The Effects of Instructional Strategies On Mathematical Discourse

Ben Bentea

Concordia University Portland

An Action Research Proposal/Report Presented to
The Graduate Program in Partial Fulfillment of the Requirements
For the Degree of Masters in Education/Continuing Teaching License

Concordia University Portland
2008
Abstract

This action research is designed to investigate the effect of various instructional strategies on mathematical discourse in a high school classroom. Mathematics lessons were presented in both traditional lecture-based formats and in student-centered formats such as cooperative learning. Data were collected and evaluated through the use of surveys, reflections, observations, informal and formal assessments.

Data analysis suggests that cooperative learning that promotes mathematical discourse increased students’ understanding of mathematical information and increased short and long-term retention of information learned. Results suggest possibilities for further research using more cooperative learning strategies and increasing student’s independence of learning mathematical topics through discovery.
# Table of Contents

Chapter 1 - Introduction ......................................................... 4
Chapter 2 - The Issue .......................................................... 8
Chapter 3 - Outcomes and Evaluation ..................................... 31
Chapter 4 - Action Plan ......................................................... 33
Chapter 5 - Results and Next Steps ....................................... 41
References ............................................................................. 64
Appendix A – Reflections ....................................................... 67
Appendix B – Survey ............................................................... 69
Appendix C- Journal Notes ..................................................... 72
Appendix D – Data Analysis .................................................... 79
As one enters into the small town in Southern Oregon, one is immediately taken with its beauty. The breathtaking hills that surround this community and the world known rivers that flow through are the reasons it is given the name, “God’s Country.” At one time it was predominately a logging town, but is now known more as a retirement destination. There are numerous retirement homes and villages throughout the city and the majority of the population consists of people age 45 or older. Many of its residents have moved up from California to live a slower and happier life. This small town of approximately 21,000 is the largest within a 60 mile radius and is evenly located between the Oregon coast and the famous Crater Lake.

Due to the increasing popularity as a retirement destination, this town’s social-economic background has a significant range. From 25%-30% are below poverty and the remaining are middle class or higher. As of a recent census, 31% of all families that live in this town make less than 25,000 per year. Although the ethnic population is predominately white or Caucasian at 97.5%, there is a steady increase of Hispanic immigrants moving in to work on the farms. There is also a serious epidemic of methamphetamine production and use that is causing issues in this town and surrounding smaller towns to the point that the county in which they are all located is now known to have the highest level of methamphetamine use in the state of Oregon.
The school district in which the researcher is working at as a high school math teacher consists of approximately 7000 students. There is one high school, two middle schools, and nine elementary schools. Five years ago the elementary schools were K-6, junior high school was 7-9 and the high school was 10-12. Due to the increasing enrollment of students, the district needed to make a decision on whether or not to build a new high school or add on to the only high school and make it bigger. After a significant amount of discussion, the decision was to change the elementary to K-5 schools, the junior high schools to 6-8 middle schools and move the 9th graders up to the high school and make it a 9-12 high school. With these changes, this high school is now one of the largest high schools in Oregon, with an enrollment of around 2100 students.

The high school population of 2100 students consists of students that are predominately white/Caucasian decent and exactly 275 students that are not white or Caucasian origin. Of those 275 students, 74% are Hispanic, 12% are Chinese or Vietnamese and the remaining 14% is made up of 12 different ethnicities. At least 40% of all students in the high school, in each middle school, and in eight of the nine elementary schools are on free or reduced lunch, which is the Federal criteria in determining the number of students that are at or below poverty level. All of those schools qualify and are now Title 1 schools. The number of student on an IEP or 504 plan is estimated to be around 300-400 students. There are 120 ELL students, with the majority of those students being Hispanic. This has a strong implication on how successful students are going to be in the researcher’s classes, especially those that are at or below poverty level. It is very hard for one to think about doing schoolwork and
seeing the importance in it if one has not eaten or does not know where one will be sleeping that night. It makes for a very challenging situation not only for the students, but for teacher as well.

There are around 100 teachers that teach at the high school and 14 of them are in the math department. The researcher is one of those math teachers. The average age of experience for the math department is around 19 years and range from two years of experience to over 35 years of experience. This is the researcher’s third year at this high school and sixth year teaching. The researcher knows that within the next five to seven years there will be some significant changes in his math department due to the retirement of seven to nine of his colleagues. There are 84 sections consisting of 16 different courses all of which can be located on one of three different tracks. The researcher will refer to these tracks as the slow track, the average track and the advanced track. Currently the researcher is teaching in the slow to average track and has three sections of pre-algebra, two sections of Algebra 1 and one section of Algebra 2.

Only the average track has a designated curriculum, which is called College Preparatory Mathematics or CPM. Both the slower and advanced track do not have a designated curriculum and it is left up to the teachers, by their choice, to produce lessons that are engaging and correlate with school and state standards. There is not a consistent teaching method among the teachers in his department. Teaching styles range from very traditional teacher-centered, lecture-based instruction to very student-centered, discovery based instruction and any thing in between.
The researcher is a student-centered and discovery based instructor. His classroom is arranged in teams of 3-4 students all facing each other. Almost all lessons are discovery-based and use prior knowledge and teamwork to achieve desired goals. He sets up a community agreement at the beginning of each year and revisits the agreement often in hopes of creating an environment where all his students feel safe to learn, express themselves mathematically and have fun. The researcher currently relies very heavily on CPM, which is a conceptual and discovery-based curriculum in designing lessons that promote teamwork and mathematical discourse. The researcher works very closely with veteran teachers that are, in his opinion, mathematical geniuses. They are not as much discovery-based instructors, but are more traditional, lecture based and he sees a lot of success from them.

The researcher loves student-centered instruction and feels that it promotes a high level of mathematical discourse. The researchers has been taught that having a classroom that is designed to promote high levels of mathematical discourse not only engages students in learning mathematics, but allows for the most retention of major mathematical concepts and creates effective problem-solvers. However, he sees other teachers that are as effective or more effective as he is and are not promoting discovery-based instructions and as much mathematical discourse in their classroom, which leaves the researcher with the question, what is mathematical discourse? What are some curricula that promote mathematical discourse and if implemented in a classroom, how will they affect student engagement and attitudes toward mathematics?
Having only been an educator for five years, the researcher has been put in the middle of a reform act that has been going on for several years. The way mathematics education was taught to the researcher, the way he was trained to teach, and how he currently sees mathematics education being taught in his school, is contrary to a reform act that was established. This puts the researcher in an uncomfortable situation that yields several questions. The researcher’s questions are; what is mathematical discourse? What type of curricula, whether it is curricula geared toward student-centered or curricula geared toward teacher-centered, promotes it and if implemented in a classroom, how will the curricula with mathematical discourse affect student engagement and perception toward mathematics?

Mathematics instruction in the past 20 years has drastically changed in this country. This is predominately due to the reform movement, which was initiated by the release of Curriculum and Evaluation Standards for School Mathematics in 1989 by National Council of Teachers of Mathematics (NCTM). This reform movement and the success of it rely heavily on teachers and their perception of how mathematics should be taught and their willingness to change. Although this reform has officially been in effect for almost 20 years, the real push for this movement has really only being occurring in the last five years. Even though this reform has been around for 20 years, there are still
teachers whose beliefs do not align with this reform, which is causing a stir in the mathematics education world.

This movement is asking educators to abandon curricula that promote mathematics as a system of well-scripted computational skills, which only reinforces rote memorizations and skill acquisition. It is asking for educators to instead take a “constructionist” approach to teaching mathematics. The constructionist approach of teaching comes from the teaching philosophy called constructivism. Constructivism is a philosophical approach that was founded on the premise that by reflection on personal experience, one can construct their own understanding of the world they live in.

A constructivist teacher sets up problems that allow for students to explore and discover new topics and information. Teachers are flexible in allowing their classes to take unexpected turns as students are given the autonomy to direct their own explorations. Lastly, a constructionist teacher recognizes the construction of new understanding is a combination of prior learning, new information, and readiness to learn. It is obvious that in a constructionist classroom, students are engaged in building conceptual understanding of mathematics through prior knowledge and discovery based lessons, in which mathematical discourse plays a significant and crucial role.

Although many educators have jumped at the opportunity in what they believe is bettering themselves as educators, there are still some educators that are not as willing to make a change. Many educators currently teaching mathematics view this reform as a “doctored up” version of a similar reform that was established in the 1960’s, which was referred to as “new math.” The reform in 1960 was in the works for 10 years before that
and it was not until the launch of the Russian satellite, “Sputnik,” in 1957 that the government and the country was convinced that the US was behind other countries in mathematics.

There were many different organizations, including NCTM and The College Entrance Examination Board (CEEB), which created similar curricula and were referred to as “Modern Mathematics” or “new math.” This name was created due to the fact that organizations like NCTM and CEEB was sending out messages that old mathematics has failed because the traditional mathematics was created before 1700. Their argument was that the failure was due to the fact that students knew the math was outdated and they had no interest in learning it. Their solution was to create curricula that promoted a more technological approach to mathematics and get students to higher levels in mathematics.

In fact, the CEEB’s commission created a nine-point program. “It called for preparation in concepts and skills to prepare for calculus and analytic geometry at college entry. The commission wanted appreciation of mathematical structure in properties of natural, rational, real, and complex numbers. Use of unifying ideas such as sets, variables, functions, and relations was recommended. For grade 12, a half-year of elementary functions was recommended along with alternative units in probability and statistics or modern algebra” (Herrera and Owenes p. 3-4). This report was restricted to just college-bound students; however other reports were given for all levels of students. Herrera and Owenes stated there were more than 60 books with supplemental materials written for the high school level all of which were written to carry out the
recommendations from the CEEB commission of mathematics. Those recommendations were:

- Treatment of inequalities along with equations
- Structure and proof in algebra
- Integrated plane and solid geometry with coordinate methods.
- Integrated algebra and trigonometry
- A twelfth grade course in elementary functions

All of this brought excited teachers with high expectations for all these changes to their math curricula. Instructors were given several days during the summer for training on how to teach these new curricula that they thought would bring such great results. Unfortunately, it all seemed to come to a dead end in the 1970’s, which some refer to as the decade of “back to the basics.” Herrera and Owens stated, “The precise, structuralist language of sets, logic, and algebraic structures, hallmarks of the new math curriculum, were abandoned in favor of more emphasis on computation and algebraic manipulations” (p. 8). Not only were the curricula abandoned, but the pedagogical approaches also were abandoned and went from the new discovery-based learning back to a prescriptive hierarchical approach in teaching.

In reaction to the “back to the basics” era and to a number of influential leaders in the mathematics world that felt several attributes of mathematics needed to be implemented in schools around the country, NCTM’s Curriculum and Evaluations Standards for School Mathematics launched a new reform in 1989. This reform would
include making problem solving a curricular focus, broaden basic skills to include estimation and logical reasoning, have more application problems and involve more technology in all math classrooms. There are undoubtedly some similar comparisons of the current reform and the “new math” reform of the 1960’s. However, some are commenting that the current reform, which they are calling the new “new math,” is a reincarnation of the 1960’s “new math.” Also, that both the 1960’s reform of “new math” and the reform that is currently trying to make an impact are being viewed as a pedagogical failure.

Even with the criticisms, there are many that view this reform as a necessary change to ensure a successful mathematics program. The math curriculum specialist that works for the researcher’s district invited the researcher to participate in a professional development opportunity called Best Practice in Teaching Mathematics. The professional development promoted and helped to train teachers to use mathematical discourse and discovery based teaching in their classrooms. All of the math teachers in the researcher’s department were asked to participate, but only the researcher and one other colleague participated due to the unpopularity of this reform among the veteran teachers at the school.

The fact that there is very strong criticism of the current reform and the researcher seeing veteran teachers being successful in teaching mathematics the “old way” leaves him wondering if promoting mathematical discourse and having a constructionist approach in teaching mathematics is, in fact, a necessary attribute to successfully teaching mathematics.
In this research proposal, the researcher is going to take some necessary steps to ensure a successful research project. He is first going to describe what mathematical discourse is. He will proceed by stating some viewpoints given by other researchers that are for mathematical discourse and against it. He will then discuss the type of curricula that promotes it and see if those were to be implemented how it would affect student engagement in learning mathematics and their perception of mathematics.

**Literature Review**

There are many different types of teaching styles and it certainly is not black and white, but most styles can fall into one of two categories. The first category is student-centered learning, which is more of the constructivist approach and teacher-centered learning, which is more of the objectivist approach. Teacher-centered versus student-centered instruction has been the debate for a lot of mathematics teachers. Traditionally, mathematics has been taught by use of teacher-centered instruction, where computation, procedural facts and skill acquisition are emphasized. However, over the past 20 years, mathematics education is under some extensive questioning. The effectiveness, retention, application and the usefulness of teacher-centered instruction are in question. Teachers are not the only ones questioning this; administration, community leaders and parents all play a significant and crucial role on how math is taught in classrooms.

*Objectivism*
If teaching styles were to be put on a continuum, which many say it is, constructivism is on the opposite end of objectivism. Objectivism is a view that knowledge exists outside the bodies of those that seek it. Knowledge is out there in the world residing in books and is independent of a thinking person. Learners are to view objects, events and phenomena with an objective mind, which is assumed to be separate from cognitive processes such as imagination, intuitions, feelings, values and beliefs. Educational researcher, Jamin Carson (2006) gives four explicit and specific examples of what characterizes objectivism. Those are four characteristics are:

- Objective reality exists outside and independent of the individual and can be objectively known apart from one’s gender, class, race, genetics, sexual orientation, religion, beliefs, or emotions.
- Objectivists hold that knowledge and concepts are human abstractions from concrete or actual experiences or things in reality.
- Objectivists maintain that knowledge is contextual, which means that knowledge is absolute only if one includes the context in which it was formed. If the context is dropped, then one renders the knowledge meaningless.
- The educational implication of objectivism is that teachers should, first and foremost, be knowledgeable of their subject matter. A subject is reality in conceptual form. A good teacher transforms the concepts of his or her subject into their perceptual equivalents so that the student can understand them. (p.2)
It is easy to see from her characteristics of objectivism, especially the fourth definition, that educators who are objectivist in nature feel very strongly that the knowledge students receive must be received independently from them. That is the teacher, along with the textbook, is the source of knowledge and students can only obtain that knowledge through them. It is from these definitions that objectivism and teacher-centered learning are associated.

Constructivism

As stated earlier, constructivism is a philosophical approach that was founded on the premise that by reflection on personal experience, one can construct their own understanding of the world they live in. A constructivist feels that learning is done through the use of prior knowledge, or personal experience and independent reality to construct knowledge. Educational researchers Steve Harlow, Rhoda Cummings, and Suzanne M. Aberasturi (2006) wrote an article in which they were attempting to clear up misconceptions about constructivism.

There seems to be misconceptions that constructivism is learning of new knowledge only through prior knowledge and what the learner already knows. “The authors’ view of constructivism holds that an independent reality does exist outside the mental world of the individual and that mental concepts and schemes are developed through the interplay of the constuctive powers of the mind and the independence of the external world” (Harlow, Cummings & Aberasturi, 2006, p.1). In fact, they referred to
Popper’s paradigm of “Three worlds” as a way to show the constructivist approach.

Popper’s three worlds are:

- **World one** is the external world of physical states and processes as they exist in nature.

- **World two** is a personal interpretation of world one that is filtered through the senses and experience. World Two is subjective in that it is comprised of internal mental states and feelings, volitions and whims, and ideas and interpretations.

- **World three** refers to products and creations of human minds, such as art, language, ethics, books, science, institutions, architecture, and other human forms and creations. (p.2)

Learning through the constructivist approach states that a person will take their interpretation of some physical processes and create their own meaning of it through prior knowledge and personal experiences.

*Teacher-centered learning*

Of the two different teaching styles, teacher-centered and student-centered; teacher-centered is easiest to describe and is currently the most common way of teaching mathematics. Teacher-centered learning is a process of teaching where the teacher is the source of knowledge. Teacher-centered classrooms are generally arranged in rows and columns and learning is done primarily through lecture-based instructions. The teacher is responsible for the transmission of specific, accurate, and generally scripted information.
to the students and the students are required to take notes and apply them to practice problems that reflect that lecture. There is virtually no student-to-student communication and the little teacher to student communication that there is requires a low level of thinking responses. Educational researcher Katsuko Hara (1995) stated that the function of curriculum that promotes teacher-centered learning is to “transmit facts, skills and values through mastering knowledge” (p.2). She continues on to say that “the curriculum focuses on learning the correct interpretation and understanding, and identifying a central theme and the author’s intent. The teacher determines all teaching content and children are just the receivers of knowledge” (p.2). The teacher does most of the work in the learning process for the students. The learner is just responsible for receiving the information and regurgitating it back during the assessment.

There are very little application components to teacher-centered learning and the students are not encouraged to explore their own thinking. “The major aim of this approach is to transmit values, attitudes and ideas from teacher to children. It is demanded that children master what is in books and in teachers’ lectures” (Hara, 1995, p.3). This approach is competency based and students are assessed by their ability to remember the required information. In order for this approach to be successful, the curriculum needs to be broken down into small components and in many cases; these small components are not put together to form the big picture.

*Student-Centered Learning*
Then there is the student-centered approach to mathematics instruction, which is based heavily on conceptual understanding, problems solving and mathematical discourse. This process is where the students are the center of the mathematics curricula. The students, through the guidance of the instructor, develop conjectures and test them. They work cooperatively with two or three other students, which form a team and all the teams in the classroom form a community of learners. With mutual respect for learning, they go through investigations and discovery lessons that the instructor designs to help conceptually understand the major mathematical topics. This approach to teaching mathematics is very new and very different for most teachers.

In January of 1999, Azita Manouchehri and Mary Enderson did a case study in a classroom of mathematics students. They noticed a classroom of students where the environment was created so that learning was “oriented around students’ own desires for construction relationships, discovering patterns, making conjectures, forming arguments to support their conjectures, and sharing those arguments with their peers” (p.5). They continue to say that; “this approach requires altering students’ perceptions of the role of the teacher, the teachers’ expectations, and their own role as learners within a classroom” (p.8). This type of environment is very different from a teacher centered classroom because the facilitator of knowledge is not coming from a textbook or a teacher, but is coming from the students’ themselves and is being developed from prior knowledge and investigations.
One cannot just move some seats around to form groups and expect for this type of environment and learning to happen. This type of environment is very hard to create and does not happen overnight. Manouchehri and Enderson (1999) say, the teacher must address expectations in class and insist that students solve personally challenging problems, explain personal solutions to their peers, listen to and try to make sense of one another’s explanation, attempt to achieve consensus about an answer, and resolve conflicting interpretations and solutions (p.8).

In order to achieve an environment that fosters these guides of social norms, there is a lot of preparation and planning that goes into it. Then the teacher needs to be ready to drop everything that was planned and improvise, because more often then not, the students discussion lead a different path that is worthy of exploring.

Against teacher-centered learning

It has been said that the curriculum that some schools are currently using to teach mathematics, which focuses on teacher-centered instruction is seriously damaging the mathematical health of our children. Sandra L. Bryan and Adriane E. L. Dorrington (2004) stated in an article that, “knowledge is constructed as the learner engages with the problem because he or she may recognize a need for a particular procedure or the application of a specific concept” (p. 4). The traditional method of teaching in giving procedural tasks and than drill on reinforcing those tasks would rarely promote students with the need to know the information. This article goes on to say that these types of
curricula need to be eliminated and replaced with one’s that promote conceptual understanding, problems solving and mathematical discourse as primary goals for instruction.

According to NCTM and other mathematics experts, all teachers need to comply with the reform if they want all their students to succeed. One suggestion on why teachers are having a hard time changing is that they want to teach math as they were taught during their K-12 experience and, for most, the way they were trained to teach during their college years. Bryan and Dorrington (2004) suggest a reason for not complying is that “many mathematics teachers demonstrate their understanding of mathematics by using procedural or algorithmic explanations and their understanding often is fragmented and lacks coherency and they cannot explain the mathematical reasoning behind the algorithms” (p.3). Another reason mentioned was some teachers feel that a student’s ability to learn mathematics is predetermined and that cognitively, some students just cannot do math. Of course, there are those that feel that this reform is unnecessary and in some cases, the wrong approach.

Against student-centered learning

There are others that say that conceptual-based and problem solving curricula de-emphasize the importance of mathematics and that is the ability to do it. Taking away the procedural aspects of mathematics is what is crippling mathematics students. There are some organizations out there that are opposed to the reform movement in changing mathematics. Organizations like Honest Open Logical Debate on math reform
(H.O.L.D.) and Mathematically Correct, which are two of the most active organizations right now state that, “de-emphasizing correct answers and competence in basic procedures, as the reformers wish, will produce students who simply cannot do the math they need to” (Ross, p.2). It is not good enough that a student can show a teacher 20 different visual representations of what it means to multiply seven by eight, if they do not have the answer to that fact memorized.

These organizations in retrospect advocate teaching traditional algorithms and drilling students to ensure competency in basic skills. A strong math program, in their view, recognizes the hierarchical nature of mathematics and builds on it from one grade to the next. The math program should teach explicit skills and concepts and then students should be drilled. The majority of the class time should be spent in teacher-directed whole-class instruction. They push school boards to reject any curricula that do not advocate those attributes and they want curricula that actually solve math problems.

*The issue*

It is hard to say which approach is more effective and this is not the purpose of this research. Although it is necessary to illustrate that there is a debate on the methodology of mathematics, this research is to determine what mathematical discourse is, which curricula promotes it, and if implemented how will it affect students engagement and attitudes toward mathematics? Mathematical discourse only consistently occurs in student-centered classrooms where cooperative learning is taking place. It is easy to see that if a classroom is successful in using curricula that promote
high level of student-to-student engagement through cooperative learning that mathematical discourse will be achieved, but how does one effectively implement such a curriculum?

*Mathematical Discourse*

Many teachers that are excited about this new way of teaching are trying to implement it into their classroom. There are a couple of aspects that need to be taken into account when implementing such a complicated method. The first things that need to be understood is that complete change is not necessarily effective and could cause more harm than good. Although the intention is great, it should not be considered. There are too many attributes to change from a teacher-centered instructor to a student-centered instructor and trying to change all of them at the same time is nearly impossible. It is better for a teacher to choice a couple of attributes, like promoting team work and justification of work. Once they get really good at facilitating those, then they can add others as time goes on. Other things to consider are, what types of discourse is going to be used? What are the classroom expectations or social norms going to consist of? What role is the teacher going to have in the learning environment?

*Social norms*

Of all those elements, social norms are going to be the biggest part of making a classroom successful in student-centered learning. One thing that needs to be addressed and continually visited is community agreements. Community agreements need to be
made by the students for the students and with little or no restrictions from the teacher. This can be, and the researcher suggests it should be, different from classroom rules or policies and procedures. These agreements are on how students should properly conduct themselves in a cooperative learning environment. Once produced by the students, the agreements should be displayed somewhere in the classroom as a reference when needed.

Once a social norm is established, it is time to practice those social norms with daily mathematical activities that promote cooperative learning and mathematical discourse. One way to insure that groups are functioning effectively is to assign roles for each group member to have them feel and understand they are part of the team and accountability is going to be measured. Alice F. Artzt (1999) writes, “that when small-group work is structured so that students are made to feel mutually interdependent and individually accountable for their work, maximum communication and active participation of all group members are likely to occur” (p.4). To insure mutual interdependence from all team members something to consider is having worthwhile tasks that are hard enough so that all members are required to participate, but not too hard, so that they all give up quickly.

**Time management**

There also needs to be the right amount of time restraint, so that students feel pressure to produce. “Students need to be given enough time to engage in rich discourse in which they have the patience to listen to and consider one another’s ideas, ask questions, and give careful explanations. However, they should not be given so much
time that they lose incentive to work together efficiently” (Artzt, 1999, p.5). Also, do not give such detailed and specific instructions, that the work is done for them, and it then becomes a procedural task. Give just enough so that everyone can get started, but they still need to communicate with their team members to determine following procedures. Having multiple representations of the same problem will also help by enriching classroom discussions. Lastly make it a classroom norm that every team member needs to be ready to articulate a response to any question on a given task, regardless if they are the original generator of that response. In other words, it is okay if that member did not come up with the answer, but they need to now know the answer as a result of their team discussing it. All these attributes will help in facilitating mathematical discourse and promoting mutual interdependence and individual accountability.

**Understanding mathematical Discourse**

Mathematical discourse is the main objective in achieving cooperative, student-centered learning in a classroom. This has a lot to do with the fact that there are many teachers who have not seen true mathematical discourse in action in a classroom. Laura R. Van Zoest and Ann Enyart (1998) state, “Discourse can be a problem area for teachers when they do not realize how important it is and have not seen or experienced dynamic classroom discourse” (p.1). They continue on to say, “once a teacher has seen students defending their mathematical ideas, questioning other students’ ideas, and helping clarify the mathematics to one another, the importance of discourse becomes clear” (p.1). There are teachers who are in the process of implementing student-centered learning and are
still using many of the traditional methods in teaching, but in a team environment. They do not realizing how much they are missing from their instructions by not promoting mathematical discourse because they have never truly seen it done. It is not until they observe it or see it in action do they truly understand how much of an impact it can make on student engagement and they become more willing to seek professional development to achieve it.

Types of discourse

Types of mathematical discourse need to be understood when trying to facilitate student-centered learning. Not all mathematical discourse will promote student-centered learning, but all play a crucial role in the learning process. Discourse predominantly from the teacher and done in a classroom discussion is what Eric Knuth and Dominic Peressini (2001) refer to as univocal discourse and what Jacqueline Leonard refers to as institutionalized discourse. “Univocal discourse is characterized by communication in which the listener receives the exact message that the speaker intends for the listener to receive” (p.2). “Institutionalized discourse is structured around teachers cues and follows rules and protocols” (Leonard, 2000, p.2). As it can be seen both are virtually the same with one exception. Univocal discourse seems to be when the instructor does virtually all the talking and gives information to the students whereas, institutionalized discourse seems to be more when the teacher gives clues and leading questions to continue problems. Although both are examples of mathematical discourse in a classroom, both are very much teacher-centered.
When discourse is predominantly a student-to-student interaction that arises from group discussions Knuth and Peressini (2001) call that dialogic discourse and Leonard (2000) calls that emergent discourse. “Dialogic discourse is characterized by give and take communication in which the listener initially receives the exact message sent by the speaker and generates meaning by using dialogue as a thinking device” (Knuth and Peressini, 2001, p.2). Leonard (2000) says that, “emergent classroom discourse happens during small group tasks because the context encourages more on-task and interacting behavior” (p.2). Again both seem to be very similar with little to no difference among them. It was noted that in both Knuth and Peressini’s article and Leonard’s article that discourse can quickly shift back and forth from univocal or institutionalized to dialogic or emergent. “Both univocal and dialogic can be seen as appropriate forms of discourse, depending on the daily instructional goals” (Knuth & Peressini, 2001, p. 8). Both articles noted that the ability to go back and forth occurs when classroom social norms are established and that both types are healthy and effective in successfully teaching mathematics.

Implementation of mathematical discourse

Implementation of mathematical discourse is a hard aspect of cooperative learning to achieve, but one article titled Talking mathematics: ‘Going slow’ and ‘letting go’ did a great job in listing some things to consider. There were five items altogether. The five helpful hints are:

- Need to plan and schedule more time for doing mathematics.
• Asking different kinds of question that promote high levels of thinking and refraining from accepting the first right answer.

• Require students to share their thinking, even if it is just is small groups at first and students will become better at doing it.

• Structure mathematics experiences to focus on finding patterns, describing and analyzing those patterns, and devising conjectures, generalizations, formulas, and rules about how mathematical objects behave.

• GOING SLOW and LETTING GO

First of all it is important to understand that change of this magnitude does not occur over night, especially not effectively. Time needs to be allotted in order for the change to be successful through transitional stages. Make sure to change things slowly and only so much that a teacher still feels comfortable teaching their class. This is a very difficult concept for many teachers, because they strive to be the best they can and have a hard time doing something the old way, if they know there is a better way, but going slow is a must.

The last hint is learning how to let go. “This process was accompanied by a loss of the comfortable feeling of closure and tidiness that mathematics once seemed to embody” (Talking Mathematics, 1993, p.4). Let students lead discussions and do not always feel like they need someone with an authoritative position to step in and correct a misconception or they need to have closure to a topic at the end of each day. Letting go is hard to do, especially with the pressures of making sure all topics that need to be
covered in an entire school year are covered and making sure lessons are strategically planned due to hours of preparation go they way they are intended and that student get out of the lessons what they are supposed to. However, sometimes cooperative teaching requires teachers to just simply let go. Teachers need to let go of a strategically planned lesson and allow for students to articulate their own approaches and give more time for reflection and analysis. In doing this teachers, should realize that they are not hurting their students, but are only strengthening their mathematical thinking.

Perception of mathematical discourse and student-centered learning

Now that the researcher has provided a brief overview of how to successfully implement a student-centered curriculum and how this implementation promotes high levels of mathematical discourse, the learner’s perception of it needs to be considered. Although, the researcher did not find much research that came directly from the learners’ thoughts, he did find a large number of researchers that indicated that successful implementation did in fact engage the learner and give more meaning to the mathematics being studied. Some research had actual comments from students. All comments that the researcher found were of a positive nature and did not allude to any discomfort or dislike of cooperative learning and the use of mathematical discourse in their classrooms.

Educational researchers Zoest and Enyart (1998) noted that they helped a teacher just implementing this new way of teaching. At first, the teacher noticed the students struggled with the idea of always having to lead mathematical discussions and were very hesitant to go up to the front of the class to explain their reasoning. However, with
persistence and encouragement from the teacher, those students started to listen more attentively to one another’s thoughts and they began to feel more comfortable coming up to present to the class. The researcher was pleased to see that after awhile, “students would just march up to the front of the classroom, take the marker out of my hand and explain how he or she would approach a problem, saying, Mrs. Enyart, I just have to tell them a great way to do this” (Zoest & Enyart, 1998, p.4).

Enyart also noticed as time went on that if an incorrect answer was presented that it did not take very much time before a student would correct that response. Also, it was noted that if a question was left unanswered at the end of the day or left with an incorrect answer, leaving it for the next day did not effect student’s achievement or confuse them. Zoest and Enyart (1998) noted that, “giving a student a day to think about it does not mean that she or he will embrace the misconception more tightly” (p.4). It was noted that in most case allowing a misconception to be left alone for a night gave a fresh start the next day in tackling the problem and also allowed some time for the teacher to strategize the best way of fixing that misconception. By the end of the year, this classroom that the researchers helped began to be more confident and the teacher did less talking and the students talked more. It worked out better and better, since students have a language and understand their peers at a different level than the teacher does and misconceptions are caught and fixed much faster when done by the students.

In another research article written by researchers Kay McClain, Maggie McGatta and Lynn L. Hodge, (2000) included some other comments that were from students. One student noted, “I liked the discussions because I can share ideas and get some back. Even
when people disagree, it makes you think” (p.5). Another student stated, “most of the
time, teachers don’t care about what you think, but in here we get to share our opinions-
that’s the whole discussion” (p.5). Lastly, one student mentioned, “It’s like the teacher
teaches you, but you also teach the teacher” (p.5). All of these comments are indications
that their classroom norms consisted of mathematical discourse, analyzing, generalizing,
creating conjectures and proving them. It is evident from those comments that those
students are doing high level thinking much of the time in their math classes.

In summary, it is obvious that there are opposing methodologies in how
mathematics should be taught and the validity of student-centered teaching is under
investigation. The researcher’s intent is to focus on the main attribute of student-centered
teaching, which is mathematical discourse, and to see if when it is implemented how
effective it is in engaging students. The researcher is also interested in seeing students’
perceptions of mathematics when mathematical discourse is implemented.
As indicated in the literature review, methodology is a crucial aspect in education. The researcher, as an educator, is in the middle of a pivotal change in education as pedagogical differences are being questioned. The fact that the foundation for student-centered learning is implementing and fostering successful mathematical discourse leaves the researcher with some goals for this action research project. The goal of this action research project is to understand what mathematical discourse is. What type of curricula, whether it be curricula geared toward student-centered or curricula geared toward teacher-centered, promotes it and if implemented in a classroom, how will the curricula with mathematical discourse affect student engagement and perception toward mathematics?

Throughout the course of this action research project, the researcher will use several techniques to collect data to be analyzed. The researcher will have a video recorder set up in his room so that lessons can be video taped for analyzing. The researcher plans on having several lessons taped during the course of four different units. The units will be grouped into two sets. The two sets, each which are two units long, will focus on the different methodology; student-centered and teacher-centered, as its focus for analyzing. Along with videotaping and analyzing his own classroom, the researcher, will also observe and analyze several of his colleagues’ classrooms in which
methodologies differ to gain insight on their effectiveness in promoting student engagement in mathematics.

The researcher will also distribute a survey. The results of the survey will indicate students’ perception of how they feel mathematics should be presented to them by the completion of a survey. The survey will be given prior to and after the completion of the action research project, to measure any changes in student perception. The survey will include questions such as how much students enjoy math, how often they speak in class about math, how often they work in groups, how often they contribute in group discussions, how often they learn something new in math class and allow some room for personal comments.

The researcher hopes with the observations of himself, his colleagues and with the surveys taken by his students that he will gain some insight on this crucial and very debatable topic of student-centered learning and the push for mathematical discourse.
Action Research Plan

Chapter Four-The Action Plan

As previously indicated in the literature review, methodology is a crucial aspect in education. The researcher, as an educator, is in the middle of a pivotal change in education as pedagogical differences are being questioned. The fact that the foundation for student-centered learning is implementing and fostering successful mathematical discourse leaves the researcher with some goals for this action research project. The goal of this action research project is to understand what mathematical discourse is. What type of curricula, whether it be curricula geared toward student-centered or curricula geared toward teacher-centered, promotes it and if implemented in a classroom, how will the curricula with mathematical discourse affect student engagement and perception toward mathematics?

Possible Solutions

In an education research article, Laura R Van Zoest and Ann Enyart shared some insights on how to make mathematical discourse a reality in a mathematics classroom. “This article describes a professional-development activity that offers a way for teachers to analyze their current classroom discourse practice and move toward the goal of dynamic and productive mathematical discourse” (1998, p. 2). They had a seven step processes that was originally done in a three-year summer institute with a large number
of teachers, in which they ended with a masters degree. This process would be best implemented if done as a department and not individually. The seven steps are:

- Videotape or audiotape for a minimum of fifteen minutes a segment of your classroom that involves talk, before reading or rereading the standards on discourse.
- Read the second, third, and fourth standards for teaching mathematics. (A book written by NCTM)
- Listen to or watch your classroom segment, and analyze the discourse in relation to the discourse standards.
- Choose one aspect of the discourse standards that you would like to implement to improve in your practice. Think about how you will meet this goal.
- Videotape or audiotape for a minimum of fifteen minutes a segment of your class in which you are making a conscious effort to carry out your goal from item 4.
- Listen to or watch your second classroom segment, and reflect on why happened.
- Bring to class a least a two-page written summary of your analysis and reflections. (1998)

Although many of the steps indicated by Zoest and Enyart are going to be part of the researchers steps in implementing mathematical discourse into his classroom, he
rejects this process. It is rejected due to not having NCTM’s standards on discourse in a classroom and the fact that his department will not be interested in participating in this process. The researcher needs a process that can be done primarily individually with minimal assistance from colleagues.

Another possible implementation of mathematical discourse in a classroom was given by Azita Manauchehri and Mary C Enderson in an educational research article. Their information was two fold, which included intervention to promoting discourse and classroom organizations in providing the best opportunity to promote discourse. “Creating a classroom environment conducive to promoting discourse requires consideration of, and attention to, both the social and mathematical elements within the learning environment” (Manauchehri & Enderson, 1999, p. 9). The researcher will first start with classroom organization or social intervention as it is the first that needs to be established in order to successfully implement mathematical discourse. Some things that were mentioned to consider are:

Social interventions

- Create a social environment by addressing expectations in the classroom.
- Establish a classroom culture by creating or listing some social norms or principles that need to be followed
- Alter student’s perception of the role of the teacher from being the authority of learning in hopes to motivate students to rely on one another for validating their results.
- Take specific incidents in which students are or are not following these social norms to capitalize or reinforce their behavior.

Mathematical interventions

- Train students on group norms and promote team dynamics possible by giving them team roles that will help establish teamwork.
- Promote in sharing ideas and elaborating on their thinking to justify their thoughts.
- Expand boundary of exploration by asking leading questions that will encourage students to analyze thoughts and ideas that have been addressed.
- Invite multiple representations of ideas.
- Make connections among different discoveries in hopes to foster deeper understanding.
- Promote interdependence and individual accountability and make sure every member is ready to present and articulate their team’s findings. (1999)

The research finds this implementation of promoting mathematical discourse to be appropriate for how he plans on implanting it in his classroom. He does, however, reject parts of it. The researcher is not ready and feels that his students will not be ready to take himself completely out of the role of authority. The researcher will also not use team roles in hope to facilitate mathematical discourse or promote a health team dynamics because it has be tried in the past and unsuccessful. The remaining attributes aligns with the researchers plan and implementation process.
The last example of a possible implementation processes that can be done was written by an unknown author in an education journal that is geared towards middle school mathematics. This implementation suggestions are similar to the previous one indicated by Manauchehri and Enderson. The suggestions are:

- Teachers need to plan and schedule more time for mathematics to allow for mathematical discourse to truly emerge.
- Teachers need to ask different kinds of questions and refrain from accepting the first right answer offered by a student.
- Teachers need to require students to share their thinking and students will become better at doing so.
- Teachers need to structure mathematics experience to focus on finding patterns, describing and analyzing those patterns, and devising conjectures, generalizations, formulas, and rules about how mathematical objects behave.
- Teachers need to work on going slow and letting go. Go slow so that mathematical discourse has the opportunity to emerge and letting go of a lesson plan that does not go as intended in allowing student the opportunity to analyze and discuss their own thoughts and findings.

(1993)

Again, the researcher approves this plan with the understanding that the first suggestion is not applicable to him in the fact that all of his class time is devoted to
mathematics. All of these attributes seem to fit the researchers need to properly and effectively implement mathematical discourse, especially part five; which indicate the need to go slow and let go, something that he is having difficulty with.

**Action Plan**

The researcher plans on implementing this project at the beginning of the 2007-2008 school year and will go for the full 18 weeks, which is exactly one semester. The researcher will use the implementation suggestions and strategies above in promoting mathematical discourse. The researcher also wants to see how, if at all, effective implanting and promoting mathematical discourse is to student engagement and performance in class. In order to achieve this, the researcher will do several parts, which was indicated in chapter three of this researcher proposal. The time line for this 18 week project is as follows.

**August-September:** The researcher will make sure to have all of his student surveys and parent notification and approvals ready for the beginning of the year. The researcher will meet with his advisor to make sure the research project proposal is approved and take any suggestions that are given in hopes to make this research a smooth and successful experience.

**September-October:** Prior to taping, the researcher will have students take home a parent notification and approval letter that allows the student to participate in the research and
then he will have students feel out the first survey. The researcher will get student comfortable with a video camera in the classroom and start taping some teacher centered lessons for analyzing at a later time. The researcher is planning on taking these two months in using teacher centered instruction and teaching to complete the two unit lessons. Once the researcher has gone through the two units and the students have been assessed, he will then use the remaining time from these two months to start implementing some cooperative learning and mathematical discourse strategies into his teaching. During this time, most likely on his prep period, the researcher will visit other mathematics classrooms that his colleagues teach and take some filed notes on how much mathematical discourse is being used in their classrooms.

November-December: The researcher will then teach two more units using cooperative learning and student centered strategies in his instructions to promote mathematical discourse. He will video tape these lessons as well for analyzing at a later time in hope to sees some changes in student engagement. Once the two lessons are done and they have been assessed, the researcher will then give his student the last survey. During this time, most likely on his prep period, the researcher will continue to visit other mathematics classrooms that his colleagues teach and take some filed notes on how much mathematical discourse is being used in their classrooms. This should take him to the end of the semester, where he will give a semester final and see if there is a relationship between retention and the two different teaching methods. The researcher then only has analyzing of information left for his project. He will spend the rest of the time breaking
down his film, comparing survey responses, taking a look at his field notes from his colleague’s classrooms, comparing assessment scores and looking at his journal to see if he has gained any insight on the effectiveness that mathematical discourse has or does not have on student engagement and perception towards math.
The methods teachers employ are critical to student learning. The researcher, as an educator, is in the middle of a pivotal change in education because pedagogical differences are being questioned in the math department of the high school research site. The fact that the foundation for student-centered learning is implementing and fostering successful mathematical discourse leaves the researcher with some ideas for this action research project. The goal of this action research project is to understand what mathematical discourse is, the type of instruction, whether teacher-directed or student-centered, promotes it, and if implemented in a classroom, how would the methods of teaching affect student engagement and perception toward mathematics?

The researcher employed a well-thought out research plan that included a pre-survey (Appendix A) asking 10 questions. This gave an indication on how the students perceived mathematics being taught and the amount of mathematical discourse they felt was present. After some initial training on team-building and cooperative learning, the researcher spent the first five weeks teaching two full units with instructional methods that were student-centered and discovery based. After the second unit, the researcher than spent another five weeks teaching two full units with methods that was teacher-centered and lecture-based. After that, the researcher returned back to student-centered, discovery based instruction, because he was most comfortable with that method. At that
point the action research was complete other than retrieving some data on test scores from the semester exam.

Throughout the 10 weeks a weekly journal of field notes kept and a video camera was present in the room so that mathematical discourse could be heard and evaluated. There were also individual short-term retention assessments given with each chapter, including a quiz, and a chapter test. With the end of the action research, a post survey (Appendix A) was given with exactly the same ten questions to measure any changes perceived by the students. Long term evaluation was measured by a semester exam at the end of the 18-week research project.

The author will now review the survey results, analyze the video information and take a look at assessments in relation to the instructional methods utilized in this action research project. He will complete the report by looking at possible topics for further research.

*Survey Results:*

The first step taken by the researcher was to evaluate students’ perceptions about mathematics and how they felt mathematics was presented to them. This was done before any lessons were presented by the researcher. The intention was to evaluate their perception about mathematics with no influence from the researcher. This was accomplished by the use of a survey. The researcher then gave exactly the same survey to the students at the end of the action research to see if there were any changes in responses.
The first question on the survey asked how often the student enjoyed math. For all questions the students had a choice of answering (N) never, (S) sometimes, (U) usually, (M) most of the time or (A) all the time. The purpose of this question was to determine how the students felt about math before they ever had a lesson presented to them by the researcher. The following graphs show the pre-research responses and the post-research responses.

This survey question shows that little change occurred by the action research on the students’ enjoyment of math class. Although most movement was in the positive direction there was not enough to indicate a meaningful connection with the action research.
Question number two, four and 10 relate to students’ perception on a class that is lecture-based and teacher-driven. The three questions asked how often their teacher spends time in class talking about math and giving them important information and whether they prefer it that way or not. The graphs below show those results.
Overall Survey Results
Question #4: How often does your teacher tell you how to do a math problem before you or your team figure it out?

![Bar chart showing responses to Question #4]

Overall Survey Results
Question #10: If you had a choice, how often would you want your teacher to present math concepts as you take notes?

![Bar chart showing responses to Question #10]
These results are not surprising to the researcher due to the fact that he spent the same amount of time in a lecture based environment as he did in a student-centered environment. The researcher is little bit disappointed, but not surprised on the results from question number 10, which asked how often would the student prefer for their teacher to give them mathematical concepts as they take notes. The reason why the researcher is not surprised is because it is easier for information to be given then it is to discover the information cooperatively. It makes sense for students to want the easiest form of obtaining the information, but the question that needs to be, and will be answered, is which one is more beneficial for the students?

Questions number three, five, six, and nine are related to students’ perception on team work and leaning mathematics cooperatively. They ask whether the students prefer learning mathematics in teams, whether they contribute to the learning process when they are in teams and if they had the choice, whether they would work in groups as opposed to individually. The graphs below show the results.
Overall Survey Results
Question #3: How much time would you say you spend in a math class period talking about math?

Overall Survey Questions
Question #5: How often do you work in a group or team in your math class?
Overall Survey Results

Question #6: If you work in a team or group in your math class, how often would you say you contribute to your team’s learning?

- Never
- Sometimes
- Usually
- Most of the time
- All of the time

Response:

Students

Pre-Research Survey

Post-Research Survey

Overall Survey Results

Question #9: If you had a choice, how often in math class would you want to work in a group?

- Never
- Sometimes
- Usually
- Most of the time
- All of the time

Response:

Students

Pre-Research Survey

Post-Research Survey
The results of these questions show that students, overall, were used to teamwork when coming into the researcher’s class and have seen it before. They prefer to be in a group setting and although they feel that they do not contribute very much to the mathematical discourse in their group, they do feel that it happens sometimes to all of the time when they are in that situation. Again, the researcher is not surprised at the results, which indicated that most students feel like they do not participate or contribute to the teams leaning when they are working in groups, which most of the time is not true. From the researcher’s experience even the most passive student contributes to his or her group’s learning on a daily basis even if they feel like they do not. Usually that feeling comes from the passive student because they are not initiating the contribution. However, when mathematical discourse is initiated by someone else even the most passive student rises to the occasion and has some very useful and helpful insights. The results also show that even though they do not feel like they contribute, they would much rather be in a group setting when leaning mathematics and that mathematical discourse does happen when they are put in that situation.

Questions number seven and eight were asked in order to determine how useful students found mathematics in their everyday lives. Whether they felt like they used it and how often they felt like they learned something new in math class. The results to those questions are below.
Overall Survey Results

Question #7: How often do you use math outside of your classroom?

- Never
- Sometimes
- Usually
- Most of the time
- All of the time

Response: Students

- Pre-Research Survey
- Post-Research Survey

Overall Survey Results

Question #8: Every day in math class, how often would you say you are learning something new?

- Never
- Sometimes
- Usually
- Most of the time
- All of the time

Response: Students

- Pre-Research Survey
- Post-Research Survey
It was nice for the researcher to see that the students’ perception on the need for mathematics and everyday practical use was not completely unnoticed. Students seem to feel like the need for mathematics in their lives is important and overall felt that even more so as the action research went on.

The last question on the survey was a request for comments that the students might have that they felt were not addressed in the survey. Most comments were similar and indicated they liked working in groups and felt like time was better spent since they had people they could ask questions of instead of having to wait for the teacher to answer them. Here are a few responses that were given. All responses are in Appendix B.

“I like working in groups because if I don’t understand something, I could ask my group members instead of the teacher.” (Female)

“Groups are good if you like who you sit by not cause you would talk all the time, but you feel more comfortable about talking about math or we can have in rows but you get to choose who you get to sit by” (Male)

“In rows you work alone, but in groups you get a chance to here how someone else thinks” (male, name: unknown)

“Being in groups is better because you get to check you answer with other people.” (Female)

“I think I liked working in rows better that way, I can concentrate and be more focused.” (Female)
“I like working in teams better because then you can hear more than one opinion and learn from it and figure out who’s right.” (Female)

**Video Analysis:**

Another part of the researcher’s analysis was to video tape classroom lessons and observe what the teacher was doing and what the students were doing. This helped to determine which instructional method promoted the most mathematical discourse. As was expected when the classroom was in a teacher-centered environment there was very little mathematical discourse occurring since the teacher spent the majority of the time lecturing as students took notes.

Although the teacher did give several opportunities for students to lean over to the neighbor next to them and share a thought or opinion, the video tape showed that very few students took that opportunity to talk about math. The researcher’s conclusion for this was the fact that all the students knew that the correct answer was going to be given to them by the teacher and they most likely felt like their thoughts were not significant. Most students wanted to get through the note taking as fast as they could so that they could get started on their homework in class to have as little as possible to do at home.

During the action research when the classroom was designed for student-centered learning, the environment and stage was set for mathematical discourse to occur. Students knew that information was not going to be given to them and that they needed to work cooperatively with their team to discover the major mathematical concepts for the
day. They did know that an overview was going to be given at the end of the period, but that the details were up to them to learn. An environment was created that allowed every student to not only feel accountable to learn the information for themselves, but that they also felt accountable for their peers understanding of the materials. They also knew that each day their assignment began with questions that would require a team effort and that the questions were going to be too hard for them to do by themselves. This helped ensure they got through the first part of the assignment, because they knew that if they did not, they were not going to be able to do it at home.

This stage resulted in a lot of mathematical discourse occurring. The video shows students talking with each other about mathematical topics, including sharing ideas, hypothesis and conjectures on a daily basis. They spent the majority of the time analyzing and generalizing information as a team and then personalizing it by recording their information or findings in their personal tool kit, which is like a journal.

These results were not a surprise to the researcher in that he knew that building a classroom environment in which students had to talk to each other to be successful in math would yield mathematical discourse. The researcher also knew that an environment that did not promote this; like a teacher-centered, lecture-based classroom, would not have as much mathematical discourse occurring. This was also evident with every visit that the researcher took in his colleagues’ classrooms. Those colleagues that had an environment that promoted mathematical discourse had students talking about math and those colleagues that did not, did not have students talking about math. The question that
still needs to be answered is which provides students the opportunity to learn and retain the most mathematical concepts possible.

Analyzing assessments:

The researcher feels like he has been successful in answering the majority of the question being asked from the beginning of this process. The last thing that needs to be addressed is which type of instruction promoted the best opportunity for learning and retaining of information. To answer this part of the question, the researcher took all four chapter tests that were given throughout this action research and analyzed them for immediate retention. He then gave a semester final about eight to nine weeks after the completion of the action research and analyzed the questions from the four chapters that were presented in the action research to measure long-term retention. Below are the results of chapter three and five, which were taught in lecture-based instruction.
In both chapters, the students’ average scores were below 70%, with chapter five being below 60%. This was very unlike the scores the researcher was used to with his Algebra 1 class. The overall average for those students in the lecture-based instruction was around 65% in short-term retention. The long term retention on those chapters showed a significant drop to 51% retention and the graph of those results are shown below.

The researcher then did the same analysis for the remainder of the chapters that were covered in that semester with all of these chapters being taught in student-centered, discovery based instruction. There is not an individual result for chapter six, due to the fact that it ended with the semester and the researcher did not feel that an individual test on chapter six needed to be done with the semester exam happening within days of the
completion of chapter six. Below are the immediate retention results for chapters one, two and four.
It is visually easy to see that students, on an average, did better on the chapter tests that were presented in a student-centered environment. The overall percentage for those three chapters was about 76% immediate retention of the curriculum. The semester exam showed the long-term retention to be around 70% for those chapters, which had a six percent drop. This was less of a drop than chapters three and five which dropped 14% from the individual chapter assessments to the semester assessment. The long-term retention for those chapters is shown below.

As shown above, chapter six is included in this graph as it was part of the semester exam. It is common for the researcher to see a drop in retention from individual
exam percentage to semester exam percentage, but a 14% drop is larger than expected. It should be noted that all materials are covered in a spiral fashion, in that there is no topic that is addressed and then never resurfaced. All chapter exams are on an average of 40% current material and 60% old material with the exception of the first chapter which is all new material. It should also be noted that the results above are percentages of correct answers from questions that were taught from the designated chapters, that is, the results of chapter four scores were determined by the chapter four exam questions that were current materials and no review problems were taken into account to determine retention percentage.

Next Step:

With the analysis of the data and the observations that the researcher made throughout this action research processes, it is evident to him that the students that he comes into contact with learn and retain mathematical information better when they are in an environment that promotes mathematical discourse. This action research adequately confirmed his suspicion and internal educational belief that students learn and retain information better when they are doing the math and the math is not simply given to them. The researcher challenges anyone that is still not convinced by this paper to reduplicate this easy to implement action research in their classroom and analyze the data themselves. The researcher believes there is more power and evidence in personally conducting action research, than there is in having someone promote that one way of teaching is better than the other.
Although there is extra initial prep time in having an environment that promotes mathematical discourse, the researcher feels that it is evident by this research and the analysis given that it is worth the extra time. The researcher also feels that mathematical discourse and student-centered learning can even be made better than he has established. He feels as he can get closer to having a math class that is self-efficient and requiring less of him, the better mathematicians and problem solvers students will become. This action research can be taken further by trying different methods of student-centered instructional methods that will take the teacher out of the information giving role.
References


Phi Delta Kappan (Vol. 74, Iss. 7; pg. 555, 4 pgs.)(March 1993). Bloomington, IN. *Talking mathematics: ‘Going slow’ and ‘letting go’*

Phi Delta Kappan (Vol. 75, Iss. 6; pg. 462, 6 pgs.)(February 1994). Bloomington, IN. *Teacher beliefs and the reform movement in mathematics education.*


Appendix A

Learning Math Survey

Date________________
Grade________________
Math class you are in right now________________
Gender______________

Please answer the following questions to the best of your ability. Remember that your name is not necessary and all information will be kept anonymous.

Please answer the following by circling the letter that best describes your answer.

Never (N), Sometimes (S), Usually (U), Most of the time (M), or All of the time (A)

1) In math class, how often do you enjoy math? N S U M A

2) How often does your teacher spend in a math class period lecturing about math? N S U M A

3) How much time would you say you spend in a math class period talking about math? N S U M A

4) How often does your teacher tell you how to do a math N S U M A
problem before you or your team figure it out?

5) How often do you work in a group or team in your math class? N S U M A

6) If you work in a team or group in your math class, how often would you say you contribute to your team’s learning? N S U M A

7) How often do you use math outside of your classroom? N S U M A

8) Every day in math class, how often would you say you are learning something new? N S U M A

9) If you had a choice, how often in math class would you want to work in a group? N S U M A

10) If you had a choice, how often would you want your teacher to present math concepts as you take notes? N S U M A

11) Comments that you feel need to be shared that were not addressed above.

Please use the back if you need more room.
Appendix B

Free responses from students post survey in no particular order.

- “I like working in teams better because I get a lot more done in class.” (female)
- “Working in groups is way better.” (male)
- “I think that you should give us some problems that are difficult to figure out.” (male)
- “I like working in teams better because than you can hear more than one opinion and learn from it and figure out who’s right.” (female)
- “I think that in a way I would learn more in rows, but in groups I learn and get my work done if I get along with the people in my group.” (female)
- “I think we should go back to the rows.” (female)
- “Groups are better.” (female)
- “I don’t like not being in a group.” (female)
- “This is a fun class.” (male)
- “That we were some times able to work in other groups.” (female)
- “I like being in groups.” (male)
- “I’ve learned a lot since this year started, Mr. Bentea is way cool.” (female)
- “I think we should try to figure problems out first to see how we are doing, then the teacher goes back to help us.” (female)
- “There is more room in groups.” (male)
• “I think that in rows people actually do stuff and learn instead of their group always giving answers.” (female)

• “If you are doing it alone then people couldn’t copy of you and not learn.” (female)

• “IDK. I like sports.” (male)

• “I would love to NEVER be in rows again, please. It helps me with others to explain to me.” (female)

• “I like the groups.” (male)

• “Brinks A Stud.” (male)

• “Be more explanatory.” (male)

• “Groups are good if you like who you sit by not cause you would talk all the time, but you feel more comfortable about talking about math or we can have in rows, but you get to choose who you get to sit by.” (male)

• “I like working in groups because if you don’t understand something, I could ask my group members instead of the teacher.” (female)

• “Groups are better to have help from others, but rows are easier, too, because you only worry about what you do.” (female)

• “In rows you work alone but in groups you get a chance to here how some one else thinks.” (male)

• “I like groups better because you get to work together and if you need help you have people to help you.” (female)
• “In the groups you can get help by your peers better than when you are by yourself.” (female)

• “I like when we sit in rows and columns because I am more concentrated on my work and it’s just better.” (female)

• “Being in groups is better because you get to check your answers with the other people.” (female)

• “Sometimes if you’re put in a not so great group working by yourself could be better, and you might get more work done.” (female)

• “Hi.” (female)

• “I think I like working in rows better that way I can concentrate and be more focused.” (female)

• “I would rather work in groups then in rows and columns.” (male)

• “I liked the rows better than the groups. I got more done and had more fun with it.” (male)

• “Less homework.” (male)

• “None.” (male)

• “I like groups a lot better than working individually but some people that are in the groups are not easy to work with and I would rather just work alone (the group I’m in now).” (female)

• “Put us back in Rows and Columns! Please I’m begging you! I HATE GROUPS!” (female)

• “Groups work is better than rows and columns.” (female)
Appendix C

Journal Notes

Week 1: Sept. 3-7

- This was the first week back with students.
  - Spent most of the time going over policies and procedures, getting to know each other and building a positive learning environment.
- Finishing up student survey’s and letter of consent for the students.
- Informed my colleagues of my action research plan and asked permission to sit in their classrooms to observe mathematical discourse.
- Set up camera without it running so students can get used to having it in the classroom.

Week 2: Sept. 10-14

- Handed out survey to students and letter of consent and asked to bring back to me by the end of the week.
- Still have the camera out so students are comfortable with it there.
- Informally observed mathematical discourse throughout both of my classes. Introduced integer with manipulatives and I noticed that student conversed together trying to figure out how to apply knowledge that they assumed they already knew about integer operations to produces a visual representation of it.
Week 3: Sept.: 17-21

- Still waiting for all letters of consent to be turned in. I am 4 students away from starting to video tape.

- Informally observed mathematical discourse throughout both of my classes. I noted that students spent most of their time independently working unless directed by me to make sure they are checking solutions with neighbors. When directed and solutions were being checked, that seemed to provoke conversations when needed about their math.

- Students seemed to talk more about their math towards the end of the week, when problems got to be more difficult and required more thought.

- Watched a colleague deliver a lesson on quadratics that are perfect squares to his ninth honors class. Within the 50 minute class, the teacher spent 30 minutes lecturing with no student to student interaction and asked a question that was a very procedural question. The students did not need to analyze or generalize any information, because it was given to them. They then spent the remaining 20 minutes working on their homework for that evening, in which they were instructed to work with the 3 or 4 other student that were closest to them. During those 20 minutes students did talk about mostly math to verify answers and ask procedural question when they did not get the right answer.

Week 4: Sept.: 24-28
Finally got all letters of consent in last Friday and spent all week this week videotaping. I have about four hours of film to go through and evaluate the mathematical discourse in my room.

Students caught on fairly quickly that the video camera was on and not just sitting there, so student behavior did change some, but not a lot and not for very long. I would have to say that after the first day, things were back to normal. I think that having the video camera in place for a couple of weeks prior to the actual taping contributed to the smooth transition to actually video taping.

I am also trying to place the camera in different places in my room to get a wider range of conversations that are occurring and to be able to hear them more clearly.

Week 5: Oct: 1-5

I spent the whole week taping both classes using a variety of methods. I would make sure to move the camera to different corners of the room to interpret conversations better. I also took the camera with me on a tripod and would move it from group to group to isolate conversations and then I also had a teacher assistant take the camera herself and go from group to group to pick up conversations better.

I finished up this week with a team test, which is no more than a glorified review. The test was also video taped and found some unsurprising results.
Teams worked much harder on this task than on a regular assignment and I feel that is due to calling it a test and making it worth more points. I noticed that a good motivator in increasing mathematical discourse and participation in my classroom is to give assignments that have higher stakes, like a team test. However, I have also noticed that strategy to not work if it is used too often.

- I spent the weekend looking over the tapes and noting the amount and quality of mathematical discourse that was present in my classroom.

Week 6: Oct 8-12

- Started a new chapter, which will be the last chapter that I will have my students working in teams for awhile. I still have the video camera out every day, but I am not running it all the time. I now am doing it once or twice in a week, because the data seems to be very repetitive.

- I did observe another teacher for a period. This teacher was very much teacher-centered and did a lot of direct instruction. She was teaching an upper level class, so discipline was not much of an issue and students spent most of the time copying notes and answering very basic questions during her lecture.

Week 7: Oct 15-19
- This week is very much like last week. We are still in a student-centered environment where students spend most of the class period through guided instruction discovering mathematical topics as a team. I video taped once this week and it was a fairly accurate representation of how this week went. Students are beginning to understand what I expect from them and are doing a lot better with working in teams. Students are asking more questions of their teammates and less of me.

Week 8: Oct. 22-26

- This week is the first week that we started in the new arrangement. I have students in rows and columns and they take more notes and primarily receive direct instruction. It took a bit of time for them to adjust but they seem to be doing fine.

- I have been video taping all week except for the first two days, because I want them to get used to the new arrangement before going for it.

- The students seem to do a lot better job of looking like they are on task and do a pretty good job taking notes as I am giving the information to them. I am stopping frequently and asking to check for understanding, but there is not a lot of interaction between the students and me. However, I think that will increase as they get more used to this set up.

Week 9: Oct. 29-Nov. 2
• This is the second week of the new arrangement and they seem to be getting more used to it and are becoming squirrelly during note taking. They are still not asking a lot of questions and there is still minimal interaction between the students and me. I have been video taping all this week as well, but there does not seem to be different information gathered from this week compared to last week, so I sometimes feel like I am wasting my time.

• I have a lot of students wanting to know when we will go back to the other way (groups) and voicing their dislike of this new arrangement. I have also had one student that said she like this way and was able to concentrate without the social distraction that groups bring to her learning.

Week 10: Nov. 5-9

• This is my third week in the new arrangement and I think I am about half way through this part of the research, and I have to admit that I too am excited to be done with this method of teaching. Not because I do not like teaching this way, but there is a lot of upfront work for me when I teach this way, because I have to create my own lessons from scratch since I do not have a curriculum that is geared towards direct instruction.

• I gave my first test for this part of the research and hope to have them graded this weekend. I am very curious to see how the grades turn out and hope that everyone does well.
Week 11: Nov. 12-16

- Scores from the first test came back very poorly with the average being around 58%. Students are not very happy with their scores and are almost all choosing to do test corrections.

- Students are becoming even more distracted with not taking and seems to not like the predictability of always having to take notes and then work on practice problems.

Week 12 and 13: Nov. 19-30

- Going though similar routines and getting similar reactions from students. I finished the last chapter and will be giving the test on this chapter next week. I am planning on going back to student centered teaching. Not just because I feel more comfortable, but my students are requesting it.

- My plans for now until the end is to finish the semester and get long term retention analysis to be able to use for my research project.
Appendix D

Data Analysis

Teacher-Centered teaching Short term retention:

<table>
<thead>
<tr>
<th>Period 1</th>
<th></th>
<th></th>
<th>Period 1</th>
<th></th>
<th></th>
<th>Period 7</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>score</td>
<td>class</td>
<td>avr.</td>
<td>score</td>
<td>class</td>
<td>avr.</td>
<td>score</td>
<td>class</td>
<td>avr.</td>
</tr>
<tr>
<td>68</td>
<td>61.45</td>
<td></td>
<td>60</td>
<td>76</td>
<td></td>
<td>49</td>
<td>59.58</td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>61.45</td>
<td></td>
<td>100</td>
<td>76</td>
<td></td>
<td>94</td>
<td>59.58</td>
<td>83</td>
</tr>
<tr>
<td>39</td>
<td>61.45</td>
<td></td>
<td>30</td>
<td>76</td>
<td></td>
<td>40</td>
<td>59.58</td>
<td>51</td>
</tr>
<tr>
<td>66</td>
<td>61.45</td>
<td></td>
<td>27</td>
<td>76</td>
<td></td>
<td>11</td>
<td>59.58</td>
<td>34</td>
</tr>
<tr>
<td>87</td>
<td>61.45</td>
<td></td>
<td>90</td>
<td>76</td>
<td></td>
<td>57</td>
<td>59.58</td>
<td>91</td>
</tr>
<tr>
<td>47</td>
<td>61.45</td>
<td></td>
<td>73</td>
<td>76</td>
<td></td>
<td>49</td>
<td>59.58</td>
<td>34</td>
</tr>
<tr>
<td>66</td>
<td>61.45</td>
<td></td>
<td>63</td>
<td>76</td>
<td></td>
<td>51</td>
<td>59.58</td>
<td>40</td>
</tr>
<tr>
<td>79</td>
<td>61.45</td>
<td></td>
<td>87</td>
<td>76</td>
<td></td>
<td>74</td>
<td>59.58</td>
<td>66</td>
</tr>
<tr>
<td>74</td>
<td>61.45</td>
<td></td>
<td>100</td>
<td>76</td>
<td></td>
<td>80</td>
<td>59.58</td>
<td>40</td>
</tr>
<tr>
<td>45</td>
<td>61.45</td>
<td></td>
<td>43</td>
<td>76</td>
<td></td>
<td>69</td>
<td>59.58</td>
<td>66</td>
</tr>
<tr>
<td>82</td>
<td>61.45</td>
<td></td>
<td>77</td>
<td>76</td>
<td></td>
<td>51</td>
<td>59.58</td>
<td>66</td>
</tr>
<tr>
<td>66</td>
<td>61.45</td>
<td></td>
<td>87</td>
<td>76</td>
<td></td>
<td>66</td>
<td>59.58</td>
<td>23</td>
</tr>
<tr>
<td>66</td>
<td>61.45</td>
<td></td>
<td>90</td>
<td>76</td>
<td></td>
<td>54</td>
<td>59.58</td>
<td>57</td>
</tr>
<tr>
<td>66</td>
<td>61.45</td>
<td></td>
<td>47</td>
<td>76</td>
<td></td>
<td>46</td>
<td>59.58</td>
<td>77</td>
</tr>
<tr>
<td>76</td>
<td>61.45</td>
<td></td>
<td>70</td>
<td>76</td>
<td></td>
<td>51</td>
<td>59.58</td>
<td>74</td>
</tr>
<tr>
<td>92</td>
<td>61.45</td>
<td></td>
<td>83</td>
<td>76</td>
<td></td>
<td>20</td>
<td>59.58</td>
<td>23</td>
</tr>
<tr>
<td>58</td>
<td>61.45</td>
<td></td>
<td>100</td>
<td>76</td>
<td></td>
<td>51</td>
<td>59.58</td>
<td>26</td>
</tr>
<tr>
<td>76</td>
<td>61.45</td>
<td></td>
<td>77</td>
<td>76</td>
<td></td>
<td>43</td>
<td>59.58</td>
<td>74</td>
</tr>
<tr>
<td>55</td>
<td>61.45</td>
<td></td>
<td>50</td>
<td>76</td>
<td></td>
<td>97</td>
<td>59.58</td>
<td>29</td>
</tr>
<tr>
<td>55</td>
<td>61.45</td>
<td></td>
<td>60</td>
<td>76</td>
<td></td>
<td>91</td>
<td>59.58</td>
<td>80</td>
</tr>
</tbody>
</table>
### Student-Centered Short Term Retention

<table>
<thead>
<tr>
<th>Score</th>
<th>Class Aver.</th>
<th>Score</th>
<th>Class Aver.</th>
<th>Score</th>
<th>Class Aver.</th>
</tr>
</thead>
<tbody>
<tr>
<td>77</td>
<td>76.86</td>
<td>102</td>
<td>80.33</td>
<td>87</td>
<td>70.43</td>
</tr>
<tr>
<td>95</td>
<td>76.86</td>
<td>100</td>
<td>80.33</td>
<td>83</td>
<td>70.43</td>
</tr>
<tr>
<td>63</td>
<td>76.86</td>
<td>47</td>
<td>80.33</td>
<td>20</td>
<td>70.43</td>
</tr>
<tr>
<td>63</td>
<td>76.86</td>
<td>47</td>
<td>80.33</td>
<td>56</td>
<td>70.43</td>
</tr>
<tr>
<td>91</td>
<td>76.86</td>
<td>98</td>
<td>80.33</td>
<td>98</td>
<td>70.43</td>
</tr>
<tr>
<td>77</td>
<td>76.86</td>
<td>78</td>
<td>80.33</td>
<td>60</td>
<td>70.43</td>
</tr>
<tr>
<td>65</td>
<td>76.86</td>
<td>92</td>
<td>80.33</td>
<td>70</td>
<td>70.43</td>
</tr>
<tr>
<td>88</td>
<td>76.86</td>
<td>84</td>
<td>80.33</td>
<td>78</td>
<td>70.43</td>
</tr>
<tr>
<td>97</td>
<td>76.86</td>
<td>95</td>
<td>80.33</td>
<td>65</td>
<td>70.43</td>
</tr>
<tr>
<td></td>
<td>76.86</td>
<td></td>
<td>80.33</td>
<td></td>
<td>70.43</td>
</tr>
<tr>
<td>---</td>
<td>-------</td>
<td>---</td>
<td>--------</td>
<td>---</td>
<td>-------</td>
</tr>
<tr>
<td>83</td>
<td>76.86</td>
<td>93</td>
<td>80.33</td>
<td>67</td>
<td>70.43</td>
</tr>
<tr>
<td>95</td>
<td>76.86</td>
<td>95</td>
<td>80.33</td>
<td>98</td>
<td>70.43</td>
</tr>
<tr>
<td>66</td>
<td>76.86</td>
<td>93</td>
<td>80.33</td>
<td>42</td>
<td>70.43</td>
</tr>
<tr>
<td>77</td>
<td>76.86</td>
<td>87</td>
<td>80.33</td>
<td>30</td>
<td>70.43</td>
</tr>
<tr>
<td>91</td>
<td>76.86</td>
<td>103</td>
<td>80.33</td>
<td>88</td>
<td>70.43</td>
</tr>
<tr>
<td>43</td>
<td>76.86</td>
<td>58</td>
<td>80.33</td>
<td>37</td>
<td>70.43</td>
</tr>
<tr>
<td>63</td>
<td>76.86</td>
<td>102</td>
<td>80.33</td>
<td>82</td>
<td>70.43</td>
</tr>
<tr>
<td>95</td>
<td>76.86</td>
<td>80</td>
<td>80.33</td>
<td>87</td>
<td>70.43</td>
</tr>
<tr>
<td>80</td>
<td>76.86</td>
<td>80</td>
<td>80.33</td>
<td>88</td>
<td>70.43</td>
</tr>
<tr>
<td>88</td>
<td>76.86</td>
<td>27</td>
<td>80.33</td>
<td>30</td>
<td>70.43</td>
</tr>
<tr>
<td>46</td>
<td>76.86</td>
<td>82</td>
<td>80.33</td>
<td>55</td>
<td>70.43</td>
</tr>
<tr>
<td>84</td>
<td>76.86</td>
<td>102</td>
<td>80.33</td>
<td>72</td>
<td>70.43</td>
</tr>
<tr>
<td>97</td>
<td>76.86</td>
<td>93</td>
<td>80.33</td>
<td>93</td>
<td>70.43</td>
</tr>
<tr>
<td>100</td>
<td>76.86</td>
<td>100</td>
<td>80.33</td>
<td>97</td>
<td>70.43</td>
</tr>
<tr>
<td>94</td>
<td>76.86</td>
<td>96</td>
<td>80.33</td>
<td>100</td>
<td>70.43</td>
</tr>
<tr>
<td>95</td>
<td>76.86</td>
<td>95</td>
<td>80.33</td>
<td>63</td>
<td>70.43</td>
</tr>
<tr>
<td>92</td>
<td>76.86</td>
<td>98</td>
<td>80.33</td>
<td>83</td>
<td>70.43</td>
</tr>
<tr>
<td>88</td>
<td>76.86</td>
<td>89</td>
<td>80.33</td>
<td>89</td>
<td>70.43</td>
</tr>
<tr>
<td>59</td>
<td>76.86</td>
<td>73</td>
<td>80.33</td>
<td>95</td>
<td>70.43</td>
</tr>
<tr>
<td>63</td>
<td>76.86</td>
<td>45</td>
<td>80.33</td>
<td>47</td>
<td>70.43</td>
</tr>
<tr>
<td>82</td>
<td>76.86</td>
<td>97</td>
<td>80.33</td>
<td>60</td>
<td>70.43</td>
</tr>
<tr>
<td>71</td>
<td>76.86</td>
<td>56</td>
<td>80.33</td>
<td>88</td>
<td>70.43</td>
</tr>
<tr>
<td>52</td>
<td>76.86</td>
<td>79</td>
<td>80.33</td>
<td>57</td>
<td>70.43</td>
</tr>
<tr>
<td>60</td>
<td>76.86</td>
<td>93</td>
<td>80.33</td>
<td>68</td>
<td>70.43</td>
</tr>
<tr>
<td>54</td>
<td>76.86</td>
<td>78</td>
<td>80.33</td>
<td>100</td>
<td>70.43</td>
</tr>
<tr>
<td>83</td>
<td>76.86</td>
<td>27</td>
<td>80.33</td>
<td>83</td>
<td>70.43</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>----</td>
<td>----</td>
<td>----</td>
<td>----</td>
<td></td>
<td></td>
</tr>
<tr>
<td>89</td>
<td>76.86</td>
<td>87</td>
<td>80.33</td>
<td></td>
<td></td>
</tr>
<tr>
<td>91</td>
<td>76.86</td>
<td>91</td>
<td>80.33</td>
<td></td>
<td></td>
</tr>
<tr>
<td>69</td>
<td>76.86</td>
<td>91</td>
<td>80.33</td>
<td></td>
<td></td>
</tr>
<tr>
<td>78</td>
<td>76.86</td>
<td>81</td>
<td>80.33</td>
<td></td>
<td></td>
</tr>
<tr>
<td>68</td>
<td>76.86</td>
<td>86</td>
<td>80.33</td>
<td></td>
<td></td>
</tr>
<tr>
<td>82</td>
<td>76.86</td>
<td>64</td>
<td>80.33</td>
<td></td>
<td></td>
</tr>
<tr>
<td>91</td>
<td>76.86</td>
<td>73</td>
<td>80.33</td>
<td></td>
<td></td>
</tr>
<tr>
<td>83</td>
<td>76.86</td>
<td>93</td>
<td>80.33</td>
<td></td>
<td></td>
</tr>
<tr>
<td>93</td>
<td>76.86</td>
<td>94</td>
<td>80.33</td>
<td></td>
<td></td>
</tr>
<tr>
<td>72</td>
<td>76.86</td>
<td>94</td>
<td>80.33</td>
<td></td>
<td></td>
</tr>
<tr>
<td>46</td>
<td>76.86</td>
<td>79</td>
<td>80.33</td>
<td></td>
<td></td>
</tr>
<tr>
<td>75</td>
<td>76.86</td>
<td>42</td>
<td>80.33</td>
<td></td>
<td></td>
</tr>
<tr>
<td>97</td>
<td>76.86</td>
<td>99</td>
<td>80.33</td>
<td></td>
<td></td>
</tr>
<tr>
<td>66</td>
<td>76.86</td>
<td>61</td>
<td>80.33</td>
<td></td>
<td></td>
</tr>
<tr>
<td>92</td>
<td>76.86</td>
<td>97</td>
<td>80.33</td>
<td></td>
<td></td>
</tr>
<tr>
<td>45</td>
<td>76.86</td>
<td>59</td>
<td>80.33</td>
<td></td>
<td></td>
</tr>
<tr>
<td>48</td>
<td>76.86</td>
<td>79</td>
<td>80.33</td>
<td></td>
<td></td>
</tr>
<tr>
<td>88</td>
<td>76.86</td>
<td>65</td>
<td>80.33</td>
<td></td>
<td></td>
</tr>
<tr>
<td>55</td>
<td>76.86</td>
<td>71</td>
<td>80.33</td>
<td></td>
<td></td>
</tr>
<tr>
<td>77</td>
<td>76.86</td>
<td>46</td>
<td>80.33</td>
<td></td>
<td></td>
</tr>
<tr>
<td>88</td>
<td>76.86</td>
<td>103</td>
<td>80.33</td>
<td></td>
<td></td>
</tr>
<tr>
<td>57</td>
<td>76.86</td>
<td>55</td>
<td>80.33</td>
<td></td>
<td></td>
</tr>
<tr>
<td>91</td>
<td>76.86</td>
<td>85</td>
<td>80.33</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Long Term Retention Data:

<table>
<thead>
<tr>
<th>Overall grade out of 100%</th>
<th>Chapter 3&amp;5 (Teacher-Centered)</th>
<th>Chapters 1-2,4,6 (Student-Centered)</th>
</tr>
</thead>
<tbody>
<tr>
<td>score</td>
<td>class avr.</td>
<td>score</td>
</tr>
<tr>
<td>81</td>
<td>65.2</td>
<td>70</td>
</tr>
<tr>
<td>87</td>
<td>65.2</td>
<td>88</td>
</tr>
<tr>
<td>28</td>
<td>65.2</td>
<td>34</td>
</tr>
<tr>
<td>31</td>
<td>65.2</td>
<td>40</td>
</tr>
<tr>
<td>94</td>
<td>65.2</td>
<td>88</td>
</tr>
<tr>
<td>62</td>
<td>65.2</td>
<td>42</td>
</tr>
<tr>
<td>48</td>
<td>65.2</td>
<td>4</td>
</tr>
<tr>
<td>84</td>
<td>65.2</td>
<td>66</td>
</tr>
<tr>
<td>71</td>
<td>65.2</td>
<td>56</td>
</tr>
<tr>
<td>64</td>
<td>65.2</td>
<td>48</td>
</tr>
<tr>
<td>86</td>
<td>65.2</td>
<td>80</td>
</tr>
<tr>
<td>61</td>
<td>65.2</td>
<td>54</td>
</tr>
<tr>
<td>52</td>
<td>65.2</td>
<td>36</td>
</tr>
<tr>
<td>94</td>
<td>65.2</td>
<td>96</td>
</tr>
<tr>
<td>32</td>
<td>65.2</td>
<td>30</td>
</tr>
<tr>
<td>37</td>
<td>65.2</td>
<td>28</td>
</tr>
<tr>
<td>82</td>
<td>65.2</td>
<td>66</td>
</tr>
<tr>
<td>64</td>
<td>65.2</td>
<td>58</td>
</tr>
<tr>
<td>63</td>
<td>65.2</td>
<td>50</td>
</tr>
<tr>
<td>71</td>
<td>65.2</td>
<td>48</td>
</tr>
<tr>
<td>25</td>
<td>65.2</td>
<td>32</td>
</tr>
<tr>
<td>56</td>
<td>65.2</td>
<td>44</td>
</tr>
<tr>
<td>55</td>
<td>65.2</td>
<td>32</td>
</tr>
<tr>
<td>Score</td>
<td>Grade</td>
<td>Score</td>
</tr>
<tr>
<td>-------</td>
<td>-------</td>
<td>-------</td>
</tr>
<tr>
<td>85</td>
<td>65.2</td>
<td>58</td>
</tr>
<tr>
<td>87</td>
<td>65.2</td>
<td>74</td>
</tr>
<tr>
<td>83</td>
<td>65.2</td>
<td>68</td>
</tr>
<tr>
<td>79</td>
<td>65.2</td>
<td>60</td>
</tr>
<tr>
<td>74</td>
<td>65.2</td>
<td>64</td>
</tr>
<tr>
<td>89</td>
<td>65.2</td>
<td>98</td>
</tr>
<tr>
<td>74</td>
<td>65.2</td>
<td>74</td>
</tr>
<tr>
<td>21</td>
<td>65.2</td>
<td>0</td>
</tr>
</tbody>
</table>

class average: 65.2%
class average: 54.4%
class average: 70%
down 10.7% of overall average
up 4.8% of overall average