be stored in both a linguistic or visual form (Lefrancois, 1995). As stated previously, an important aspect of concept maps is the visual representation of knowledge. According to Michael Zeilik (1999), a professor at the University of New Mexico, concept maps can depict the structural knowledge people have stored in long-term memory. In support, a study conducted by Gerstner and Bogner (2010) on students in a biology course, suggested that when students were asked to take a delayed assessment, those students that completed a concept map of the biological science concepts showed better retention of the information. Results also indicated that the quality of the map played a role in the quality of the long-term retention of those concepts. Further, research conducted upon a class of university psychology students (Jacobs-Lawson & Hershey, 2002) found that students constructing and using concept maps throughout the semester had greater

retention of the material presented than those that did not construct maps. These studies led me to deduce that creating concept maps might have a positive effect on my students' long-term memory of math concepts.

In addition to the research I conducted on concept maps and the effect they have on conceptual knowledge and on long-term memory, I wanted to learn more about how concept maps effect a student's motivation towards the subject in question. In an article published by *A Journal for Physical and Sport Educators* (2008), one teacher stated that she noticed an increase in the attentiveness in her students when maps were presented. In addition to an increase in attention, the students also responded better to the maps rather than informational handouts. A study conducted by Chiou (2008) found that students who used concepts maps reported "...that concept mapping stimulated them to learn and think independently," (p. 381). Those same students went on to say that, "...concept mapping helped them to reduce the barriers to learning and enhance their interests in learning..." (p.381). These findings indicate that the use of concept maps within the classroom may increase the students' motivation to learn within the given subject area.

Up to this point, the use of concept maps in the classroom and the effects the maps have on the student population have been considered. But, how do concept maps affect the teacher who chooses to implement them within the classroom? My third subquestion addressed the benefits that concept maps would have on a teacher's professional stance. My main goal, as set forth by the Teaching Goals Inventory (Angelo & Cross, 1993), points to my belief in the importance of promoting higher order thinking skills. Further, it is important to me to increase my professionalism within the teaching community. Afamasaga-Fuata'I (2008) suggests that by creating concept maps prior to

conducting a lesson a teacher can gain a greater knowledge of the most important concepts as well as initiate dialogs and discussions based on the most important concepts of the lesson. With a greater knowledge of what the most important concepts are, a teacher will be able to guide classroom discussions and push students to think at a higher level and connect their understanding. Conlon (2009) investigated the effects of mapping on teachers and their approach to their everyday work. Results maintained that teachers were encouraged by the amount of productivity within the classroom as well as the interest garnered by colleagues outside of the classroom. This research supports my belief, in that, the use of concept mapping will help me to obtain my goals as set forth by the TGI as well as increase my professionalism within the community.

As the educational system continues the shift towards a constructivist teaching model, the role of concept mapping in the classroom needs to continue to grow. The National Research Council (2010) reminds educators that learning is an active process occurring within and influenced by the learner. The use of concepts maps adheres to these processes and allows the learner to construct meaning of new concepts. The review of the literature indicates that the use of concept maps in mathematics would not only lead to the development of conceptual knowledge and understanding of math concepts, but would also have a positive effect on students' long-term memory and motivation towards math as well as aid in the ongoing professionalism of teachers.

METHODOLOGY

Project Treatment

In order to best assess the outcomes and effects of concept mapping within my classroom, data were collected from both a nontreatment and treatment unit for comparison. The nontreatment unit was taught using the lesson guidelines formatted in *Investigations in Number, Data, and Space* (Russell & Economopoulos, 2008). The treatment unit included lessons from the same resource. However, in addition to the standard lessons, concept mapping was used to complement and extend the math curriculum. It is important to note that the research methodology for this project received an exemption by Montana State University's Institutional Review Board and compliance for working with human subjects was maintained.

To fully understand the details, reasons for conducting my project, and the extent of the effects of concept mapping, it is necessary to include a description of both the nontreatment and treatment units. The mathematics units used by my district are part of *Investigations in Mathematics* (Russell & Economopoulos, 2008). The curriculum is based on a constructivist approach to learning. The lessons are designed to build on the students' knowledge gained from previous classes and concepts. Many lessons require students to work in pairs or small groups, use manipulatives, explain thinking, and apply knowledge to real-world situations.

As shown in the project timeline found in Appendix A, the project spanned an entire mathematics unit that occurred between mid December and late February. The purpose of the unit was to have students become familiar with, and use, landmark numbers in order to help them solve addition and subtraction problems accurately and

efficiently, and then use the information to solve real-world math problems. The unit was broken down into smaller sections called “investigations”. The first two investigations focused on the place value of numbers up to 1,000 and addition strategies. The use of concept maps was not implemented in these two investigations. The latter investigations focused on the place value of numbers up to 10,000 as well as addition and subtraction of large numbers. As a compliment to the math curriculum, concept maps were used in conjunction with the last two investigations in order to determine their effectiveness as a teaching tool.

During the nontreatment investigations, “How Much is 1,000,” and “Adding It Up,” the lessons were carried out in the standard tradition set forth by the district curriculum. A sample of a lesson taught during the nontreatment unit can be found in Appendix B. The unit began with students working with numbers up to 1,000. It then built on this concept to have students determine the place value of different digits and then use the information to determine the best strategies for addition. Once students achieved fluency within the concepts, they were asked to explain their mathematical thinking and solve math word problems that required them to use their knowledge to determine total distance. The lessons in the unit used math manipulatives that included: student made booklets, connection cubes, chart paper, and game cards. As stated previously, students often worked in cooperative groups to help them discover the math concepts. In order to get a baseline for the effects of concept mapping on the students’ ability to understand math concepts, multiple sources of data were collected for the nontreatment unit.

Prior to the onset of the nontreatment investigations, students were given a preassessment to determine current knowledge of the given math concepts. The assessment can be seen in Appendix C. At this time, concept interviews were also conducted (questions can be found in Appendix D). In addition to the regular math lessons, all students were asked to complete a journal entry in response to a prompt midway through the unit (Appendix E). Upon culmination of the nontreatment units, students were asked to complete a motivation survey (Appendix F), a postassessment, postunit concept interviews, and a second journal entry, in order to assess the knowledge gained. In addition to this data, six students were asked to partake in interviews focused on their motivation in mathematics. These interview questions can be found in Appendix G. Classwork and homework and field notes were also used to determine the learning that took place during the unit.

The two treatment investigations primarily dealt with larger numbers and subtraction, while still visiting addition strategies. The goal of the treatment units, “Working with Numbers to 10,000,” and “Subtraction,” was to have students extend their knowledge of the number system and describe, analyze, and compare strategies for adding and subtracting numbers. As with the nontreatment units, students participated in discussions and used their previous knowledge as a stepping stone for the upcoming lessons. The implementation of concept maps was the main difference between investigations 1 and 2, the nontreatment units, and investigations 3 and 4, the treatment units. In addition to using math manipulatives and working in small groups, students were introduced to the idea of concept maps in order to study the effects of mapping on

their ability to understand new math concepts, the effect of maps on long-term memory, and their effect on student motivation.

To directly assess the effects of mapping in the various contexts of the project, data were collected before the actual start of the treatment investigations. A treatment unit preassessment, found in Appendix H, was administered to the entire class and pretreatment concept interviews also took place at this time (questions can be found in Appendix I). After these data points were gathered, the use of mapping in the classroom began. Concept maps were implemented from the onset of the teaching of investigations 3 and 4 and were continuously revisited until the units' culmination.

Prior to requiring the students to construct a map based on mathematics, the students were given the task to create a map based on something of high interest to them, such as football or music. The idea of concept maps was explained in detail, with emphasis placed on the use of linking terms, and models of different maps were shown to the students in order to ensure understanding of the overall idea and form. Once the idea of concept mapping was understood by the students, I required the students to construct a concept map based on the number system. Each student was given a paper with a word bank containing approximately 10 terms that related to the number system, this document can be found in Appendix J. The most general term was identified for them before they began their maps, and students were instructed to use the terms from list one only at this time. This concept map was used as a preassessment in and of itself to determine where students had misconceptions, what concepts were not understood or known at all, and where students were strongest in their knowledge of the number system. I assessed the maps using a standard rubric designed to assess concept maps (Appendix K). I then gave

the maps back to the students, informing them that we would be working with and revising them throughout the investigation as well as adding to the maps using words from list two.

As the class worked through treatment unit 1, focusing on large numbers up to 10,000, students were required to revise their map based on the knowledge they gained from class or from the feedback provided by me. It was suggested to the students that their maps were always with them so that revisions could take place at any time. Students were encouraged to work both as individuals and as groups to revise their maps. The idea of allowing students to complete maps independently and then work in collaborative groups stemmed from the belief that students would create their own meanings first and then discuss the meanings in a small group. Map revision was designed this way in order to enhance the learning experience and add to the knowledge of students. At times during the investigation, I would collect the maps and use them to assess the knowledge students had of the concepts being learned. Once the maps were assessed, I would provide feedback on the maps and return a copy of the maps to the students. When time permitted, whole class discussions would take place and students were encouraged to revise maps, as needed, at this time. In addition to the discussions held about the maps themselves, I frequently referred to the maps during the lessons in order to strengthen the connection between the maps and what was being taught.

At the onset of investigation 4, the second treatment unit on addition and subtraction of large numbers, students were given a new bank of words to construct a second concept map based on addition and subtraction. An example of the word bank can be found in Appendix L. As with the first treatment unit, students were asked to construct

an initial map using the words from list one. As the investigation progressed maps were revised and added to using words from list two. Students were expected to have their maps with them throughout class; however, 15 minutes were dedicated to working on the maps during each math block, as was also the case with the first treatment unit. These 15 minutes were used not only to revise but also discuss maps. Field notes were collected at this time as well in order to assess student understanding of the concepts being taught in the unit. Appendices M, N, and O, respectively, depict typical lessons taught during the treatment investigations as well as prompts used to guide teacher reflection on the lessons.

At the culmination of the treatment units, students were once again given an assessment in order to determine the knowledge gained during the investigations. Surveys, journal writes, and interviews were also conducted upon the completion of the treatment unit. Final concept maps for both the treatment units were collected so that further analysis could take place.

Approximately two weeks after each treatment unit, students were asked to take a delayed assessment and complete the construction of a concept map based on the previous learning. They were also asked to write a response to a journal prompt focusing on conceptual knowledge. In addition to these data, delayed concept interviews were also administered. Examples can be found in Appendices P and Q respectively.

Data Collection Instruments

The capstone project was conducted on a fourth grade class at Rooney Ranch Elementary School in Lakewood, Colorado. Lakewood is a suburb of Denver with a population of approximately 140,000 people. The median resident age is 37 years old, and the median income for the area is \$54,000. Most residents commute to Denver on a daily basis and live in single family homes. Rooney Ranch Elementary is nestled in an older neighborhood in Lakewood and has a student population of 416. Of these 416 students, 83.4% are identified as white, 16.6% are identified as a minority, and 13.7% of the population of students receives a free or reduced lunch.

Data were collected from a class of 22 students, consisting of 13 girls and 9 boys. The class spanned all levels of ability including both low and high-achieving students as well as students considered proficient, as based upon standardized state tests. Two students in the class were identified as Special Education and an additional four students were English Language Learners. The cohort of students came from primarily middle-class families and the majority of students were white. The classroom environment is one of high activity and cooperation, with most students working well with others.

In order to obtain valid results, several sources of data were collected. Each data assessment technique addressed one or more of the questions pertaining to the project itself. The data were compared in order to assess trends, determine validity, and exclude outlying results. The data triangulation matrix is shown in Table 1. For each of the project questions, three sources of data were used. Most of the sources include observational data as well as inquiry data.

Table 1
Data Triangulation Matrix

Focus Questions	Data Source 1	Data Source 2	Data Source 3
<i>Primary Question:</i> 1. What are the effects of concept mapping on the students' conceptual knowledge of mathematics?	Pre and postunit assessments	Pre and postunit student concept interviews	Student journal writes
<i>Secondary Questions:</i> 2. What are the effects of concept mapping on the students' long-term memory of math concepts?	Delayed assessments	Student reflective journals	Construction of delayed concept map and comparison to postunit map
3. What are the effects of concept mapping on the students' attitude and motivation towards mathematics?	Instructor observations and journaling	Pre and posttreatment attitude surveys	Pre and posttreatment student interviews
4. What are the effects of using concept mapping on my goals set forth in the TGI and the building of my professionalism?	Instructor journaling	Assessment of student work	Comparison and revisit of Teaching Goals Inventory, and collaboration and reflection with Instructional Coach

The use of multiple sources of data allowed for different perspectives that answered the same base questions. One will notice that the data collected for any given question used

observations of student work, collaboration with students and colleagues, and reflection from both teacher and student.

In order to collect meaningful data that would represent the class as a whole, I chose to conduct interviews with a sample of students that was proportional to the overall class. Interviews were conducted with one high-achieving student, three proficient, and two low-achieving students. The students chosen to participate in the interviews throughout the project were picked not only for their achievement level, but also attendance, believed openness (as it pertained to answering questions) and gender. Other forms of data collection including surveys, assessments, and reflective journals were completed by the entire class. In addition to the formal data collection techniques, the concept maps were also used as a way to determine the effectiveness of the treatment.

In order to answer the focus question concerning the effects of concept mapping on students' conceptual knowledge of mathematics, I chose to administer pre and postassessments, conduct student interviews, and had students write in response to journal prompts based on the concepts being studied. The assessments were designed in such a way that all questions required free-response answers. The students were instructed to show all of their work as well as explain their thinking on all questions. The interviews were conducted at various times throughout the study to determine if the concept maps were having a positive influence in the classroom. Interviews were used as a way to gain more in-depth answers (see Appendices D and I) in regards to the conceptual knowledge of students. Interviews were conducted before or after school and often during recess. For the reflective journals, the students were given prompts in

reference to a new concept or a lesson from the investigation as can be found in Appendix E. The students were then allowed to write for a five to 10 minute time period.

To address the question of the effects of concept mapping on the students' long-term memory, I chose to administer delayed assessments, use reflective journals and compare different versions of the concept maps. The delayed assessments were given at least 14 days after the completion of the treatment unit in order to determine if the concept had made it into the long-term memory (reference Appendix P). The assessments were virtually the same with only minor differences in numbers or sequence. The concept maps were used as a data source as well and the student maps were compared with postunit concept maps generated by the students at the culmination of the treatment unit. Once again, reflective journals were used and students were prompted to write for a 5 -10 minute period (see Appendix Q).

In order to answer the question about student motivation in the mathematics classroom, I chose to administer attitude surveys and conduct interviews. In addition to the formal data collected, I also observed students in the classroom and kept field-notes of perceived motivation and attitudes towards lessons and mathematics in general. Prompts used to guide my reflective process can be found in Appendix O. The class as a whole was administered an attitude survey at the onset and culmination of the unit, while the six previously chosen students partook in the interview sessions.

The final question posed for the project was one based on my goals and professionalism. In order to collect information pertaining to this question, I wrote in a reflective journal, assessed student work, and collaborated with the instructional coach on campus. My reflections included how I perceived the treatment and the effect it was

having in the classroom as well as any noteworthy events that occurred during the project. In my collaboration with the instructional coach, both the effectiveness of the treatment and ways to improve on the research were covered. Interview questions addressing the areas specified can be found in Appendix R.

In order to analyze all of the data collected during the project, I first collected and compiled all data and then began a systematic analysis. To analyze the data collected pertaining to my focus question on students' conceptual knowledge, several different approaches were used. For the journal writes and interview questions pertaining to the students' understanding of concepts, a scale score of 0 to 2 was assigned to each. Students' answers were then analyzed to determine how many points were obtained out of two. I also looked for any apparent themes in order to gain qualitative data. Assessments, both pre and post, and for both the nontreatment and treatment units, were analyzed by marking either correct or incorrect for each response. The received scores were then used to determine an overall percentage obtained on the task. Scores were then compared to determine students' knowledge.

To determine the effects of concept mapping on the long-term memory, data collection techniques similar to that of the conceptual knowledge of students were used. Students completed delayed concept maps and delayed assessments. The maps were compared to the maps created at the culmination of the treatment unit and were scored using the rubric found in Appendix K. The delayed assessments were scored using a simple correct or incorrect response and then by determining the percentage of points obtained. Reflective journals were scored using a scaled score where students could

obtain 0 to 2 points depending on their response to the prompt. The journal writes were also analyzed to determine if there were any underlying themes.

To analyze the results pertaining to my subquestion that focused on motivation, a variety of techniques were used. To gain knowledge of the changes in attitude over time, I conducted two separate surveys. The first of these was administered at the end of the nontreatment unit and the other was at the culmination of the treatment unit. The surveys (see Appendix F) were focused on the students' general feelings towards mathematics and were based on a simple Likert scale of 1 to 5, with 1 equating to strongly disagreeing with the statement and 5 being in total agreement with the statement. The surveys were conducted anonymously and data was tallied and graphed. The graphs were then overlaid to determine the shift in attitude towards mathematics. The same approach was taken with the motivation interviews conducted during the study. The chosen students were interviewed both at the beginning and end of the unit, and answers were compared in order to determine a change in attitude towards mathematics. In addition to the data collected from student surveys and interviews, field notes were kept and analyzed with the focus on motivation and attitude trends (reference Appendix O).

The qualitative data, related to the final subquestion focusing on the teacher's goals and professionalism, were addressed by analyzing the field notes taken throughout the treatment unit and by the reflective conversation held with the instructional coach. Any trends found in the teaching notes or trends emerging during the reflective conversation were noted and discussed. Frequency of comments or specific events were also recorded and analyzed. Quantitative data were addressed by the assessment of student work throughout the project.

DATA AND ANALYSIS

Data from the nontreatment and treatment units were compared to determine the effects of concept mapping on students' understanding of mathematics concepts as well as my subquestions pertaining to students' long-term memory, motivation, and my professional goals. For each of the units, data were methodically collected and triangulated in order to address each question.

To fully ascertain the effects of mapping on conceptual understanding, pre and postunit assessments, pre and postunit concept interviews, and student journal writes were completed throughout both the nontreatment and treatment units. In addition to these data collection instruments, the concept maps were also analyzed during the treatment units to determine the amount of understanding each student gained over the course of the math units. The use of pre and postunit assessments (see Appendices C and H) allowed me to compare the percent change between the nontreatment and treatment units. Overall class data from these assessments can be found in Table 2. As one can see the results for the treatment units were mixed as reflected in the percent change. Data show positive results in the percent change for both the nontreatment unit and treatment unit 2, with treatment unit 2 having the greatest increase. Whereas, the percent change for treatment unit 1 was negative.

Table 2
Average Scores of Preassessments and Postassessments, (N=22)

Description of Data	Nontreatment (%)	Treatment 1 (%)	Treatment 2 (%)
Preassessment Average	68	93	38
Postassessment Average	94	88	70
Percent Change	38	-6	84

Further analysis of the data by achievement group yielded mixed results as well, as found in Table 3. As shown in both sets of data, both the nontreatment and treatment 2 units yielded positive results in student learning as reflected by the averages, particularly for treatment unit 2 where the percent change was the greatest and over 100% for both the high and low-achieving groups. In contrast, treatment unit 1 shows a decline in student test scores. However, one will notice the high preassessment scores for treatment unit 1 in all achievement groups. These scores possibly reflect the bridge of concepts between the nontreatment and first treatment unit. The percent change in treatment unit 2, compared with the change in the nontreatment unit, possibly indicates a larger improvement in learning in the treatment unit.

Table 3

Average Scores by Achievement Group, High-Achieving (n=2), Mid-Achieving (n=14), and Low-Achieving (n=6) for Preassessments and Postassessment (N=22)

Group	Description of Data	Nontreatment (%)	Treatment 1 (%)	Treatment 2 (%)
High	Preassessment	76	100	33
	Postassessment	98	91	67
	Percent Change	29	-9	103
Mid	Preassessment	72	97	45
	Postassessment	95	92	71
	Percent Change	32	-5	58
Low	Preassessment	55	83	22
	Postassessment	89	79	67
	Percent Change	62	-5	205

Results of the pre and postunit concept interviews (Appendices D and I), conducted with students that represented the class proportionally as determined by standardized test scores, provided further insight on the effects of concept mapping in math. Table 4 depicts the average number of points obtained on questions pertaining to

each of the units. For each interview question, students were assigned a score of 0, 1, or 2 depending on their use of vocabulary, correctness, and overall understanding of the question. Unlike the assessment scores, all results reflect an increase in student understanding. It is critical to recognize that the first treatment unit builds on the conceptual knowledge of the unit before, therefore explaining the higher preunit interview scores. It is also important to note that although the percent change for the nontreatment is higher than that of either treatment unit, the postunit interview averages for both treatment units were almost double that of the nontreatment unit.

Table 4
Average Number of Points Obtained on Concept Questions by Interviewed Students, (N=6)

Description of Data	Nontreatment (%)	Treatment 1 (%)	Treatment 2 (%)
Preunit Interview	14	30	37
Postunit Interview	31	59	62
Percent Change	122	97	68

When analyzed qualitatively, trends in the students' answers became evident. The responses given during the nontreatment postunit interviews did not contain answers that would prompt me to believe that students had made connections between the different concepts. For example, in response to the questions pertaining to the Base-10 Number System and how patterns in the number system help to compare whole numbers, one high-achieving student responded, "...the base-10 system is basically when you multiply by 10 and you get the next number up with an extra zero." In response to the second question about patterns, the same student responded, "...are there patterns? I mean like, I use landmark numbers or even numbers and I guess that helps me compare." Another mid-achieving student answered, "...the base-10 number system is kind of like when you have 1,000 and you multiply by 10 you get 10,000 and then multiply that by 10 and you

get 100,000....” and then answered, “...I have no clue about patterns in numbers.” These responses indicate that students were having trouble connecting the concept of the base-10 system to the concept of how the number system works and how to use that system.

In contrast, themes from both posttreatment interviews pointed to the students’ understanding of key vocabulary and the connections between concepts. Often, these connections were in direct correlation with the links formed on the concept maps. The goal of the first treatment unit was to understand the relationship between large numbers and how patterns are repeated in the number system. When asked about the relationship between 10,000, one thousand 10s, one hundred 100s, and ten 1,000s, a mid-achieving student responded, “...that’s easy, they all equal the same thing. See look, if I take one zero from one of the numbers but I give it to the other, it doesn’t change the answers.” That same student stated that, “...the patterns in the number system never change. They go [ones], tens, hundreds all the way up. Like the question you just asked, one thousand 10s is 10,000, but if I had ten thousand 10s it would be 100,000, there’s a pattern.” Similar answers were shared during other interviews, pointing to a deeper understanding by use of vocabulary and connections, of the concepts in the treatment unit with concept mapping.

The second treatment unit focused on the concepts of the number system and place value and how understanding the system helps one to solve mathematical equations. All of the questions for treatment unit 2 were based around strategies that could be used to help solve multi-digit addition and subtraction problems. A theme that became most evident in the interviews, in regards to question 3, indicated a deeper understanding and knowledge of the relationships between the concepts based on the

number system. In response to a question about how to use the break-apart method to solve problems, a low-achieving student remarked that, "...breaking numbers apart helps me solve problems because I break them up by place value, like hundreds and thousands, that gets me to landmark numbers. Then I use the landmarks because it's so easy. So, I add those step-by-step in the places, and then add all of those together in the end. It's easy." This student used the concept of place value and landmark numbers to explain exactly how to solve a multi-digit addition problem. This level of understanding, use of vocabulary, and deeper content knowledge was demonstrated throughout the achievement levels and for both of the treatment units, which was in contrast to the nontreatment unit.

To collect additional data in regards to the effects of concept mapping on conceptual understanding, students were asked to complete short written responses to questions focusing on their learning throughout the math investigations (found in Appendix E). Table 5 depicts the average percentage of points earned on the various journal writes, by the overall class as well as by the different achievement groups, throughout both the nontreatment and treatment units. One will note that the overall averages obtained by the students during the treatment units were higher than those of the nontreatment unit.

Table 5
Average Percentage of Points Obtained on Journal Writes, (N=22)

Group	Nontreatment Journal 1 (%)	Nontreatment Journal 2 (%)	Treatment Journal 1 (%)	Treatment Journal 2 (%)
High	75	75	100	100
Mid	75	50	88	89
Low	33	75	50	75
Overall	61	67	79	88

Trend data in the journal writes were also analyzed and considered. For both of the journal prompts administered during the nontreatment phase, students responded with very vague answers. The class could answer the questions but lacked the vocabulary and knowledge to explain the concepts at a deeper level. In addition few students were able to correctly provide examples to support their thinking. As an example, when questioned about the most important number in our number system a mid-achieving student wrote, "...well I think 10, because the poster on your wall has a bunch of 10s on it underneath all of the bigger numbers." Another low-achieving student answered, "...it's the number 10 because 10 is a very good landmark number." Similarly vague responses were given for the second journal write as well. When asked how landmark numbers can help you solve problems a high-achieving student wrote, "...they make it easy to solve problems. I know them and they are not hard to get to..." indicating that the student uses the numbers but is not sure how to explain their thinking or why landmark numbers work.

In contrast to the journal responses given for the nontreatment unit, the write-ups for the treatment units demonstrated a deeper understanding and an ability to express thinking. A clear example of this was one low-achieving student's answer to the posed question pertaining to breaking apart numbers. In response the student wrote, "Breaking apart large numbers helps me solve problems because I break apart by place value. For example, if the equation is $674 + 145 = ?$ I would do $600 + 100 = 700$ and $70 + 40 = 110$...once I break them down I am adding landmark numbers and they are easy to use and that's why breaking up large numbers by place value makes math so much easier." A mid-achieving student responded to the same question stating, "I break apart large numbers by place value, for example if I had $1,633 + 2,467$, I would break up the

numbers by thousands, then hundreds, then tens, and finally ones. Now all but the ones place has landmark numbers that are super easy to add...” Both the low and mid-achieving students used key vocabulary terms and learning from previous lessons to explain their answers, as well as providing solid examples to support their thoughts during the treatment units.

Pre and postunit concept maps were also analyzed. The concept maps were used as a tool for learning throughout both treatment units, in addition they also provided valuable information as to how the students were connecting the mathematical concepts presented. Figure 1 shows the overall points earned on pre and postunit concept maps, as well as scores earned per achievement group.

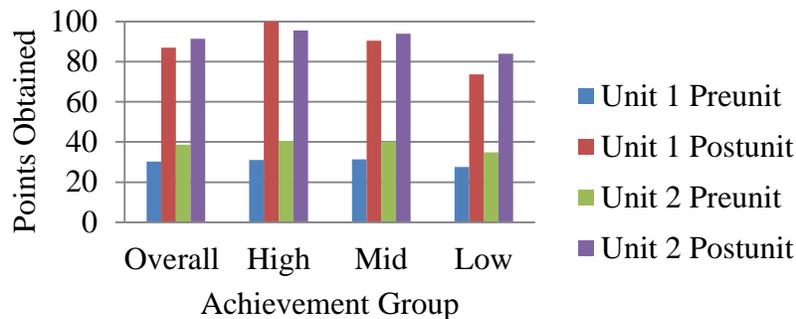


Figure 1. Average points obtained on pre and postunit concept maps, ($N=22$).

The constructions of the maps were also noted when analyzed. How the terms were linked and the depth of the propositions used indicated the level of understanding by the students. Analysis of both sets of preunit concept maps showed a very basic level of understanding, if any, of the targeted math concepts. Many terms were linked with vague propositions indicating a surface level understanding. However, in contrast to the preunit maps, the postunit maps showed a higher level of understanding in several different areas. Most students included at least four levels of hierarchy in the final maps and the

propositions were more exact and clearly connected to the overall arching concept. For example, to link the two terms “Base-10 Number System” and “10” one student connected the terms with the proposition, “the primary number used in the.” Another strong linking termed used by a student connected “Subtraction” and “Difference” by writing, “the answer to a subtraction problem is a.” In addition, many maps included examples or additional vocabulary terms the students connected to the ones provided.

The results from these four different forms of data suggest that concept maps play a role in helping students to increase the depth of their knowledge in regards to mathematical concepts. When asked conceptual questions, such as questions based on how the number system uses patterns, students could demonstrate their understanding through written test answers, verbal responses, written examples, and visual representations. However, when students were given a math computation problem, they did not necessarily use their knowledge of the concepts to help them solve equations. This indicates that maps may not increase the students’ overall computational abilities in mathematics, thus yielding the mixed results as they pertain to the assessment scores.

In addition to determining the effects of concept mapping on the overall understanding of mathematics concepts, I was interested in knowing if the mapping had an effect on students’ long-term memory of the concepts. To address this question fully, delayed assessments, journal writes, and the construction of delayed maps were completed by the class. Delayed interviews were conducted with students representing the class as a whole.

The use of postunit and delayed assessments (Appendix P) allowed me to compare the percent change between the nontreatment and treatment units two weeks

after the culmination of each investigation. Overall class data from these assessments can be found in Table 6. One will notice that the results, as shown by the percent change, are mixed. Data show positive results for treatment unit 1 only, whereas there is no change between the post and delayed assessment for the nontreatment unit. Of particular interest is the decline in test scores for treatment unit 2. These data indicate that mapping may not have been effective for the long-term retention of math concepts.

Table 6
Average Scores of Postassessments and Delayed Assessments, (N=22)

Description of Data	Nontreatment (%)	Treatment 1 (%)	Treatment 2 (%)
Postassessment Average	94	88	70
Delayed Assess. Average	94	89	58
Percent Change	0	1	-17

Figure 2 shows a comparison of all units and also includes all assessments within the units. One will note the high scores for all tests given during the first treatment unit possibly corresponding with the carryover of concepts from the nontreatment unit. Whereas, the second treatment unit introduced new concepts and follows a more typical pattern in regards to assessment scores.

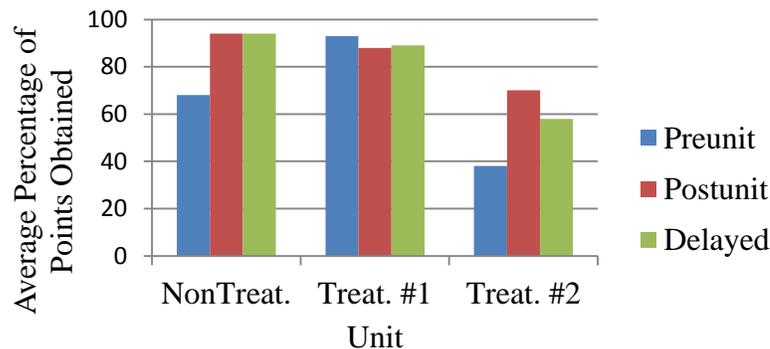


Figure 2. Average points obtained on all assessments throughout units, (N=22).

Further analysis of the data by achievement group shows a high variance in test scores when comparing post and delayed assessments. Table 7 presents a remarkable difference in the two treatment units' test scores for the high-achieving subgroup. By comparison the mid and low-achieving groups did not show as much variance in scores between post and delayed assessments. Particularly, the low-achieving group seemed to demonstrate more stable numbers throughout, including only a nine percent decrease between the post and delayed assessment for treatment unit 2 where the high-achieving group had the highest percentage of any group for that unit.

Table 7
Average Scores by Achievement Group, High-Achieving (n=2), Mid-Achieving (n=14), and Low-Achieving (n=6) for Postassessments and Delayed Assessment (N=22)

Group	Description of Data	Nontreatment (%)	Treatment 1 (%)	Treatment 2 (%)
High	Postassessment	98	91	67
	Delayed Assess.	100	100	33
	Percent Change	2	10	-45
Mid	Postassessment	95	92	71
	Delayed Assess.	96	92	55
	Percent Change	1	0	-23
Low	Postassessment	89	79	67
	Delayed Assess.	86	80	61
	Percent Change	3	1	-9

To gather additional data in regards to the effects of concept mapping on students' long-term memory, students were asked to complete reflective journal writes two weeks after the culmination of each unit (see Appendix Q). These reflections were focused on the primary concepts learned during each of the investigations. Table 8 depicts the average percentage of points earned on the three reflective journal writes, by the overall class as well as by the different achievement groups. The overall averages obtained by

the students during the treatment units were higher than those of the nontreatment unit, with perfect scores obtained by students in the high-achieving group.

Table 8
Average Percentage of Points Obtained on Reflective Journal Writes, (N=22)

Group	Nontreatment Reflect. (%)	Treatment 1 Reflect. (%)	Treatment 2 Reflect. (%)
High	75	100	100
Mid	57	58	68
Low	33	40	42
Overall	55	58	63

In an effort to gain qualitative data, along with the quantitative data, trends from the three reflective journal writes were also analyzed. Although students were in the midst of treatment unit 1 when completing the reflection for the nontreatment, which had a high carryover of concepts, students were not able to fully explain and answer the prompt. The prompt for the nontreatment unit asked a question about our number system, particularly the base-10 system. As was seen in the journal writes that took place during the nontreatment phase of the study, many students referenced the chart on the wall and indicated that they understood that 10 was an important number because it was on the poster. Some were able to explain that when multiplying by 10 you are increasing the place value, but few were able to provide a well referenced answer to the prompt as a whole.

By contrast, the reflections based upon the primary concepts stemming from the treatment units indicated that students had a firmer grasp on the concepts studied. Most high and mid-achieving students were able to provide examples as well as construct well thought out responses when answering a prompt about patterns in the number system. A high-achieving student answered, "...there are patterns because we use the number 10.

When you multiply by 10 it increases the place value. Then when I have to say the number, I say the same words like ten and then I'd say ten-thousand or ten-million. The numbers have the same names each time." Answers such as this showed a link between prior learning and indicated students understanding of foundational mathematics.

Likewise, answers to the reflection based off of the second treatment unit, showed a high understanding and ability to explain thinking at a higher level as well. When asked about breaking numbers apart to help solve math problems, a mid-achieving student wrote, "Breaking apart numbers helps me solve large calculations like $9,063+8,639=?$ I'll break apart numbers by their place value, this allows me to work with landmark numbers and now it's easy to solve." The answers, from most students, were well supported with examples and key vocabulary from the units.

Delayed interviews (Appendices D and I) were also used as a way to determine the effect of concept maps on long-term memory. By interviewing the same six students that were representative of the class as whole, according to achievement level, students were given the chance to articulate their learning of the focus concepts for each unit. As with the other data collection instruments targeted for long-term memory, these interviews took place approximately two weeks after the culmination of each unit. Each question answered was analyzed both quantitatively as well as qualitatively. Quantitative results can be seen below in Table 9, with a comparison to the postunit interview scores.

Table 9
Average Number of Points Obtained on Postunit and Delayed Unit Concept Questions by Interviewed Students, (N=6)

Description of Data	Nontreatment (%)	Treatment 1 (%)	Treatment 2 (%)
Postunit Interview	31	59	62
Delayed Interview	48	46	62
Percent Change	55	-22	0

Results for the delayed interviews are mixed. There was an increase in delayed responses for the nontreatment unit, a decrease for treatment unit 1, and no change occurred in the delayed responses for treatment unit 2. Once again, a high carryover of concepts between the nontreatment and treatment 1 units may have affected the scores of delayed data for the nontreatment unit.

When the responses to the interview were viewed qualitatively, the results were again, mixed. Several of the interviewed students were able to properly articulate and address the questions of the second treatment unit using vocabulary and learning from the investigation. However, students struggled with the concepts from the first treatment unit. The largest struggle was apparent in a question from treatment unit 1, addressing how the patterns in the number system can help solve addition and subtraction problems. Most students, with the exception of the low-achieving, could not say why any knowledge of the system would help them. One mid-achieving student commented, "...well, I can line the numbers up. Like when I put one on top of the other to add or subtract." Another high-achieving student stated, "Knowing the patterns helps me say the numbers." This student never directly addressed the question of solving math problems. In contrast, a low-achieving student was able to answer the question fully commenting, "I use the place value patterns like tens, hundreds...then I'll add the places in steps. If the numbers didn't follow a rule, I couldn't do that."

Of high interest, is that the high and mid-achieving students performed very well on the delayed interview for the nontreatment unit but struggled with treatment unit 1. Whereas, the low-achieving students did poorly on the nontreatment portion of the interviews and excelled during the treatment interviews. Throughout both sets of

interviews for the treatment units, the low-achieving students were able to articulate their answers and showed an increase in the use of vocabulary and higher-order thinking.

The concept maps themselves were used as a fourth data collection instrument to assess long-term memory. Comparisons of the initial and final maps for each of the treatment units were made against two delayed maps constructed approximately two weeks after each unit ended. Results of this comparison can be seen in Figure 3.

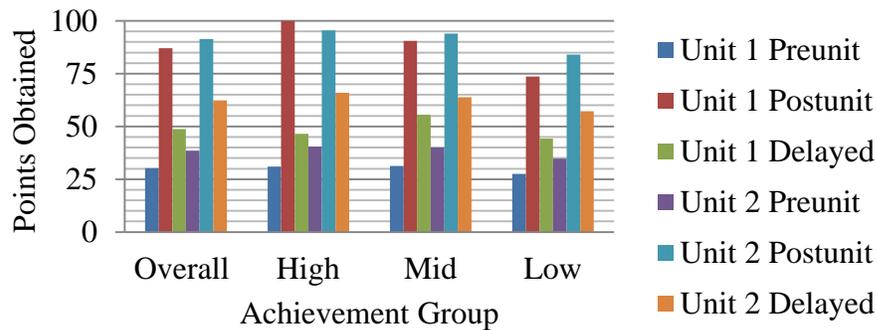


Figure 3. Average points obtained on pre and postunit and delayed concept maps, ($N=22$).

Results indicate that while the delayed constructions of the maps were not as high as those of the postunit maps, the points obtained on the delayed were remarkably higher than those of the initial maps. These results indicate a level of learning achieved by the constructions of the maps during the treatment phase of the study.

Once again, the physical constructions of the maps were considered along with the points obtained. As was the case with the postunit concept maps, students used more in depth propositions, although there was a higher incidence of improperly linked terms and very few cross links were shown on the maps. For example, one student linked “Addition” and “Difference” indicating that she believed the answer for addition problems was called a difference. Another student properly linked “Base-10 System” to

“10” using the proposition “the most important number used in the” but did not cross link the term to “Number System” or “Place Value”. These inconsistencies in construction account for lower points obtained on the delayed maps.

Taken in its entirety, the effects of concept mapping on long-term memory are mixed. High carryover from the nontreatment unit to the first treatment unit surely had an effect on the data as a whole. Results do indicate a level of retention in regards to the concepts, particularly for those in the low-achieving group.

Data were obtained and analyzed through use of pre and postunit surveys, student interviews, and classroom observations to assist in answering my subquestion pertaining to concept mapping and the effect on student motivation. Surveys were completed before and after the treatment units, as were the interviews. Classroom observations through teacher journaling were collected throughout both phases of the treatment.

Students were surveyed in order to determine several factors that correlated with attitudes towards mathematics, performance, and learning (see Appendix F). Figure 4 shows the results of five targeted questions based on a Likert scale score. As can be seen, overall attitude towards mathematics and student confidence increased upon the culmination of the treatment units. The highest gains were seen in the students’ confidence as it pertains to their own mathematics abilities.

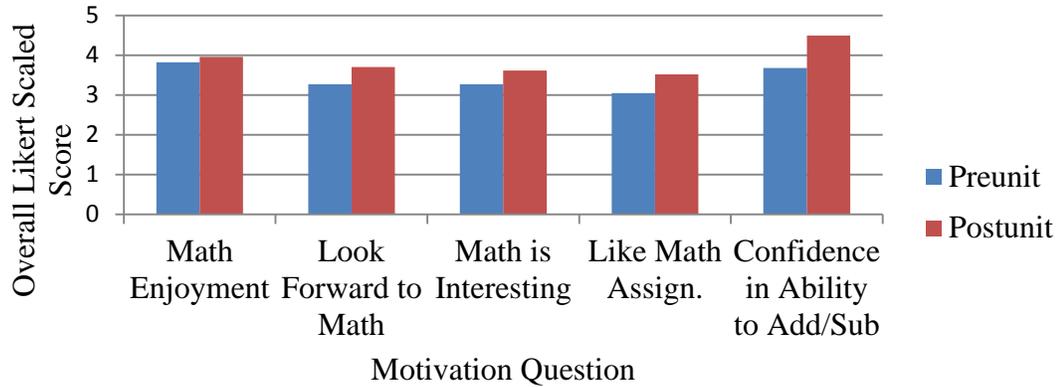


Figure 4. Results from 5 targeted questions based off of pre and postunit motivation survey ($N=22$). *Note.* 5=Strongly Agree, 4=Agree, 3=Neutral, 2=Disagree, 1=Strongly Disagree.

In support of the anonymous student surveys completed by the entire class, motivation interviews were also conducted with six students from the cohort (Appendix G). Table 10, shown below, depicts the preferences in learning styles, perceived achievement level, and overall feelings towards math of the six students broken down by achievement level before and after the treatment units. As one can see, the overall attitude towards math increased, with none of the students reporting that they did not enjoy math. Perceived achievement level also increased, with all six students reporting that they felt they were at least a mid-achieving math student. There was also a slight shift in learning style preferences after the treatment units. Prior to the use of concept maps, students that were interviewed predominantly chose “practicing problems” as their preferred learning style. However, after the treatment units, there was a 50/50 split between practice problems and concept mapping as the learning style preferred.

Table 10
Student Interview Responses Pertaining to Learning, Attitude, and Perceived Achievement Preunit and Postunit, (N=6)

Targeted Question	High-Achieving Student Responses (%)	Mid-Achieving Student Responses (%)	Low-Achieving Student Responses (%)
Learning Style Pref.- Pre	Notes = 0 Practice Probs. = 100 Manipulatives = 0	Notes = 33 Practice Probs. = 66 Manipulatives = 0	Notes = 0 Practice Probs. = 50 Manipulatives = 50
Learning Style Pref.-Post	Notes = 0 Practice Probs. = 100 Manipulatives = 0 Concept Maps = 0	Notes = 0 Practice Probs. = 33 Manipulatives = 0 Concept Maps = 66	Notes = 0 Practice Probs. = 50 Manipulatives = 0 Concept Maps = 50
Math Attitude – Pre	Like = 100 Neutral = 0 Dislike = 0	Like = 66 Neutral = 33 Dislike = 0	Like = 50 Neutral = 0 Dislike = 50
Math Attitude – Post	Like = 100 Neutral = 0 Dislike = 0	Like = 66 Neutral = 33 Dislike = 0	Like = 100 Neutral = 0 Dislike = 0
Perceived Achieve. - Pre	High = 100 Mid = 0 Low = 0	High = 0 Mid = 66 Low = 33	High = 0 Mid = 0 Low = 100
Perceived Achieve. - Post	High = 100 Mid = 0 Low = 0	High = 66 Mid = 33 Low = 0	High = 50 Mid = 50 Low = 0

Note. Pref. = Preference and Achieve. = Achievement

In addition to the results found from both the student surveys and interviews, anecdotal notes taken throughout the treatment phase of the study were also analyzed. A typical math class using *Investigations in Math* (Russell & Economopoulos, 2008) can sometimes be wrought with off topic conversations and a general lack of focus. Frequently, when working in small groups there is one predominant leader and some followers that write down what the other students tell them to. As I observed the conversations centered around the concept maps I noticed that even the students that

usually choose to follow the others, were asserting themselves and explaining the connections they had made on their maps. I also noted that there were times when students mentioned the connections from mapping even when they were performing a different task such as solving larger addition or subtraction problems. In addition, to focused conversations that referenced the maps, several students asked to use the maps as a tool on their tests, particularly for the second treatment unit.

At one point, during the second treatment unit, I held a class discussion pertaining to the concept maps we had been working on and using. During the discussion, just over 50% of the class felt that the concept maps were useful. A particularly interesting point is that most of the students in the low-achieving group reported that they liked using the maps and found them to be beneficial. One low-achieving student said, "I like them because now I can actually see how things are connected." Another interesting observation made was that both a gifted visual-spatial student as well as gifted verbal student reported that the maps were very useful, while the majority of high-achieving students were not completely sold on the benefits of the maps. With both the anecdotal notes and the class discussion taken into account, it appears that concept maps do have a place in the mathematics classroom, even if only for the lower performing students.

Data suggests that the use of concept mapping in the classroom does play a role in increased motivation towards mathematics. Further, the use of maps may build confidence in mathematical abilities as well as providing a desired learning tool for some.

The final subquestion addressed by this action research project pertained to my goals set forth by the Teaching Goals Inventory (TGI) and the effect of mapping on my professionalism. My goals as set forth by the TGI pertained to higher order thinking skills

(HOTS) and basic academic skills. To obtain data for this question, journaling, assessment of student work, and a teacher reflection were completed.

During the course of the entire project, I completed journal writes in an attempt to track my thinking as well as any notable observations made in the classroom (see Appendix O). Several of the prompts pertained to the students understanding of the mathematical concepts in question. A notable journal entry made during the nontreatment unit stated, "...had to ask student several different ways about how the place value system works. Student did not understand my questioning so I reworded three or four times and resorted to examples to promote understanding." This entry indicated that some students in the class may have little to no understanding of place value or numbers in a specific place. In contrast, an entry made during the first treatment unit read, "Group seems to understand how to break apart numbers by place value. Students were asked to teach others and were also able to articulate how they performed the math in question."

For journal entries responding to the prompts focused on the effectiveness of the concept maps, two distinct trends become evident. During the first treatment unit most of the entries pointed to frustrations I encountered when explaining how to construct the maps. However, during treatment unit 2 the entries were centered more on how students were responding positively to the maps in regards to both attitude and learning. As an example, during a class discussion I directly asked questions pertaining to the concepts in the unit, students in the class demonstrated their deep understanding of the math concepts by answering directly and extending on one another's comments.

The second data collection instrument used to collect information about my goals and professionalism were various assessments of student work. Through these

assessments, I tracked student understanding and thinking as well as their computational abilities. Student work completed during the nontreatment unit showed that students had a firm grasp on computational skills. However, students struggled with explaining their own thinking in regards to how they solved particular problems. Treatment units 1 and 2 yielded mixed results when it came to assessing student work. For the first treatment unit, the results mirrored that of the nontreatment unit in regards to the students' ability to explain their thinking. In addition, the computational abilities remained much the same as well. However, I noticed a sharp upward trend in the students' explanations when analyzing the work from treatment unit 2. Students went through great lengths to explain their work and tied much of their reasoning to past concepts. The results from the analysis of student work supported much of my other findings throughout the study.

The final instrument used in analyzing my goals and professionalism was a reflective interview conducted by my Instructional Coach (reference Appendix R). During the reflection several things became apparent. I realized that the project did not have the exact results I had hoped for, but it did have value in different areas I did not anticipate. For instance, when asked about whether the project was worthwhile, I responded, "Yes, it didn't have the effect I was looking for on all of my students, but I noticed that it really seemed to help the ones that struggle. So that made it worthwhile right there." In addition, when I was asked about the effects of the project on my teaching I stated, "The project has helped me realize that I can experiment in the classroom. Kids are resilient so if I don't get something right the first time I can try again. They also responded positively to trying something new and out of the box. Maybe it made them feel special because the other class wasn't doing the same thing. I'm a better teacher

because I learned something and now I can push myself to places I might not have gone before this project.” The reflection with the coach indicated that although the maps may not have directly had the results I anticipated, there was still a great amount of value in using them in my classroom.

Overall, the use of concept mapping in the classroom positively influenced my teaching and helped me with the accomplishment of one of my goals. The use of maps does influence the students’ higher order thinking skills. Students are able to respond to deep seeded questions and have a grasp on many underlying concepts that will drive math in the future. However, the use of maps does not show as strong of a correlation to the building of the students’ basic academic skills.

In addition to obtaining my goals, my professional standing in my school has increased, as noted by the principal and my coach. Several of my colleagues question me as to best practices in mathematics and about the use of maps within the classroom. I am often asked about data analysis and ways in which to view student data, not just in math but in other areas as well.

INTERPRETATION AND CONCLUSION

Data were analyzed to answer my focus question on the effects of concept mapping and the understanding of mathematical concepts. In addition, data were also analyzed to assist in my understanding of the effects of concept maps on long-term memory, motivation, and my professionalism. Evaluation of the data collected from a nontreatment and two treatment units suggests that the greatest overall impact of concept

mapping is towards the actual concept behind the math. Meaning, students demonstrated a deeper knowledge of the concepts, such as the Base-10 Number System, when creating and using concept maps. However, data also indicates that the maps did not have a positive influence on the students' computational abilities during the limited time of this capstone project.

These mixed results, as indicated by pre, post and delayed unit assessments, show that concept mapping is not the answer to all of my students' struggles in math. However, the results indicating a higher understanding of the concepts behind the math lead me to believe that mapping could play a valuable role in certain parts of mathematics, such as geometry. Along with focusing the use of concepts maps to a more vocabulary or concept heavy area of math, the mapping may prove valuable to low-achieving students. Results from interviews, journal writes, as well as assessments showed that students in the low-achieving group had an increase in knowledge and ability when concept maps were implemented.

The assessment data related to long-term memory provided mixed results also with treatment unit 1 showing a positive result and treatment unit 2 showing a decrease in scores. Due to the high carryover of concepts and content between the nontreatment and first treatment unit it is hard to know if the results are reliable. Students demonstrated no change between the nontreatment postunit assessment and the delayed assessment. Another factor possibly influencing this lack of change was the fact that the delayed assessment was given during the first treatment unit. Once again, with the high carryover of content, the analysis was problematic.

By comparison, the journaling and interview data collected to address long-term memory yielded mostly positive results. Students were able to write as well as articulate their answers and demonstrated a deep understanding of the math even after a prolonged amount of time. This is indicative of the effectiveness of concept mapping on the understanding of foundational concepts in math, yet the lack of consistency between all forms of data collected indicates the need for further analysis.

A detailed look at the effects of concept mapping on student motivation indicates a positive result. Through student surveys, interviews, and classroom observation, students reported their increased enjoyment in math and an increased confidence level in their abilities. Students appeared to be highly engaged when creating and discussing their concept maps in math class. Over 50% of students reported that the maps had a positive result on their abilities, with the majority of the low-achieving students reporting positively. I believe that a student's confidence level and engagement have a direct impact on their abilities, and thus see a value in the use of mapping within the classroom.

As an educator, this action research project has proved beneficial to my own professionalism and teaching goals. Although the use of mapping only had a positive effect on one of my goals, pertaining to higher order thinking skills, it has undoubtedly influenced my professionalism in a good way. Many co-workers came to me for advice, and continue to ask questions still, based upon best practices in teaching mathematics. In a data driven instructional environment, I am often sought to help analyze data in order to ensure instructional practices that meet the needs of all students.

The implementation of mapping in the classroom has helped me to listen to and observe my students in such a way that it helps me realize their needs in the classroom. It

has changed my attitude towards trying new things in the classroom, has enlightened me to the idea that perfection on the first try is not necessary, and the lack there of may be even more valuable. Seeing my students so willing to work with me and help me as well as their fellow classmates has rekindled my beliefs in a sense of classroom community and the important role that community plays.

There were some things about this project that could be improved upon in the future. The first of these would be the units of study. Concept mapping proves valuable in the students' understanding of concepts, it does not have that profound of an effect on computational fluency over a short period of time. My two treatment units were centered on the students' ability to solve addition and subtraction problems. Taking this into account offers a possible explanation for the mixed results on the assessments that had a computation focus, but for the positive results of interviews and journal writes with a concept focus. With this caveat in mind, mapping would prove to be more beneficial in the area of geometry in the mathematics classroom, or in other contents such as science or social studies where the focus is on conceptual understanding and vocabulary.

In addition to those improvements, I would avoid collecting data before the standardized state test. The stress level of both students and teachers at this time is immense. As the test date drew near, math lessons were often prolonged in an effort to continue collecting data and using the maps, while also teaching completely different bits of math in an effort to prepare them for the test. The use of concept mapping in the first semester would prove most useful in that the maps could be recreated as the test drew near as another way to help students review prior to the exam.

Another limitation of this project was the physical construction of the maps by the students. Prior to the onset of the treatment units, I had the students construct a high interest map based on music or sports. I also used a concept map as an assessment in science in the hopes that students would understand construction, propositions, and cross links. Even given this amount of practice and guidance, several of the students struggled initially with what the maps were, how to construct them, and how they were useful. It was only after several class discussions and corrections to the initial maps during the first treatment unit that the thinking and idea behind the maps became clear. It is apparent that more practice is needed in order for the maps to have the maximum benefit on student learning. In the future I would spend a larger amount of time on mapping in other areas before beginning the project, with the focus being on how to create and use concepts maps, good propositions, and proper cross links.

The practice of concept map construction, timing of when the maps are implemented, and use of the maps for concept heavy subjects will help to improve the quality of data collected, thus allowing for a better assessment of the effects of concept mapping in its entirety.

VALUE

This capstone project has provided me with the opportunity to grow professionally as an educator by exploring new teaching methods that will allow me to better meet the needs of all students within my classroom. Developing, implementing, and reflecting on this project have allowed me to revisit my role as a teacher, as well as

assess my professional goals and how I can accomplish those goals. With the knowledge gained in creating, implementing, and completing this project, I am now more aware of ways in which I can provide a meaningful learning experience to my students. Taking all of this into account, I now fully understand the importance of providing students with various learning tools, including concept maps.

The use of concept mapping within the mathematics classroom provided me with a tool to better understand my students' thinking and how the students were connecting and forming their knowledge. Concept mapping was not only a way for students to analyze their thought processes, but also provided a platform for discussion that enabled students to solidify different aspects of their learning. Mapping was engaging and promoted a positive attitude towards math, which many students lack due to low confidence in their abilities.

The use of concept maps within a mathematics class is not a traditional approach in helping students succeed in math. However, the maps proved beneficial in helping students to understand the conceptual underlyings of mathematics, they had a positive impact on attitude, and in some cases improved retention of the concepts taught. Although concept mapping may not be the only answer to drastically increased math scores, research indicates that it does have value in the math classroom. Mapping, along with a focus on computational strategies will give students the tools they need to succeed in a subject where most fall down.

As I look ahead to next year and a new grade, teaching 28 sixth graders, I am planning ways in which to improve the use of concept mapping both within mathematics and other content areas. I now know from experience that the constructing of the map

itself is something that must be solidified and well understood prior to being used as a tool for learning. I will incorporate more modeling of map construction and allow students to create several maps based on high interest topics before asking them to create maps based on subject content. Furthermore, I will focus the use of concept mapping in the classroom to subjects or areas that are concept heavy such as science and geometry, and focus on having students map how to solve different problems. Concept mapping is valuable in helping students connect the various vocabulary terms and concepts, but as I used it in my project it does not address computational areas as well as it does the prior mentioned areas.

This capstone project has revitalized my desire to teach and to learn. It has made me evaluate all aspects of my teaching and the ways in which I view my students and their learning. I am convinced of how important it is to provide students with multiple ways to learn, whether that's with concept maps or another learning tool. It is my job as a teacher to reach all of my students, to push my students and challenge them in the classroom, and to engage students in their learning and provide them with the tools they need to become successful.

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APPENDICES

APPENDIX A

PROJECT TIMELINE

Proposed Capstone Project Timeline

Note: Although it is not stated, students will revisit and revise their concept maps 3 to 4 times per week for 15 minutes, prior to the onset of the new lesson. Field notes on students and teacher reflections/journaling will be completed throughout the project.

December 12th: Intro to project

- ✓ Students create a high interest concept map as a class (teacher model)

December 14th: Begin project

- ✓ Begin preunit concept interviews

January 6th: Students take nontreatment preassessment

January 9th: Session 1.1 *How Much is 1,000*

- ✓ Students make initial journal entry

January 10th: Session 1.2 *Finding Numbers to 1,000*

January 11th: Session 1.3 *Changing Places*

January 17th: Session 1.4 *How Many Miles to 1,000*

January 18th: Session 1.5 *Numbers to 1,000 and Rounding*

- ✓ Construct practice concept map (teacher model and student complete)

January 19th: Session 1.6 *Adding and Subtracting to 1,000*

January 23rd: Session 2.1 *Solving Addition Problems*

January 24th: Session 2.2 *Addition Strategies*

January 25th: Session 2.3 *Starter Problems*

January 26th: Session 2.4 *Addition Algorithm*

January 27th: Session 2.6 *Solving an Addition Problem Two Ways*

- ✓ Students complete motivation survey

January 30th: End nontreatment unit

- ✓ Students take nontreatment postassessment
- ✓ Begin postunit concept interviews
- ✓ Conduct motivation interviews
- ✓ Students complete journal entry

January 31st: Begin treatment unit 1

- ✓ Students take treatment unit 1 preassessment
- ✓ Begin treatment unit 1 preunit concept interviews

February 1st: Session 3.1 *Making a 10,000 Chart*

- ✓ Students complete initial concept map

February 2nd: Session 3.2 *How Much is 10,000*

- ✓ Students complete journal entry

February 3rd: Session 3.3 *Working with the 10,000 Chart*

February 6th: Session 3.4 *Thousands of Miles*

February 7th: Session 3.5 *Adding Numbers in the Thousands*

February 8th: Session 3.6 *Larger Number Place Value*

February 9th: Students take treatment unit 1 postassessment

- ✓ Assess and discuss concept maps on treatment unit 1
- ✓ Students complete journal entry
- ✓ Begin treatment unit 1 postunit concept interviews

February 10th: Students take treatment unit 2 preassessment

- ✓ Begin treatment unit 2 preunit concept interviews

February 13th: Begin treatment unit 2 - Session 4.1 *Representing Subtraction Problems*

- ✓ Construct new concept map

February 14th: Session 4.2 *Strategies for Subtraction*

- ✓ Students take nontreatment delayed assessment
- ✓ Conduct nontreatment delayed concept interviews

February 15th: Session 4.4 *Do I Add or Subtract*

February 16th: Session 4.4A *Using the Standard Algorithm to Subtract*

February 21st: Session 4.5 *Solving Addition and Subtraction Problems*

- ✓ Assess and discuss treatment unit 2 concept map
- ✓ Students complete journal entry

February 22nd: End treatment unit 2

- ✓ Students take treatment unit 2 postassessment
- ✓ Begin treatment unit 2 postunit concept interviews
- ✓ Conduct motivation interviews
- ✓ Students complete motivation surveys

February 23rd: Delayed construction of concept map

- ✓ Delayed assessment for treatment unit 1
- ✓ Begin treatment unit 1 delayed concept interviews
- ✓ Students complete first reflection

March 12th: Delayed assessment for treatment unit 2

- ✓ Students complete second reflection

March 13th: Delayed construction of concept map

APPENDIX B

NONTREATMENT SAMPLE LESSON

Below is an outline for a typical lesson within the nontreatment unit. Due to the nature of *Investigations in Mathematics*, students used manipulatives and participated in discussion groups as part of the routine in math class.

Lesson Plan 1 – Nontreatment Unit

Learning Goal	Agenda
<ul style="list-style-type: none"> - Add and subtract multiples of 10, 100, and 1,000 - Read, write, and sequence numbers to 1,000 	<ul style="list-style-type: none"> - Jump Start = Story Problem - Introduce <i>Practicing Place Value</i> - <i>Changing Places</i> - Adding and subtracting multiples of 10 and 100 - Daily practice sheet
<p>Notes = 1) Students start the class by solving a story problem, 2) Students called to the front and are introduced to <i>Practicing Place Value</i>, 3) Students work with a partner to complete the <i>Changing Places</i> activity using their change cards and record sheet, 4) Students return to the front of the room and a discussion is held about adding and subtracting multiples of 10 and 100, 5) Students complete page 6 as daily practice</p>	

APPENDIX C

PRE/POST/DELAYED NONTREATMENT ASSESSMENT

Assessment Nontreatment Unit

Adapted from Investigations in Number, Data, and Space

1. Listen to the 3-digit number and write in down. _____
- a. What is 1 more than the number? _____
 - b. What is 1 less than the number? _____
 - c. What is 10 more than the number? _____
 - d. What is 10 less than the number? _____
 - e. What is 40 more than the number? _____
 - f. What is 40 less than the number? _____
 - g. What is 200 more than the number? _____
 - h. What is 200 less than the number? _____

2. Put these numbers in order from least to greatest.

106 90 793 49 581

3. Solve the following addition problem in two different ways. Show each of your strategies in clear and concise notation.

$$2,697 + 743 = \underline{\hspace{2cm}}$$

First Way:

Second Way:

APPENDIX D

NONTREATMENT CONCEPT INTERVIEW QUESTIONS

Student Concept Interview Questions

Nontreatment unit

1. Describe the Base-Ten Number system.
2. How do patterns in our number system help you compare whole numbers?
3. What are Landmark Numbers and how can they help you solve math problems?
4. What helps you to understand math? Explain.
5. What class activities are most helpful? Explain.
6. How well do you remember math from the class lessons? Explain.
7. What helps you to remember math? Explain.

APPENDIX E

JOURNAL PROMPTS

Student Journal Prompts

1. What number is our place value system based off of? How do you know this?
Make sure to answer in complete sentences, and please provide examples.
2. How can landmark numbers help you solve addition problems? Make sure to answer in complete sentences, and please provide examples.
3. How can you break-apart large numbers? How does breaking-apart a large number help you solve addition problems? Explain using complete sentences, and examples.
4. How do you know when a story problem is asking you to add? Subtract? Explain your answer in complete sentences.

APPENDIX F

MOTIVATION SURVEY

Motivation/Attitude Survey

This survey is for the purpose of gaining student feedback in math. Participation is voluntary, and you can choose to not answer any question that you do not want to answer, and you can stop at anytime. Your participation or non-participation will not affect your grade or class standing.

Rank yourself on a scale of 1-5 for each of the following questions:

5 – Strongly Agree 4 - Agree 3 – Neither Agree or Disagree 2 - Disagree
1 – Strongly Disagree

1. I enjoy math. _____
2. I look forward to math time in class. _____
3. I think math lessons are interesting. _____
4. I like doing my math assignments. _____
5. I am confident in my abilities to add and subtract large numbers. _____
6. I am confident in my ability to use the standard algorithm to solve addition problems. _____
7. I am confident in my ability to solve addition word problems. _____
8. I am confident in my ability to solve subtraction word problems. _____
9. Over all, how do you feel about your abilities in math? Support your answer with at least two reasons.

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

APPENDIX G

MOTIVATION INTERVIEW QUESTIONS

Name of Student _____

Date of Interview _____

1. Do you like our math curriculum? Why or why not?
2. How do you feel you do in math overall? Explain.
3. Do you look forward to math time? Why or why not?
4. Is there anything else you would like me to know?

APPENDIX H

PRE/POST TREATMENT ASSESSMENT

Assessment Treatment Unit

Adapted from Investigations in Number, Data, and Space

Solve the following problems. Make sure to show all work and your solutions with clear and concise notation.

1. Listen to the 4-digit number and write in down. _____
- a. What is 10 more than the number? _____
 - b. What is 10 less than the number? _____
 - c. What is 400 more than the number? _____
 - d. What is 400 less than the number? _____
 - e. What is 3,000 more than the number? _____
 - f. What is 3,000 less than the number? _____

2. Put these numbers in order from least to greatest.

5,706 889 8,002 3,652 358

3. $1,505 - 618 =$ _____

4. Ryan is saving to buy a new snowboard. He is keeping track of how much money he saves each month on a chart. This is how much he has saved so far.

November	\$48.85
December	\$72.00
January	\$56.54

- a. How much has Ryan saved altogether?
- b. A new snowboard costs \$375.95. How much more does Ryan need to buy the snowboard?

APPENDIX I

TREATMENT CONCEPT INTERVIEW QUESTIONS

Student Concept Interview Questions

Treatment unit

1. Describe the relationship between 10,000, one thousand 10's, one hundred 100's, and ten 1,000's.
2. How are place value patterns repeated in large numbers?
3. How does understanding the place value system help you solve multi-digit addition and subtraction problems?
4. How can pictures or stories help you with solving addition and subtraction problems?
5. How can breaking numbers apart help you solve addition and subtraction problems?
5. What helps you to understand math? Explain.
6. What class activities are most helpful? Explain.
7. How well do you remember math from the class lessons? Explain.
8. What helps you to remember math? Explain.
9. Does mapping help you to learn math? Yes or No. Explain.

APPENDIX J

CONCEPT MAP 1

Treatment Unit Map #1 – The Number System

Throughout this unit we will use the following words to create a concept map on the topic of **The Number System**. Use the words from list one to create your first map. We will add from list two as we continue through the unit investigations. Use a pencil as we will continue to revise. Also, please make sure you remember to add your “linking term”.

List 1

Number System

Place Value

Digit

Tens Place

Hundreds Place

Thousands Place

List 2

Multiple

10

Landmark Number

Base-Ten System

APPENDIX K

CONCEPT MAP RUBRIC

Map Component	Possible points	Awarded points	Special things noticed about map
Proposition			
Clear and meaningful to the central topic	2 each		
Beyond given set of terms	3 each		
Not properly linked	1 each		
Vague	1 each		
Branch			
Top	1		
Successive branches	3 each		
Levels of hierarchy (general to specific)	5 each level		
Cross Links	10 each		
Examples	1 each		
Total			
Overall reaction to map and special things noticed.			

References

Novak, J. D. & Gowin, D. B. (1984). *Learning how to learn*. New York, NY: Cambridge University Press.

APPENDIX L

CONCEPT MAP 2

Treatment Unit Map #2 – Addition and Subtraction

Throughout this unit we will use the following words to create a concept map on the topic of **Addition and Subtraction**. Use the words from list one to create your first map. We will add from list two as we continue through the unit investigations. Use a pencil as we will continue to revise. Also, please make sure you remember to add your “linking term”.

List 1

Addition

Subtraction

Breaking Apart

Number Line

Sum

Difference

Plus

Minus

List 2

Strategies

Place Value

Algorithm

Borrowing

Carrying

Sequence of Steps

APPENDIX M

TREATMENT UNIT SAMPLE LESSON 1

Below is an outline for a typical lesson within the treatment unit. Due to the nature of *Investigations in Mathematics*, students used manipulatives and participated in discussion groups as part of the routine in math class.

Lesson Plan 1 – Treatment Unit

<p>Learning Goal</p> <ul style="list-style-type: none"> - Read, write, and sequence numbers to 10,000 - Understand the structure of 10,000 and its equivalence to one thousand 10s, one hundred 100s, and ten 1,000s 	<p>Agenda</p> <ul style="list-style-type: none"> - Jump Start = Division Practice - How many hundreds are in 10,000 discussion - Making rows of 1,000 <ul style="list-style-type: none"> o Students construct their 10,000 chart using adding machine tape - Daily practice sheet page 36 - Discuss and revise concept maps
<p>Notes = 1) Students start the class by completing division problems, 2) Students are called to the front of the room and a discussion about how many hundreds are in 10,000 is held, 3) Students work in small groups to construct their assigned section of a 10,000 chart, 4) Students practice their math skills with a daily practice sheet</p>	<p>Treatment = Students use their concept maps (previously started) to create links between what they have learned about number system patterns, some may need to revise only, others may choose to create totally new propositions, students will work individually for 5 to 7 minutes and then work as a group to compare and discuss their maps. Monitoring of progress and feedback will be given during group revision time.</p>

APPENDIX N

TREATMENT UNIT SAMPLE LESSON 2

Below is an outline for a typical lesson within the treatment unit. Due to the nature of *Investigations in Mathematics*, students used manipulatives and participated in discussion groups as part of the routine in math class.

Lesson Plan 2 – Treatment Unit

<p>Learning Goal</p> <ul style="list-style-type: none"> - Solve subtraction problems by breaking numbers apart - Represent subtraction situations - Find combinations of 3-digit numbers that add to 1,000 	<p>Agenda</p> <ul style="list-style-type: none"> - Jump Start = Multiplication Practice - Strategies for subtraction discussion - Subtraction story problems <ul style="list-style-type: none"> o Students solve word problems on pages 55 and 56 o Students play <i>Close to 1,000</i> - Discuss and revise concept maps
<p>Notes = 1) Students start the class by completing multiplication problems, 2) Students are called to the front of the room and a discussion about different strategies for subtraction is held, 3) Students work individually to complete story problems dealing with subtraction, 4) Students play the game <i>Close to 1,000</i> with a partner</p>	<p>Treatment = Students use their concept maps (previously started) to create links between what they have learned about addition and subtraction, some may need to revise only, others may choose to create totally new propositions, students will work individually for 5 to 7 minutes and then work as a group to compare and discuss their maps. Monitoring of progress and feedback will be given during group revision time.</p>

APPENDIX O

TEACHER REFLECTION PROMPTS

Teacher Reflection/Observation Prompts

1. What content did students seem to have a good understanding? Explain.
2. What areas of content did student struggle with, and why did they struggle? Explain.
3. What areas of instruction seemed to be effective in helping students? Explain.
4. What would I do in the future to improve instruction? Explain.
5. What activities and lessons seemed to be effective/not effective with student content understanding and motivation this week? Why were these effective/not effective?
6. Did concept mapping seem to help students understand and apply knowledge? How?
7. Were there any ah-ha moments this week? If so, explain.
8. How are students responding to the math lessons?
9. How are students responding to the use of concept maps within the classroom?

APPENDIX P

DELAYED ASSESSMENT

Delayed Assessment Treatment Unit

Adapted from Investigations in Number, Data, and Space

Solve the following problems. Make sure to show all work and your solutions with clear and concise notation.

5. Listen to the 4-digit number and write in down. _____
- a. What is 10 more than the number? _____
 - b. What is 10 less than the number? _____
 - c. What is 300 more than the number? _____
 - d. What is 300 less than the number? _____
 - e. What is 4,000 more than the number? _____
 - f. What is 4,000 less than the number? _____

6. Put these numbers in order from least to greatest.

6,006 779 8,402 4,691 558

7. $2,507 - 708 =$ _____

8. Avery is saving to buy a new iPad. She is keeping track of how much money she saves each month on a chart. This is how much she has saved so far.

July	\$102.30
August	\$78.85
September	\$52.26
October	\$86.54

- c. How much has Avery saved altogether?

- d. A new iPad costs \$499.95. How much more does Avery need to buy the iPad?

APPENDIX Q

REFLECTIVE JOURNAL PROMPTS

Student Reflection Prompts

1. What is the Base-Ten Number System? Why is it called that? Make sure to answer in complete sentences, and please provide examples.
2. What patterns do you notice in our number system? Explain and show examples.
3. How does breaking numbers apart help you to solve large calculations (such as $4,593 + 239$)? How do you break the numbers apart? Make sure to answer in complete sentences, and please provide examples.

APPENDIX R

TEACHER REFLECTION INTERVIEW

Teacher Reflection Interview

The following questions were asked by the Instruction Coach at the end of the project

1. How did the project affect the classroom atmosphere?
2. Would you make any changes to the treatment implemented in your classroom?
3. Did the project seem worthwhile? Why or why not?
4. How has the project helped you to become a better teacher?

APPENDIX S

Student Concept Map Example 1

APPENDIX T

Student Concept Map Example 2

