

2006-992: ASSESSMENT OF A COORDINATED EFFORT TO INCREASE STUDENT LEARNING IN MATHEMATICS AND SCIENCE THROUGH ENGINEERING EXAMPLES

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Assessment of a Coordinated Effort to Increase Student Learning in Mathematics and Science through Engineering Examples

Abstract

A public research institution, the Colorado School of Mines (CSM), has formed a partnership with the Delta School District and Cedaredge Middle School to improve student learning. The partnership program has included inservice teacher recertification courses and school/student projects. This partnership is one part of an ongoing effort by the middle school to become the leading school for mathematics and science in the region. The area is predominately rural with about half of the students receiving free or reduced-cost lunches. Generally, schools with this profile do not rank highly on standardized tests. However, Cedaredge Middle School has shown great progress and has been named a 2005 Gain-Maker School by the state for being the most improved middle school in the area of mathematics. The average scale score gains on the state assessment in mathematics were 35.7 over the time period from 2002 – 2004. Teachers from the middle school have participated in two workshops (including academic year followup) of the university that emphasized engineering applications for the mathematics and science classrooms. Also, two engineering senior design teams from CSM have worked on projects in curriculum and classroom material development for the middle school. These programs have been coupled with a focused effort on the part of the teachers to improve specific mathematics and science skills throughout each class. The methods used by this middle school can serve as a model for improvement for other schools in the state and nation.

Introduction

Several groups^{1,2,3} have raised concerns about the low level of scientific and mathematical literacy that exists in schools. Many of these concerns are based on results from state and national and standardized achievement tests^{4,5}. Results from the National Assessment of Educational Progress⁶ suggest that U.S. students from low-income families are performing below their middle class peers in science and mathematics. These findings and concerns that they raise have resulted in a broad range of reform activities that are designed to improve the education that all students receive in science and mathematics in elementary, middle school and high school^{7,8}. Many experts agree that engineering applications have helped students to better understand mathematics and science. Quoting Anwar⁹, “By infusing science and engineering problem solving concepts into mathematics curricula, students may be provided with a context for the material they are learning. Demonstrating how engineers and scientists use mathematics to solve real world problems would encourage students to continue their math and science studies.” The state of Massachusetts has adopted this concept and introduced engineering standards into the state curriculum. They are convinced¹⁰ “that engineering is a great way to make science and math more engaging to youngsters”. In this paper we will discuss a multifaceted effort to improve middle school mathematics and science achievement as measured by standardized tests. First we will describe the university and middle school partners involved in the process. We will then discuss the unique features of the middle school curriculum and their target topic efforts. Next we will describe some professional development offerings and senior design projects offered through the engineering university.

Finally, we will look at science and mathematics test scores over a four-year period and draw conclusions based on these observations.

Colorado School of Mines

The Colorado School of Mines is the second oldest and one of the largest colleges of mineral engineering and applied science in the country. It has distinguished itself as an innovative leader in undergraduate engineering education and graduate research with an emphasis on minerals, energy and materials. Its faculty consists of primarily experts in science, mathematics and engineering. The university offers more science content-based teacher (K-12) re-certification courses than any other institution in Colorado through the Office of Special Programs and Continuing Education. The university, as a direct result of this office, has been nationally recognized as a leader in both teacher training and K-12 curriculum design. The Teacher Enhancement Program serves approximately 2500 teachers each year through more than 200 science, mathematics, and technology courses. Participants receive graduate-level credit that may be applied to teacher re-licensing. The university also has a strong commitment to K-12 educational programs, especially programs aimed at minority populations. These programs, which were established as early as 1970, encourage minority students to pursue a higher education in mathematics, science, and engineering process.

Cedaredge Middle School

Cedaredge Middle School, located in a remote rural county south of Grand Junction, is small (about 210 students) with more than 50% of students on a free/reduced lunch program. Delta County is the 6th poorest county in the state. Many schools with this profile are assessed as “unsatisfactory” by the state. However, the Overall Academic Performance for this middle school is “Average” and improving. The commitment and forward thinking of the staff is responsible for this standing. The school is fortunate to have dedicated, visionary teachers who work well together. Technology (1.5), science (3), and mathematics (2) teachers have discussed ways to coordinate the present curriculum and to enrich the future curriculum. They are excited about upcoming possibilities. They also have an administration that supports their efforts. The staff goal is to have this middle school recognized as the best science/ engineering/ mathematics school in the region.

Curriculum Issues

Some unusual features of the middle school curriculum are a technology and an engineering class. All students are required to take one semester of technology per year. Technology curriculum includes more than computers. The project-driven technology class space is well organized and spacious. There are metal-working, wood working, electronics and plastics areas. The equipment includes an electronics snap set, Lego robots, hydraulics, a construction set (crane, forklift, etc), and plastics injection molder, blow molder, oven, and a sign engraver. In addition, a media center contains computers with a Macintosh Computer Aided Drafting program, media software for movie making, and PowerPoint. The Engineering Design Steps are displayed on the wall in the Technology Classroom and used by each student during project design and completion. Along with the Technology Class, an Engineering Class is offered as a

one-semester elective. Other electives include Band and Journalism. Up to 25% of the students take Band and Journalism and these are often the top students. Therefore there is a need and a plan to embed engineering in the regular curriculum.

Target Topic Efforts

Cedaredge Middle School has established a program for targeted instruction for improvement of student achievement as measured by the Colorado State Assessment Program (CSAP). An instructional target is a specific curricular area that has been identified as deficient. The targets are treated in addition to the adopted curriculum. Teachers deliver instruction focusing on the target and integrate this into their standard curriculum. Through analysis of standardized tests, the entire staff identifies weak areas. These are categorized as critical, serious, or significant. Critical targets are defined as 70% or more of the students have not achieved mastery, serious – 60%, and significant – 50%. The problem area is considered with respect to the current curriculum, instructional materials, and previous year's test data. Next a plan of action is designed. The critical areas are given three weeks of emphasis, serious – two weeks, and significant – 1 week. During the target week(s) each student receives 10-15 minutes targeted instruction per academic class period daily and five minutes per non-academic class period daily. An average student takes four academic and three non-academic classes and therefore receives 1.25 hours of focused instruction per day on a problem topic. Each of the targets must be integrated into the curriculum, not isolated. For example, if measurement with a ruler was a target, the band instructor had students measure the length of tubing for each instrument. An example of isolation would be for the band instructor to stop music instruction and have a lesson on the use of a ruler. Another integrated example involved the target of ratios and proportions. A Language Arts teacher had students read a paragraph, count the number of nouns and verbs, and then calculate the ratio of nouns to verbs.

Teacher Enhancement Programs through CSM

Since 1998, CSM has offered Profession Development opportunities for the remote rural portion of the state. Middle school mathematics and science teachers have been active in every program. Two recent courses are discussed.

Engineering Our World (2003)

The purpose of the program “Engineering your World”, was to improve teacher knowledge and student understanding of the concepts of various engineering disciplines and how these related to their current science and mathematics curriculum. The program was designed to both engage and educate middle school students through the use of hands-on, inquiry-based experiments in a mathematically rich environment. An unusual feature of this program was the inclusion of both summer teacher workshops and monthly follow-up classroom visits. The focus of the summer workshops was threefold: to improve the middle school teachers' backgrounds of engineering disciplines and their relevance to physical science and associated mathematical concepts in their current curriculum, to introduce the teachers to techniques for integrating content and learning standards (including content literacy) into the curriculum, and to provide teachers with instruction concerning how to use inexpensive materials to provide hands-on learning

experiences in their classroom. The purpose of the follow-up classroom visits was to assist the teachers in implementing the hands-on engineering experiments in their classrooms and to respond to teachers' questions concerning science and engineering concepts. Cedaredge Middle School used this workshop as a foundation for the curriculum of their one-semester elective engineering class.

Physical Science and Mathematics for Middle School: A Rural Initiative (2004-5)

A partnership which includes three districts from the remote rural portion of the state, CSM, and the University of Colorado- Denver School of Education was formed to improve middle school students' and teachers' content knowledge of mathematics and science through development of a cadre of middle school teachers that have strong content and knowledge in these areas. The project goals were similar to "Engineering Our World": upgrade the physical science and mathematics subject matter understanding of middle grade teachers, assist teachers in the development of a repertoire of teaching strategies, activities and lesson plans for physical science and mathematics through engineering and provide teachers with a sustained experience that aids in continuous improvement and innovation. A unique structure of a series of three workshops allowed for both content improvements in mathematics and science as well as integration of these topics. In the morning session, mathematics and science teachers were separated and worked on content-specific lessons. In the afternoon, teachers came together and worked with engineering applications to hands-on activities that required both mathematics and science skills. An example was a design of a voltage divider to deliver 3 volts from a 9-volt battery. The science teachers had studied circuits while the mathematics teachers had concentrated on ratios and proportions and algebraic equations.

CSM Senior Design Projects with Cedaredge Middle School

Two senior design projects have partnered engineering students with middle school students and faculty. These partnerships have been a positive experience for both sets of participants.

Engineering Curriculum (2003-4)

The team designed and built various engineering devices and incorporated them into an engineering curriculum that the seniors also designed. These devices and this curriculum introduced the middle school students to mechanical, electrical, environmental, and civil engineering. The main goal of the project was to educate the students, make them more interested in mathematics and science, improve CSAP scores and adhere to all of the State Education Standards in mathematics and science. Units included a small-scaled water treatment facility and a project to reverse engineer a bicycle.

Learning Hall (2005-6)

The goal of this project was to design and construct a learning hall for middle school students. The team has designed multiple interactive displays and stations that will reinforce the basic principles taught in the mathematics, science, technology, and engineering classrooms. The seniors have designed learning stations that will challenge students at multiple levels and have

tried to avoid gender bias. Displays include a radio and broadcasting station, a computer-interactive disasters area, and an athlete wall where students can compare dimensions with a tall basketball star and short gymnastics star.

Results and Conclusions

Colorado State Assessment Program (CSAP) standardized testing scores were used to evaluate the success of the multifaceted efforts in improving mathematics and science learning for the students of this middle school. Table I lists the percentages of students to achieve proficient or advanced status on SAP from 2002 - 2005. The other possible categories are partially proficient and unsatisfactory.

Year	Subject	State	Cedaredge Middle Sc.
2002	6 th math	51	42
	7 th math	39	31
	8 th math	39	30
	8 th science	50	42
2003	6 th math	50	49
	7 th math	41	47
	8 th math	38	33
	8 th science	49	29
2004	6 th math	53	54
	7 th math	41	53
	8 th math	41	49
	8 th science	51	63
2005	6 th math	56	42
	7 th math	46	52
	8 th math	44	54
	8 th science	50	49

Table 1: CSAP scores showing % of students achieving proficient or advanced scores for the state and the middle school¹¹

In Colorado, mathematics is tested annually. However, science is only tested at grades 5 and 8. A graphical representation of each subject and year is presented in Figures 1 – 4. These data are only for advanced and proficient scores combined. Overall, this middle school showed average gains of 35.7 points over the years 2002-4 making it the most improved middle school in the state. In addition, the state Department of Education named this Middle School a 2005 Gain-Maker School for exceptional improvement in student achievement in mathematics and science for 2003-2005.

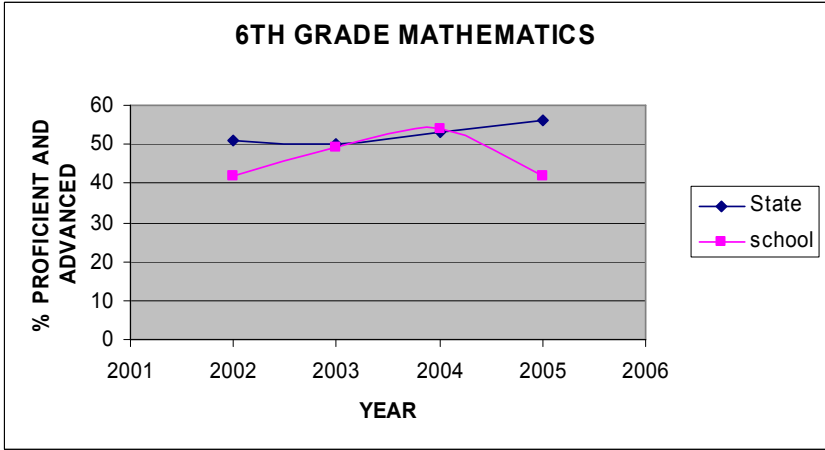


Figure 1. % of proficient and advanced students for 6th grade mathematics

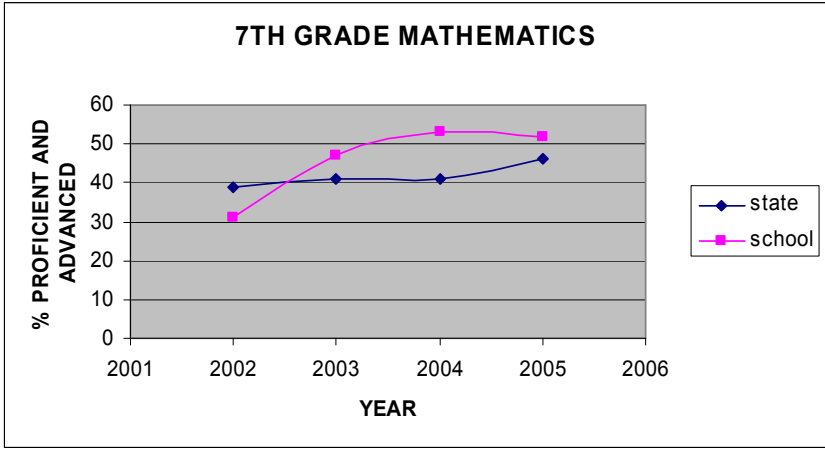


Figure 2. % of proficient and advanced students for 7th grade mathematics

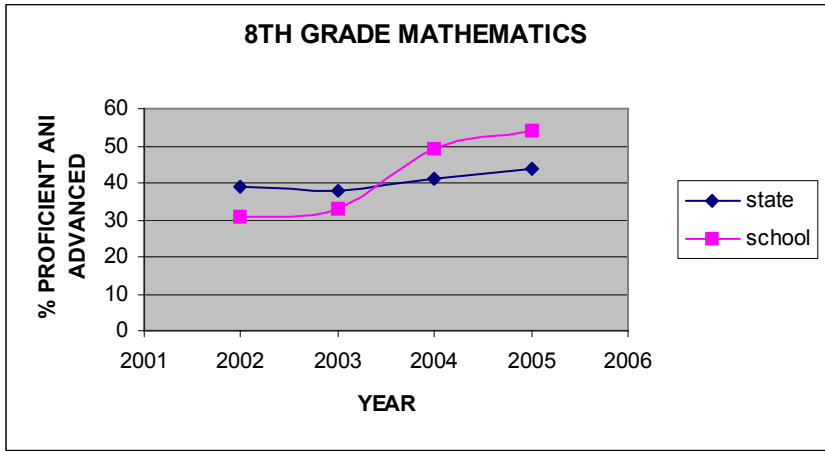


Figure 3. % of proficient and advanced students for 8th grade mathematics

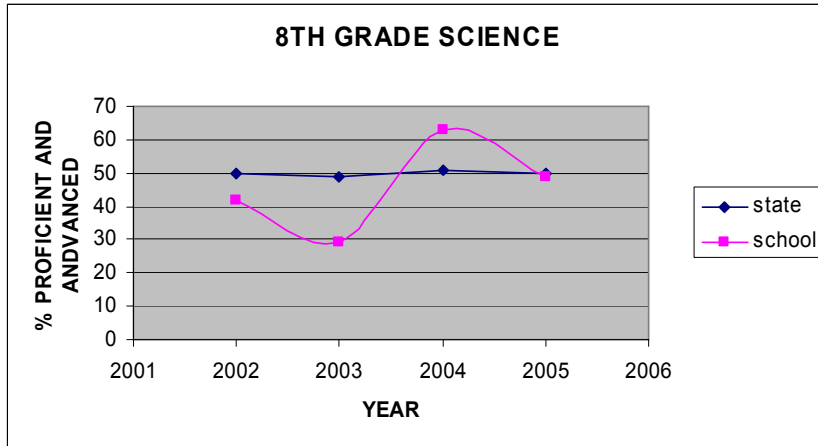


Figure 4. % of proficient and advanced students for 8th grade science

	6 th Math	7 th Math	8 th Math	8 th Science
2002 – Unsat.	20	17	34	26
-Part. Prof.	31	50	35	33
-Proficient	37	27	23	37
-Advanced	5	4	7	5
2003 – Unsat.	15	13	20	27
-Part. Prof.	34	35	48	44
-Proficient	44	32	26	28
-Advanced	6	14	6	1
2004 – Unsat.	19	4	20	17
-Part. Prof.	26	41	31	20
-Proficient	39	40	29	55
-Advanced	15	13	20	8
2005 – Unsat.	19	14	13	14
-Part. Prof.	39	23	33	36
-Proficient	32	31	36	41
-Advanced	9	21	19	9

Table 2. % of students ranked Unsatisfactory, Partially Proficient, Proficient, or Advanced for Mathematics and Science testing for this Middle School¹¹.

No single effort has caused the overall improvement in scores. The combined efforts of dedicated staff, targeted topic efforts, technology and engineering curriculum to augment mathematics and science classes, participation in professional development by staff, and cooperation among senior design students and the middle school have all contributed to the increase in mathematics and science student achievement. These efforts are not completed and must be continued for the future to ensure that future students continue to improve. While figures 2 and 3 show positive trends in mathematics, figure 1 appears to show a concern with

performance. However, note (Table 2) that the percentage of advanced students has increased. However, the percentage of unsatisfactory students has remained constant. The science data of Figure 4 shows overall growth but a continued need to improve. In conclusion, the total picture must be studied. This middle school is ranked by the state as AVERAGE and IMPROVING. Their goal is to be ranked as HIGH or EXCELLENT and be the premier mathematics and science middle school in the region.

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