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Creating a Dynamic Mathematics Curriculum

This article describes a curriculum initiative that took place in a Florida high school between the years of 2007 to 2010. Educators unhappy with current student performance and with the state of adopted textbooks, the teachers at one Florida high school took a radical approach: to throw out the textbooks and begin writing their own curriculum. The goals of this curriculum reform were to create a rigorous mathematics curriculum that would minimize learning gaps, heighten student engagement, and most importantly, improve student achievement by providing opportunities to go deeper into the mathematics. These are very similar to the goals of the current shift towards the Common Core State Standards for Mathematics (CCSSM). Results of the curriculum initiative are discussed and related to the current CCSSM movement.

Introduction

Throughout history there has been much talk of mathematics curriculum reform. Some of the more notable reform efforts of the past include the Unified Mathematics Movement, the New Math movement, the National Council of Teachers of Mathematics (NCTM) Standards-Based Reform (Kilpatrick, 1997), and now the shift towards the Common Core State Standards for Mathematics (CCSSM). Each of these reform efforts have grown out of the nation's discontent with student performance, an attempt to keep up with the advancements in the field of mathematics (Herrera & Owens, 2001), and an aim to inspire educators to "teach better mathematics and to teach mathematics better" (Begle, 1962, as cited in Kilpatrick, 1997, p. 961). While the curriculum initiative described in this article is not a national movement, it was born of similar reasons as those of past and present national reforms.

A Need For Change

The purpose of this article is to describe a curriculum reform that took place at a Florida high school between the years of 2007 and 2010. Beginning in the 2007-2008 school year, the mathematics teachers of Dubel High School[1] were ready for a change. Between the years of 1998 and 2010, Florida high school students were required to take the Florida Comprehensive Assessment Test (FCAT) in their freshman and sophomore years. Test scores ranged from Levels 1-5. In order for students to be deemed mathematically proficient – performing at grade level – students had to score at or above a Level 3 on the mathematics portion of the FCAT. At Dubel, approximately 59 percent of incoming freshmen were considered proficient mathematics students. While this was already an alarmingly small percentage, in the years of 2004-2007 an even smaller percentage, 53-56 percent, went on to perform at or above their grade level during their high school years. This was approximately 13 percent lower than that of the state average (Florida Department of Education, 2012a). These alarming statistics made it very clear that a change was needed.

At the time, most mathematics instruction was largely dictated by state adopted textbooks, which often contained gaps and targeted procedural fluency rather than conceptual understanding of the mathematical topics presented. There was also little collaboration between mathematics teachers and it was not at all uncommon for one classroom to be two weeks ahead of another. In recent years, a

few Algebra teachers had begun using what they called a "worksheet curriculum" created by one of the department's mathematics teachers and newly appointed department head, Lucy Smith. With the success of the curriculum in Ms. Smith's classroom and – in recent years – other Algebra classes, the department decided to create a similar curriculum for all mathematics courses in the high school. The goal was to create a rigorous curriculum that would minimize learning gaps, heighten student engagement, and most importantly, improve student achievement by providing opportunities to delve deeper into the mathematics. These are very similar to the goals of the current CCSSM movement (National Governors Association Center for Best Practices, 2012).

Collecting Information

Having much experience in writing her own curriculum and with the full support of school administrators, Lucy took the lead in this initiative. The first step was to have the teachers begin thinking about the school's current student body. In order to be successful in their task, it was essential to know the student population and create a curriculum that was specific to their individual needs. The high school is located in Florida's Polk County school district and, in 2008, served approximately 1,385 students. It is a Title 1 school, receiving government funds to support the high percentage of students coming from low-income families. The high school was also a recently converted charter school. Student demographics may be found in Table 1.

Table 1
Dubel High School Student Demographics

Ethnicity	Percentage
White	55.9
African American	27.1
Hispanic	14.9
Asian	0.4
American Indian	0.1
Other	1.4

The mathematics teachers of Dubel High School spent countless hours analyzing student FCAT data in order to determine the areas in which students scored the lowest. These concepts were recorded and would later be written heavily into the Algebra 1, Geometry, and Algebra 2 courses. It was also deemed beneficial to include in each of these courses one week of intensive instruction on the five mathematics strands tested on the FCAT. This instruction, named FCAT Boot Camp, would take place the week before the spring administration of the examination.

For upper level courses containing juniors and seniors who had already passed the mathematics portion of the FCAT, teachers observed the data as well as students' future mathematical plans. For example, students taking Pre-Calculus in the fall semester (the school was on a 4x4 block schedule) would not be moving on to Calculus and were instead pursuing college majors that would require a course in College Algebra. FCAT data showed that a major area of weakness for these seniors was that of functions, which would be heavily covered in a College Algebra course. Taking this into account, the fall

course would cover all required course standards, but also be heavily infused with the functions that students would encounter in College Algebra. The spring course, however, would be mostly composed of students who would move on to AP Calculus. For this reason, the Pre-Calculus course offered in the spring would have to be constructed slightly different from the one offered in the fall, by focusing on pre-requisite concepts of Calculus.

The next step in the curriculum creation was to examine the Florida Sunshine State Standards to identify overlapping areas within courses. The mathematics teachers found many overlapping standards and began to discuss the purpose of these overlaps. It seemed that overlaps occurred for two reasons: to review information needed to understand another concept or to develop a relational understanding of a previously learned concept. When the purpose was simply to review, the educators felt that the first course in which the concept was introduced should strive to cover the concept at great depth, with subsequent courses providing brief reviews. In the second instance, the development of relational understanding, the teachers felt that the first course should strive for both operational and relational understanding of the concept. The priority, however, would be placed on operational understanding because the student would have another opportunity to develop their relational understanding in a later course. With the introductory courses providing a firm operational understanding, subsequent courses would be responsible for pushing students to explore the mathematical relationships between these concepts. The educators hoped that by building a strong foundation, students would no longer consider concepts such as domain and range, factoring, and slope as a rate of change to be recurring, illusive mathematical concepts.

After examining the curriculum standards, the mathematics teachers began to think in terms of academic supports. Each teacher was encouraged to create a list of essential pre-requisite skills for their courses. These skills were relayed in a top-to-bottom fashion. The Calculus teacher passed her list on to the Pre-Calculus teacher, the Pre-Calculus teacher passed hers to the Advanced Topics and Algebra 2 Honors teachers, and so on. The teachers would then take the list of skills given to them and make sure each suggestion received special focus throughout their course's curriculum (Waid, 2010).

Building a Curriculum

Now that the educators had determined what needed to be covered in each course and to what extent, it was time to determine how the curriculum should be structured. The mathematics team wanted to create a curriculum that was consistent and would provide seamless transitions between mathematics courses. This led to a discussion of elements that should be present in every course. The first element that each course should possess was to provide students with a great deal of practice and to continue to "spiral" through topics by way of continuous review. The purpose of constructing courses in this spiraling fashion was to maximize the retention of knowledge (Waid, 2010).

The next important element considered was to engage students in cooperative learning activities. Research indicates that student engagement has a positive effect on academic gains of students in mathematics courses (Park, 2005). The teachers wanted students to actively learn and to communicate their mathematical understanding, rather than passively taking in the information presented. In order to accomplish this goal, teachers would not only encourage students to engage in

mathematical conversation by incorporating teaching strategies such as think-pair-share and guided discussions during lessons; but also integrate several cooperative learning activities and projects that would allow students to further explore mathematical concepts and relationships presented in the course. For example, all students enrolled in Pre-Calculus would be required to work in pre-assigned pairs to build a catapult in which they would launch water balloons at their teacher. In order to hit the teacher, groups would complete a number of calculations using parametric equations to determine exactly how far from their catapult the teacher should stand.

The last, and probably most important, element considered by the mathematics team was to provide students with an abundance of opportunities to engage in critical thinking. While many of the cooperative learning activities would require students to use their critical thinking skills, educators were afraid that group settings may lead some students to take advantage of another's ability without ever trying for themselves. Due to this, critical thinking problems should not be limited to such activities. The teachers felt that students should be encouraged to engage in critical thinking as much as possible and determined that questions and tasks that required these skills would be incorporated throughout each course in multiple formats. In order to create these critical thinking questions, the mathematics teachers viewed free response questions from released Advanced Placement Calculus exams and considered how questions containing similar elements could be implemented in other courses. For example, one problem to be incorporated into an Algebra 2 assignment during a unit on polynomials was what the educators called the "Box Problem." In the problem, students would be given a hypothetical scenario in which they must cut a square, of side length x, from each corner of a 9" by 12" piece of computer paper. After making their cuts, they must fold up the sides of the paper to create a box. Students would be encouraged to explore this situation and to determine what size cut will give the maximum volume of their box. By introducing many critical thinking tasks, such as the "Box Problem" early on, the educators hoped to have developed strong critical thinking skills in their students by the time they had reached upper level mathematics courses.

Having determined a direction and structure, the only task left was to actually write the curriculum. In order to do this, the mathematics teachers were partnered according to the courses they would be teaching during the academic semester. Throughout the semester these teachers would collaborate to create the lessons, homework assignments, activities, and projects, which would be utilized in their courses. Assignments and problems were inspired by a variety of textbooks, online sources, and articles. The teachers would follow the same teaching schedule, teaching the same topics on the same days. Also, meetings within the mathematics department would be held regularly to allow inter-course collaboration. After meeting and discussing the struggles observed, teachers would return to their classrooms and adjust the curriculum to better serve the needs of their students. After the first semester the curriculum would remain dynamic, constantly being updated and changed. This was because its sole audience—the students—and their needs, would evolve over time (Waid, 2010).

Effects

During the years of the Dubel High School curriculum reform, educators saw an increase in student performance both in the classroom and on the state examination.

Table 2 shows the increased percentage of tenth grade students scoring at a Level 3 or higher, as compared with district and state percentages, on the mathematics portion of the FCAT between the years of 2004 and 2010. In recent years, Florida has begun phasing out the FCAT and instead implementing End-of-Course examinations in Algebra and Geometry, which is why the 2010-2011, 2011-2012, and 2012-2013 school years have not been included in this data.

Table 2
10th Graders Scoring Level 3 or Higher on the Mathematics FCAT

Year	School	District	State
2003-2004	56	57	62
2004-2005	53	59	65
2005-2006	53	59	66
2006-2007	56	62	68
2007-2008	65	65	72
2008-2009	68	66	72
2009-2010	66	67	73

As can be viewed in the table, beginning in the 2006-2007 school years, Dubel High School saw an increase in the number of students considered mathematically proficient. At the start of the curriculum initiative, the percentage of students considered mathematically proficient at the school was six percent lower than that of the district and twelve percent lower than that of the state. In the 2008-2009 school year Dubel High School had surpassed the district's percentage by two points and was now within four points of the state percentage. While the mathematics teachers considered this to be a great achievement, these numbers alone make it hard to determine whether the students in subsequent years were really showing great improvement or whether they entered the classroom at a higher level than the students that came in the years before them.

In order to accurately view the increase in student achievement it may be better to view the mathematics learning gains made by students over the years. A learning gain measures the point increase in a single students mathematics score between two academic years. In order for a student to make a learning gain, the student must increase their mathematics score more than the expected years growth. Students may also make a learning gain by moving up an achievement level or maintaining at Level 3 or higher (Croft, 2009). The percentage of students making mathematics learning gains at Dubel High School between the years of 2004 and 2010, as compared with the district and state percentages, have been included in Table 3.

Table 3
Students Making Learning Gains in Mathematics

Year	School	District	State
2003-2004	70	65	69
2004-2005	71	66	69
2005-2006	67	66	69
2006-2007	76	67	69
2007-2008	78	69	71
2008-2009	78	67	68
2009-2010	78	67	69

As can be viewed in the table, in the 2005-2006 school year 67 percent of the students at Dubel High School were making learning gains in mathematics. This was one percentage higher than that of the district and two percent lower than that of the state. Between the years of 2008 and 2010, the percentage of students making mathematical learning gains at Dubel High School had increased by 11 percent and was now 11 percent higher than that of the district and 9 percent higher than that of the state (Florida Department of Education, 2012a; Florida Department of Education, 2012b).

Discussion and Conclusion

In many ways, the curriculum reform that took place at Dubel High School is similar to the current shift towards the CCSSM. In the introduction to the standards, the writers state that research indicates that in order to improve students' mathematics achievement, the curriculum "must become substantially more focused and coherent" (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010). The authors state that the standards have been created in response to that need. They claim to focus on key concepts of mathematics, exploring them at greater depths than ever before, and are designed in such a way as to highlight the connections between mathematical concepts (Umphrey, 2011).

The worksheet curriculum created at Dubel High School allowed the mathematics teachers to achieve similar goals as the ones described above. Through practice, activities, and spiraling, they were able to take students deeper into the mathematics, showing them the inner-workings and relationships between concepts. The creation of this curriculum fostered positive collaboration between mathematics educators. It also compelled educators to fully consider the standards and the different avenues, as well as the depth, at which each standard should be taught in order to match the needs of the current student body.

This curriculum initiative, however, was by no means an easy task. Over the years the educators have struggled with many aspects of this new curriculum, such as parent complaints about the lack of textbooks and teachers becoming overwhelmed due to the amount of time and effort required by this on-going project. These struggles were overcome in large part by the support of the schools administrators. It was not uncommon for the principal of the school to listen to and attempt to address the concerns of parents and teachers. To address the concerns of parents, the principal made textbooks available for students to use as resources, if they felt the need to do so. In the majority of cases, this seemed to be sufficient. In addressing teacher concerns, the principal built in as much planning time as possible for the mathematics teachers: he hired an assistant for the mathematics department who was to make all necessary photo copies of worksheets created by the teachers; he provided the teachers with a yearly two day professional development retreat in which they could collaborate and write curriculum; and in addition to their daily 90 minute planning periods, the principal ensured that none of the teachers would be required to perform any duties, such as lunchroom or bus supervision, in order to provide extra planning time before, during, and after school.

The success of the teachers at Dubel High School between the years of 2007 and 2010 had many contributing factors, but the commitment of the administration and the mathematics teachers was key to the success of this curriculum. For the CCSSM to be a success, this is the attitude we must take in the coming years of implementation. There will also need to be strong support for

educators as they push forward, as there was for the educators at Dubel High School. These educators must be provided with resources, with professional development, and most importantly, time to plan and to perfect their teaching strategies and materials. While it will not be an easy task, educators and administrators around the nation must be encouraged to take up their torch and change the face of education. Otherwise, CCSSM will become nothing more than another failed mathematics reform.

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Notes

[1] All names used in this article are pseudonyms.

About the Author:

Brandie Waid received her undergraduate degree in mathematics and mathematics education, as well as her master's degree in curriculum and instruction at the University of Tampa. In the past five years she has taught a variety of high school subjects, ranging from Intensive Algebra to AP Statistics. Brandie is currently a graduate student in the Mathematics Education doctoral program at Teachers College, Columbia University. She is teaching a seventh grade mathematics class in New York City's Harlem, as well as developing a summer problem-solving program for incoming high school freshmen who struggle with mathematics. Brandie may be reached via email at: bew2126@tc.columbia.edu.