Capstone Project

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Connections throughout the Standards

I. Introduction:

When I was in high school I remember asking the teacher, "Why do we have to learn about this anyway?" I never expected her to give me a good answer, because teachers never did. I was offered responses to the question, but none satisfied my curiosity at the time. One answer was, "Because if you don't learn it, we will not be able to build on it and if we don't build on your mathematical knowledge you won't know anything." Her answer made me start thinking. I didn't know that people build on mathematical knowledge. Math to me was a set of disjoint ideas, where certain properties were shared and that was it, but I now see this is not true. Connections in mathematics are there if you seek them. It may be difficult at first, but once you have your toolbox of connected mathematical ideas, you will be able to logically problem solve, without knowing how to do it upfront. I am not the only one who has come to this conclusion.

In the early 1980's the mathematics education began to change. This reform was prompted mostly by the National Council of Teachers of Mathematics (NCTM), as a response to the push to go back to the basics of reading, writing, and arithmetic. In 1989 the NCTM published *Curriculum and Evaluation Standards for School Mathematics*. This caused the standards movement in mathematics education to begin, and it hasn't stopped. No other document has ever had such an enormous effect on school mathematics or in any other area of the curriculum, but the NCTM didn't stop there (Van de Walle, 2013, p. 2).

In 1991, they published *Professional Standards for Teaching Mathematics*, which focused on a vision of teaching mathematics in such a way that significant mathematics could be a vision for all students, not just a few. In 1995, the NCTM published *Assessment standards for school Mathematics*. This document focused on the importance of integrating assessment with instruction, as well as how important assessment is in implementing change.

Now in the mid -1990's, the largest study of mathematics and science education, known as the Third International Mathematics and Science Study (TIMSS) was conducted. Data was collected from 41 nations from 500,000 students and teachers in grades 4, 8, and 12. This study revealed that the United States of America performed above the international average at 4th grade, below average in 8th grade, and significantly below average at the 12th grade. TIMSS studies were conducted in 1999, 2003, and again in 2007 (Van de Walle, 2013). This study was very important because it found the United States' mathematics to be lacking. As one report on the original curriculum analysis found the US's curriculum to be too unfocused and barely scratching

the surface. Teaching in the high-achieving countries of these studies, more closely resembled the recommendations of the NCTM standards than the United States' repetitive teaching. In 2000, the NCTM updated its original standards with *Principles and Standards for School Mathematics,* which articulated six principles that are essential to high-quality Math education: equity, curriculum, teaching, learning, assessment, and technology. This document also provided a common set of five content standards which are found throughout the grades: Numbers and operations, algebra, geometry, measurement, data analysis and probability.

Also provided in the *Principles and Standards for School Mathematics* were the five process standards: Problem solving, reasoning and proof, communication, connections, and representations. Now, the process standards are not separate content, but should be a part of the toolbox of a student and/or teacher throughout all of the content strands. The process standard I will be focusing on is connections, which is broken into two parts: a) it is important to connect within and among mathematical ideas, such as connecting students' preexisting ideas to new ideas; b) mathematics should be connected to the real world and other disciplines. This document changed the game; mathematics was going in the direction of more focused curriculum.

In 2006, the NCTM published *Curriculum Focal Points*, whose message was mathematics in each grade level needs to be more focused, go into more depth and explicitly shows connections to mathematics that had already been discussed in class as well as connecting to real world problems (Van de Walle, 2013,). This document led the Council of Chief State School Officers, CCSSO, to present the *Common Core State*

Standards. These standards were specific to each grade level, and integrated concepts from international curriculums as well as the NCTM's *Curriculum Focal Points*.

The state of Georgia has seen three stages of mathematics education reform from the 1980s to now. Looking back at the state curricula, in the mid 1980's Quality Core Curriculum, QCC, standards came in to the scene, developed by the Georgia Board of Education because of the Quality Basic Education Act of 1986. The QCC is a uniformly sequenced core curriculum that specified what students were expected to know in each subject and grade. These standards were finalized in August of 1988. This curriculum remained in use for many years until the No Child Left Behind Act, NCLB, of 2002. The NCLB act was actually a revision of the Elementary and Secondary Education Act, ESEA, of 1965, which established a federal presence in the public schools of the US. The curriculum was reviewed and found lacking. It was described by many as "miles wide and half an inch deep" (Van de Walle, 2013, p.2). Thus in Georgia, there was a push for a new curriculum. This push was led by the Georgia Department of Education, GDOE, and the State Superintendent of School, Kathy Cox.

Finally, the Georgia Performance Standards, GPS, replaced QCC in 2005. These standards were expected to drive instruction, assessment, and formation of guidelines and result in improved student achievement (Cox, 2005). The GPS also isolated and identified the skills students need to use in order to solve mathematics. These skills known as the five process standards were found in NCTM's *Principles and Standards for School Mathematics*. From the GPS, Georgia went to the next step and adopted the common core with the other states. Georgia refers to this set of standards as the Common Core Georgia Performance Standards (CCGPS).

The purpose of this paper is to determine how implicit or explicit connections are throughout the standards in the state of Georgia, from the era of the QCC's to the current CCGPS. I will focus on the standards written for the ninth and tenth grades specifically. First I need to decide what is meant by connections in mathematics.

II. Literature Review:

As mentioned before, the NCTM's *Principles and Standards for School Mathematics* list connections as a process standard. This standard states that instructional programs from prekindergarten through grade 12 should enable all students to:

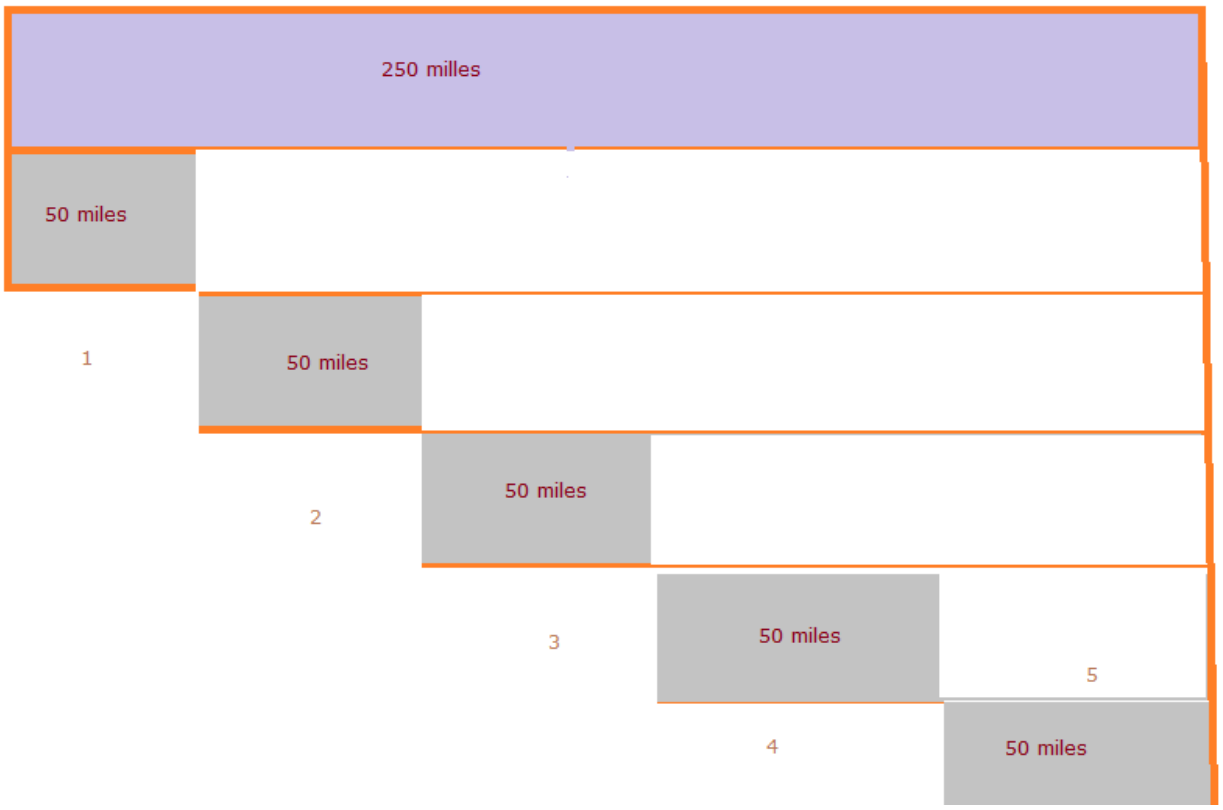
- Recognize and use connections among mathematical ideas
- Understand how mathematical ideas interconnect and build on one another to produce a coherent whole
- Recognize and apply mathematics in contexts outside of mathematics (NCTM, 2000, p.64).

The NCTM goes farther and breaks this standard into two parts:

- Connect within and among mathematical ideas
- Connect to the real world and to other disciplines (NCTM, 2000, p.64).

Merriam-Webster's dictionary defines connections as the act of connecting two or more things (2013). It goes on to define connecting as thinking of something as being related to or involved with another thing or idea (Merriam-Webster, 2013). From this we can infer that connections in mathematics are connecting two or more mathematical ideas, or thinking of mathematical ideas as being related to or involving other mathematical ideas. An example of connecting mathematical ideas would be if a student has just learned division, and is given a division problem without being told how to solve it:

If I drive 50 miles per hour and my destination is 250 miles away, how many total hours will I be driving? How did you find you answer? Are there any other methods you could use to come to the same conclusion?



Most students will model this problem first and probably solve by repeated subtraction as shown above. (250-50=200,200-50=150, etc...). As they continue to the next questions hopefully they notice that 250/50=5, which is the answer they should have gotten, and they will connect subtraction to division.

This brings us to another question. Does making connections to other ideas in mathematics suggest the student is learning more or less than a student who is not

making connections? To answer this we must look at the three different kinds of knowledge suggested by Piaget. Jean Piaget was a psychologist, who was well known for his studies with children and how children acquire knowledge. The first type of knowledge is physical knowledge, which is knowledge of objects in our external reality, or real life (Kamii, 2000, p.5). The second type of knowledge is social knowledge, which is knowledge of societal rules which were created by convention among people (Kamii, 2000, p.5). The third and most pivotal to mathematics is logico-mathematical knowledge (LMK). This knowledge "consist of mental relationships and the ultimate source of these relationships is in each individual" (Kamii, 2000, p.5). It follows that connections are a type of LMK, as Kamii (2000) states, "children construct LMK by putting previously made relationships into relationships" (p.5), and connections in mathematics are basically putting mathematical ideas into relationships.

Now to answer the question presented last, if a student is not connecting mathematics, the student will not be learning that mathematics is a whole integrated course; rather they will see mathematics as a set of disjoint ideas. NCTM (2000) states "understanding involves making connections" (p.64). In fact, Hiebert and Carpenter (1992) feel the more connections that exist among facts, ideas, and procedures the better one's conceptual understanding becomes. Hiebert goes on to say that making connections suggest a conceptual emphasis in mathematics (1999, p. 119). NCTM (2000) also states:

> When students can connect mathematical ideas, their understanding is deeper and more lasting. They can see mathematical connections in the rich interplay

> among mathematical topics, in contexts that relate mathematics to other subjects, and in their own interests and experience. (p.64)

The literature points to making connections, but when connections are made, how could we ask a student to represent how and what they connect together? A concept map is a good place to start. With a concept map, one could connect several different ideas in several different ways, figure 1a is a simple example of this. Another way to represent connections in mathematics would be by models an example of which is located in figure 1b.. With a model, whether it is a drawing, manipulatives, or any other representation, a student can see how a problem may be related to several different strategies, as well. Also, it is important to note, that connections are not always the same for other people. As a

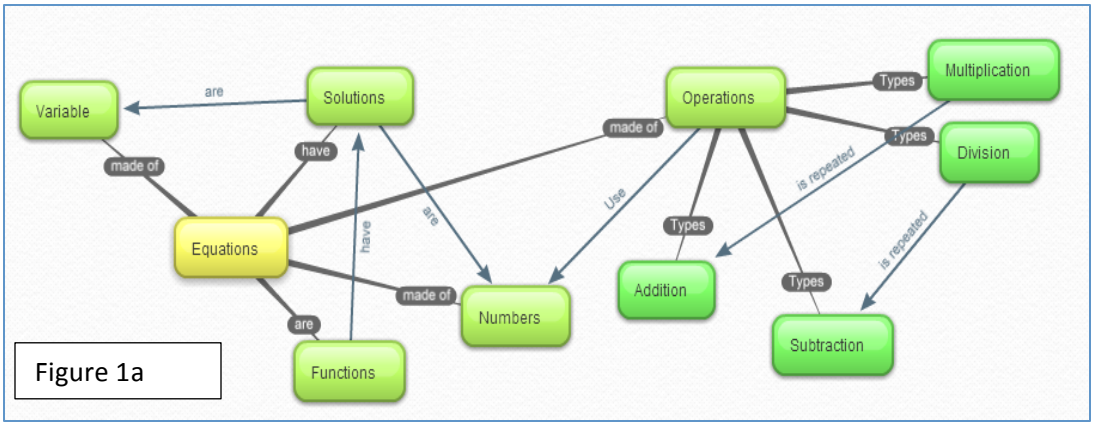


Figure 1a

Figure 1b:

A child is using manipulatives as a model to better understand fractions.

teacher I might find connections between exponential functions and trigonometric functions, while a student might not see a connection at all. Since everyone makes different connections, "it is critical for students to make connections themselves" (Langrall, 2008, p.3).

I should also mention the different ways a student may be able to connect mathematical ideas. NCTM (2000) suggests that students should see new ideas as extensions of previously learned mathematics, which means students should connect new ideas to already known mathematical concepts, without this students will not be able to see mathematics as a coherent whole (p. 65). Mathematics should also connect to the real world, and other disciplines.

Students should connect representations to mathematical concepts as well. If a student does not connect a representation to the mathematical concept, the student may not understand what is happening in the concept. Take for instance the case of Benny. Benny was a sixth-grader who had been using Individually Prescribed Instruction (IPI) Mathematics. He seemed to be doing rather well, until he talked to a mathematics education researcher named Erlwanger. In fact, Benny had learned some of the foundational mathematics incorrectly. It is important to note that Benny did not see connections in mathematics. In fact he saw mathematics was not a "rational and logical subject in which one has to reason, analyze, seek relationships, make generalizations, and verify answers" because "mathematics consisted of rules that have all been invented," and "[these rules] work like magic, because the answers one gets from applying the rules can be expressed different ways, 'which we think they're different but really they're the same'" (Erlwanger, 1973, p. 99). When using fraction disks to simplify $\frac{3}{6}$ he came to the correct answer $\frac{1}{2}$, however he didn't understand this representation was the correct way to solve the problem. He thought it was one of those answers that we think are different, but they are the same. Benny is a great example of a student

who does not connect previous ideas to new ideas, as well as connecting various representations in mathematics. I am not implying that Benny's case was specifically about a lack of connections, but with connections I feel Benny would have understood certain ideas better. However, the standards have been changing to push connections in mathematics more as time passes, so cases like Benny's never happen.

III. Description & Analysis:

Quality core curriculum, standards for the 9th grade, has 37 standards, while the 10th grade has 48 standards. These standards are grouped into topic, and then standards. Figure 2 is an example of one of these standards and how they are formed.

Figure 2	**Topic:** Connections, Patterns, and Functions **Standard:** Connects patterns to the concept of function and uses patterns, relations, and functions to solve problems.

This one explicitly shows a connection, but most of the standards do not as a whole. Only about two per grade level explicitly mention connections, and maybe 15 per grade level implicitly mentions them. In 9th grade, the connections in the standards are roughly 40%, while in the 10th grade these connections are 33%. This is interesting to me because when I went to school, this is the curriculum that was taught to me in high school. My teachers never tried to connect mathematics; of course it's possible I was missing what the teacher might have thought was obvious, but like I used to think, many students seem to think that math is all rules, and if you didn't get the rules you were just bad at math. Which means, most people were just bad at math, and if you were bad at math you drilled until you knew the steps perfectly (or failed).

The Georgia Performance Standards were more organized and it better described how the standards should be progressing. It is subdivided into the five content standards which were suggested by NCTM. These conceptual categories portray a coherent view of high school mathematics. Because even though we learn the simplest of equations in elementary school, we also progressively build and build on that knowledge for many different course boundaries even farther than calculus. Figure 3 is specifically is under the Algebra heading. However, in 9th grade GPS, we also have Geometry as well as Data Analysis and Probability standards. It is important

to note that every grade level in GPS also has the 5 process standards which of course include the connections standard. Looking at substandard f under the standard, MM1A1 in figure 3, notice that functions are being connected to sequences and not only sequences but whole numbers as well. This is only one example of the GPS standards, while other sections may not have many connections, we see the standards getting progressively more and more well connected. The standards mention connections explicitly at least four times in each grade level, and implicitly at least 8. In the 9th grade, this percentage is 48%, while in 10th grade this percentage is 40%. Now when you look at the standards you will find that they are not a mile wide and an inch deep.

Figure 3

MM1A1. Students will explore and interpret the characteristics of functions, using graphs, tables, and simple algebraic techniques.

a. Represent functions using function notation.

b. Graph the basic functions $f(x) = x^n$, where $n = 1$ to 3, $f(x) = \sqrt{x}$, $f(x) = |x|$, and $f(x) = \frac{1}{x}$.

c. Graph transformations of basic functions including vertical shifts, stretches, and shrinks, as well as reflections across the x- and y-axes.

d. Investigate and explain the characteristics of a function: domain, range, zeros, intercepts, intervals of increase and decrease, maximum and minimum values, and end behavior.

e. Relate to a given context the characteristics of a function, and use graphs and tables to investigate its behavior.

f. Recognize sequences as functions with domains that are whole numbers.

g. Explore rates of change, comparing constant rates of change (i.e., slope) versus variable rates of change. Compare rates of change of linear, quadratic, square root, and other function families.

h. Determine graphically and algebraically whether a function has symmetry and whether it is even, odd, or neither.

i. Understand that any equation in x can be interpreted as the equation $f(x) = g(x)$, and interpret the solutions of the equation as the x-value(s) of the intersection point(s) of the graphs of $y = f(x)$ and $y = g(x)$.

The enacted curriculum under the GPS was similar to the enacted QCC standards, mainly because this change was so very sudden to many teachers at the beginning, but as time progressed, teachers started to try and make the lessons curve back to connections to other mathematics.

The last progressions of standards, CCGPS, are the most explicit by far, with as many as ten explicit connections, and many more implicitly. Each grade level standards in CCGPS begin

with the Standards of Mathematical Practice (SMP) which are 8 varieties of expertise that mathematics educators at all levels should seek to develop in their students. These 8 SMP are m uch like the process strands in the GPS. The standards are then broken into conceptual categories: Number and Quantity, Algebra, Functions, Modeling, Geometry, and Statistics and Probability. The connections percentage in each part is as follows for each respectively: 51.6%, 47.2%, 50.3%, 46.5%, 52.3%, 55%.

The transition from GPS to CCGPS, in theory should not be as difficult as the transition from QCC to GPS because those who were in charge of rolling out the GPS knew that the Common Core standards were part of a shift toward standards that were more connected, where students would have more opportunity to engage in worthwhile mathematics. Much like the GPS, the CCGPS also has frameworks which can help with lesson planning, and making sure the enacted curriculum is similar to the intended curriculum.

Understand the concept of a function and use function notation

Figure 4

MCC9-12.F.IF.1 Understand that a function from one set (called the domain) to another set (called the range) assigns to each element of the domain exactly one element of the range. If f is a function and x is an element of its domain, then f(x) denotes the output of f corresponding to the input x. The graph of f is the graph of the equation y = f(x).

MCC9-12.F.IF.2 Use function notation, evaluate functions for inputs in their domains, and interpret statements that use function notation in terms of a context.

MCC9-12.F.IF.3 Recognize that sequences are functions, sometimes defined recursively, whose domain is a subset of the integers. *For example, the Fibonacci sequence is defined recursively by f(0) = f(1) = 1, f(n+1) = f(n) + f(n-1) for n ≥ 1 (n is greater than or equal to 1).*

Earlier the standard given from the QCC located in figure 2, the standard was connecting functions to patterns. From connecting functions to patterns, the standards progressed from figure 2 (QCC standard) to figure 3 (GPS standard), which connects functions to sequences, and sequences are patterns. Note here the vocabulary is more mathematical. Now, from figure 3 we

move to figure 4 MCC9-12.F.IF.3 (from CCGPS), we are not only connecting functions to sequences but also to recursion and the integers. I find that figure 4 is not only a better standard, but also more connected. Comparing the three standards it is clear that the same vocabulary wasn't used. I find vocabulary very important to student success, and these CCGPS standards are explicit with its vocabulary. Amen (2006) discovered math vocabulary plays an important role in a student's ability to understand daily lessons, complete homework, discuss ideas in groups, take tests and be successful on achievement tests. The CCGPS also tends to give an example of what we want the students to know, and how we want them to know and understand these concepts, which was not as present in the other two curricula.

The CCGPS standards explicitly have more connections and a more mathematically rigorous vocabulary than the QCCs or the GPS. However, the CCGPS has more room to make connections even more explicit. In fact it has the possibility to completely connect every course to each other; the only problem is the implementation of the standards. Teachers must be flexible and try to use these standards to its full potential.

STANDARD	Grade Year	Total Number of Standards	Total Number of Explicit Connections	Explicit Standard Percentage	Connections Percentage
Quality Core Curriculum	9th	37	2	5.4%	40.2%
	10th	48	2	4.2%	32.8%
Georgia Performance Standards	9th	63	10	6.3%	48.4%
	10th	67	7	10.4%	40.1%
Common Core Georgia Performance Standards	9th	59	9	15.3%	58.6%
	10th	71	15	21.1%	55.3%

IV. Implications and Conclusion:

I believe that it is evident, if we continue on the current path, we are moving from the mile wide and inch deep, to three-fourths of a mile wide and half of a mile deep. This means as a country we are working to bring our children to not only a better understanding of mathematics, but a more connected, well rounded conceptual understanding, that many students have not had. However, teachers and students are finding it hard to transform to this new set of standards. With the standards, we have frameworks, which are blueprints for implementing the content standards and are the most helpful in the implementation of standards. These frameworks give teachers a start to teaching math in such a way that it is not only connected but it has the opportunity to make sense to the student. If student achievement does not start increasing, the standards may progress backwards. Many people are still pushing to go back to the QCC standards, because they were used for a long period of time and during that period were successful to some extent. Some students were able to go far, even to the extent of majors in mathematics in college, while some students slipped through the cracks, and didn't even graduate high school.

The standards are pushing for mathematics to make sense by offering performance and learning tasks within the frameworks that teachers can make use of. In the classroom there needs to be opportunities for mathematics to make sense, by connecting new ideas to students' current ways of operating and connecting mathematics to other disciplines and the real world. However, this does not seem to be happening in the majority of the classrooms in the state of Georgia. Until more teachers, administrators, and parents see the benefits of a more connected curriculum, the majority of the students will continue to not meet the standards on high stakes tests. Teachers need to make sure that students are not only keeping up, but deeply understand the connections between and among mathematical ideas, representations, and content strands. A good way of doing this is asking the student to relate the lesson with what the student understands; as Van de Walle (2007) says

“understanding is a measure of the quality and quantity of connections a student has with an existing idea”(p.25). There are several ways the students could relate the lesson, one of which is by the concept map discussed earlier. Another way a student can relate their ideas is by a journal prompt or by solving a problem that looks different from the examples given, but is solved in a similar way. By doing this one could find many misconceptions or unique ways of thinking that could prove productive as they progress through the standards. Teachers should remain vigilant, and question continuously, in order to make sure that no student slips through the cracks.

Not only should teachers question continuously but they should also be aware of what questions can do for the students. Driscoll (1999) believes that by giving well timed pointers can expand or shift a student’s thinking; this can also help the students know what is important in the lesson. By using a variety of questions, teachers can help students organize their thinking. I feel one of the most important questions will be how the student made connections to other types of mathematics.

In the CCGPS frameworks, there are many math activities that help foster the students’ sense making. An example of a framework is “Scaffolding Task: Acting Out” which is located in unit 1 student edition in the CCGPS frameworks (Barnes,2013). This activity has two essential questions, uses five CCGPS standards, as well as three standards of mathematical practice. The activity is useful for helping students understand equations, and constraints. It begins with two actors, and on a grid students have to figure out all the many places they can live by using coordinate pairs. The second task is similar in the fact that it deals with equations, and requires students to act it out. However, it takes equations one step farther. Each question on the activity is designed to get the students thinking in more depth; the task is located in appendix A.

I have discussed what these standards mean for teachers, but principals’, students’ and parents’ roles are changing as well. Parents need to know about the shift we are moving in mathematics. Not only do we want our students connecting more mathematics together, but we also want our students to

focus more on the big picture in these standards, as well as not forgetting the details. Parents should help their children understand why it is important for mathematics to make sense. This could be done by the parent or a secondary tutor, if the parent is unable. Parents should also push their children to do better, because ALL students are capable of doing significant mathematics. Principals should know CCGPS in and out; there are many different resources in order to find all that is needed to know about CCGPS. Principals should also talk with the other schools and make sure the schools line up in such a way as to better promote understanding (which means as the student progresses from school to school, the student will not have any gaps in information). Lastly, the principal should monitor, and make sure teachers have the adequate amount of time and professional development to implement these standards.

I for one am going to keep pushing for better standards or better implementation of the standards as well as following these recommendations, because we cannot truly be content while our students are not connecting mathematics. Connections are essential in the learning and teaching of mathematics whether these are connections to other mathematical ideas, to other disciplines, or to the real world.

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APPENDIX A

Scaffolding Task: Acting Out

Name_____ **Date**_____

Adapted from Shell Center Leaky Faucet Short Cycle Task
http://www.map.mathshell.org/materials/tasks.php?taskid=267&subpage=apprentice

Mathematical Goals

- Model and write an equation in one variable and solve a problem in context.
- Create one-variable linear equations and inequalities from contextual situations.
- Represent constraints with inequalities.
- Solve word problems where quantities are given in different units that must be converted to understand the problem.

Essential Questions

- How do I choose and interpret units consistently in formulas?
- How can I model constraints using mathematical notation?

Common Core Georgia Performance Standards

MCC9-12.A.CED.1	Create equations and inequalities in one variable and use them to solve problems. Include equations arising from linear and ~~quadratic functions, and simple rational~~ and exponential functions.
MCC9-12.A.CED.3	Represent constraints by equations or inequalities, and by systems of equations and/or inequalities, and interpret solutions as viable or non-viable options in a modeling context.
MCC9-12.N.Q.1	Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.
MCC9-12.N.Q.2	Define appropriate quantities for the purpose of descriptive modeling.
MCC9-12.N.Q.3	Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.

Standards for Mathematical Practice

1. Make sense of problems and persevere in solving them.
5. Use appropriate tools strategically.
6. Attend to precision.

Scaffolding Task: Acting Out

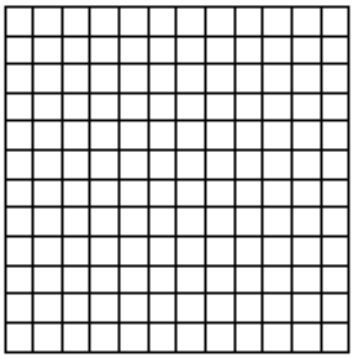
Name_____ **Date**_____

Adapted from Shell Center Leaky Faucet Short Cycle Task
http://www.map.mathshell.org/materials/tasks.php?taskid=267&subpage=apprentice

Part I:

Erik and Kim are actors at a theater. Erik lives 5 miles from the theater and Kim lives 3 miles from the theater. Their boss, the director, wonders how far apart the actors live.

1. On the given grid:
   a. pick a point to represent the location of the theater.
   b. Illustrate all of the possible places that Erik could live on the grid paper.
   c. Using a different color, illustrate all of the possible places that Kim could live on the grid paper.



2. What is the smallest distance, *d*, that could separate their homes? How did you know?

3. What is the largest distance, *d*, that could separate their homes? How did you know?

4. Write and graph an inequality in terms of *d* to show their boss all of the possible distances that could separate the homes of the 2 actors.

Part II:

The actors are good friends since they live close to each other. Kim has a leaky faucet in her kitchen and asks Erik to come over and take a look at it.

1. Kim estimates that the faucet in her kitchen drips at a rate of 1 drop every 2 seconds. Erik wants to know how many times the faucet drips in a week. Help Erik by showing your calculations below.

2. Kim estimates that approximately 575 drops fill a 100 milliliter bottle. Estimate how much water her leaky faucet wastes in a year.