AC 2008-1728: GEARING UP FOR THE FUTURE: A K-12/UNIVERSITY PARTNERSHIP TO CREATE AN ENGINEERING MAGNET ELEMENTARY SCHOOL

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Gearing up for the future: A K-12/University Partnership to Create an Engineering Magnet Elementary School

This paper will describe the genesis of a new engineering themed magnet school in New Hanover County, North Carolina. A parent choice school assignment plan was adopted by the school system two years ago, immediately creating several extremely high needs schools in the downtown area. One of these schools, Rachel Freeman Elementary, gets the majority of its students from a nearby subsidized housing project. This year, the school is over 85% African American and over 75% of the students qualify for the federal free and reduced price lunch program.

Rachel Freeman administrators made the decision to convert the school to an engineering magnet using the *Engineering is Elementary* curriculum developed by the Boston Museum of Science as its basis for engineering instruction. The College of Engineering at North Carolina State University was brought in as a professional development partner to train staff in project based learning, engineering problem solving, the *Engineering is Elementary* curriculum and the use of engineering notebooks. The team developed a summer workshop and ongoing regular curriculum support plan that is now in process.

The paper will describe the development of the partnership, the collaboration between these two partners, as well as others who have been instrumental in developing similar programs elsewhere in the country, and the progress to date. The burgeoning interest in engineering magnet programs, in North Carolina an elsewhere, makes this topic timely. Even though this school/university partnership is in its first year of full implementation, the need to convey progress to date is vital. Future publications will share evaluation results at all levels as well as progress.

Introduction

One of the well-documented challenges faced by today's K-12 educational system is the underrepresentation of minorities and low income students in higher level mathematics and science courses. The resulting effect of few students from these demographic groups pursuing careers in Science, Technology, Engineering and Mathematics (STEM) fields is of enormous concern to many people both inside and outside of STEM. In addition the poor performance of American students, including our best and brightest, on international comparative assessments is alarming. But retention of knowledge is not the measure of most concern. Rather, it is the lackluster performance of American 15 year olds on the two most recent Programme for International Student Assessment (PISA) assessments[1], which measures how well students can apply the knowledge they have gained, that is the strongest indicator of the need for major changes in the way K-12 students are taught.

The long time and accepted methods of pedagogy practiced in today's classrooms were developed for an industrial revolution era society. Relying on the efficacy of traditional direct and deductive instruction to effectively teach all students is an erroneous generalization whose lack of e is demonstrated in lower No Child Left Behind (NCLB) test scores for certain

subgroups and a persistent achievement gap between higher performing Caucasian, Asian and Non Economically Disadvantaged (NED) students and their minority and economically disadvantaged classmates. All of these factors combine to make it abundantly clear that new pedagogical approaches are not only desirable, but vitally needed.

Inquiry science is one method which has been employed successfully with high needs populations, including predominantly African American (AA), Limited English Proficient (LEP) and Economically Disadvantaged (ED) populations. One of the earliest successful and widely reported projects was the Valle Imperial Project in El Centro, CA. The implementation of inquiry based science kits using the National Science Resources Center (NSRC) model of exemplary science education (research based curriculum, ongoing professional development, authentic assessment, community support and materials support)[2] resulted in significant increases in not only science achievement, but also reading, math and writing achievement.[3] These gains occurred in the poorest county in California where the large majority of students are limited in their English proficiency. Others have reported similar gains by utilizing instruction presented in a hands-on, inquiry based manner. Delaware is another example. State educators are closing the achievement gap between majority and minority students in science starting in grade four.[4]

In the fall of 2006, when the Rachel Freeman Elementary School staff was considering an instructional theme for their new magnet program, inquiry science was one of the components they considered necessary. But the administrative team decided to take it a step further and employ inquiry methods in the implementation of an instructional program rooted in engineering which they viewed as not only applied science, but also applied mathematics and a platform for the increased use of technology. At the same time, the K-12 outreach group of North Carolina State University's College of Engineering was getting an increasing number of requests for aid in development of K-12 engineering courses and curriculum from around the state. For the elementary grades, our university had already worked closely with the Boston Museum of Science and their *Engineering is Elementary* (EiE) program and had an engineering education staff member trained as a professional development provider for the curriculum. EiE is a research based elementary curriculum whose foundation is in literacy and incorporating social studies and mathematics in the engineering projects. The units are stand alone but are designed to be taught during the same time period as the corresponding science content. Each unit is based on a specific engineering discipline and features critical thinking and problem solving activities and projects using an elementary engineering design process of "Ask-Imagine-Plan-Create-Improve."[5] The initial meeting between Rachel Freeman and our university took place in December, 2006 and collaboration began.

Planning

The leadership team at Rachel Freeman had already decided on engineering as their magnet theme, but had not yet investigated existing curricula or contacted other schools in the country who were engineering themed schools (for example, the Raymond Academy of Engineering in Aldine, Texas

or the Douglas L. Jamerson Elementary Center for Math and Engineering in Pinellas County, Florida). They had become familiar with the *Engineering is Elementary* curricula thorough online research and were eager to explore the use of it at the school. It is interesting to note that the teaching staff did not have buy-in, or understanding, of the engineering magnet theme at this point. The first year of operation of the Rachel Freeman Elementary School of Engineering was to be 2007-08. The implementation of the new magnet theme was complicated by the nearly complete turnover of the student population due to a new district-wide student assignment plan that utilized a neighborhood school concept vs. the socio-economically based one previously used. The net result was that Freeman, located in downtown Wilmington, NC, went from a mix of suburban and urban students to one composed of over 85% African American students from a subsidized housing project near the school. The majority of these students (~75%) qualify for the federal free and/or reduced lunch program, the recognized identifying component of the Economically Disadvantaged (ED) subgroup of NCLB. Previously, the students from the complex were split among three schools in the county. This meant that the teachers would be teaching under a new paradigm just at a time when the population they were to teach became more challenging.

Further complicating matters was that the school district had extended the cut off date for teacher transfer requests from early spring to the end of June. In other words, the administrative team would not know which staff members were staying or leaving with certainty until mid-summer. This meant not only gray areas in planning staff development but the necessity to hire during the summer, long after other schools and districts had finished hiring. By the time the 2007-08 staff reported in August, over 50% of the staff was new to the school.

During regular meetings throughout the spring 2007 semester, the lead K-12 engineering education specialist from the university and key members of the Freeman staff and administration met to outline the needs for initial professional development as well as ongoing training. The decision was made to start from the beginning with the basics of project-based and inquiry instruction, move on through engineering itself and finally concentrate specifically on the *Engineering is Elementary* kits as well as the science kits provided by the school district. The engineering topics of EiE were mapped to the North Carolina Standard Course of Study in Science learning objectives, and the team would work together to provide engineering content for those curriculum strands not covered. Of particular need is engineering content for grades K 1. The majority of the professional development would take place for four and a half days, two weeks prior to school starting in late August. The university specialist planned to visit the school one to two days a month throughout the year, conducting additional professional development workshops on early release and teacher workdays, as well as working directly with students and classroom teachers modeling the integration of engineering concepts throughout the core curriculum.

Implementation

The university specialist worked primarily with the school's technology teacher, who has an avid interest in the engineering concept and is exceptionally skilled in both working effectively with classroom teachers and curriculum integration. During summer meetings, we refined the agenda for the professional development (PD) week by strengthening connections to science content in particular. While the school district had previously recommended schools purchase inquiry based kits from Carolina Biological Science and Technology for Children (STC) and Delta Full Option Science System (FOSS) they were not required to do so, and limited professional development was provided to teachers and was optional as well. As a result, the kits were delivered and removed each nine weeks, but few teachers used them for instruction. The professional development week would be an excellent opportunity to extend the use of the kits and ease the transition into the world of EIE. The final agenda for the week is in Appendix A.

It is interesting to note that, while many of the teachers at Freeman were new or had little teaching experience (relatively new graduates), none had received formal instruction in inquiry teaching and learning, and few had participated in project based learning experiences. Some of the more experienced teachers had done small scale project-based learning units, but for the most part, these were new concepts to the teachers. In addition, these elementary teachers, like many of their peers, were not totally comfortable with the science and math content behind the engineering. In this the school had a big advantage. Nearby GE Nuclear had committed to provide both grant funds and significant volunteer time from their engineers to support the teachers in the implementation of engineering and by providing science content expertise.

The goal of the summer professional development workshop was to present engineering as not a separate and new topic, but rather a tool that integrates the core subject areas of math, science, social studies and language arts. As many who work regularly in the K-12 arena are aware, non-tested subjects are quite difficult to get into regular instruction due to the pressure exerted on teachers and administrators by NCLB and state testing. But the data indicate that hands on, inquiry based learning and teaching appeals to a wide variety of learning styles.[6] This provides an informed basis for using the hands-on, project based, inquiry approach of engineering as an integrator. In addition engineering as a curriculum integration tool is a powerful application of the 21st century needs of Life and Career; Learning and Innovation; Information, Media and Technology skills along with core subject expertise[7] and also provides a method to strengthen both rigor and relevance to core subjects.

We made the decision to have every student utilize an engineering notebook daily. Based on the research on the effectiveness of science notebooks[8] and modeling the real life habits of working engineers, the notebook would be used not only in the regular classroom but also taken by the children to their daily specials (art, music, PE, social skills and media), who would be working with classroom teachers to integrate engineering concepts into these subjects as well. We modeled the use of engineering notebooks throughout the week, with the teachers documenting data on the projects they did as well as completing a daily journal entry in response to a prompt from the specialist. Each evening, the specialist read and commented on each entry. This proved to be an effective method to get real time feedback on how the week was going, address areas of ongoing concern and use as a tool to modify the agenda to address topics of general interest, while at the same time gave the teachers a model for how they might implement the notebooks in their classrooms and use them as an information tool to guide both instruction and assessment.

Entries from the notebooks, as well as remarks left on the 'issue bin,' indicated a large amount of trepidation at the beginning of the week. The teachers were worried about having to become engineers in order to be effective instructors in the methodology, and also about knowing all the answers to questions students ask. In our experience, this is a common fear among teachers when first using inquiry based instruction. Throughout the week, the specialist noticed a definite increase in confidence levels of the teachers as they learned more about both engineering itself and the specifics of the EiE curriculum. Because of its base in literacy and social studies

and the fact that extension activities and masters are provided within the kit, the material design of the EiE units was familiar. This in turn helped the teachers to be able to look at the content with less trepidation. By the end of the week, journal responses were longer, very positive and full of questions and excitement. Having questions no longer dampened the excitement of the teachers, which was an indicator of increased comfort with inquiry in general.

Mid week the teachers were joined for several hours by GE Nuclear engineers who had volunteered to work with different grade levels. The teachers took advantage of this meeting time to ask questions about science and engineering content, as well as to plan how the engineer would spend his/her time in the classroom. This is an important collaboration for the school, and the engineers were very enthusiastic about the potential opportunities.

An adjustment was made to the agenda late in the week due to feedback in the teachers' notebooks. An afternoon was spent discussing how to create a culture that fosters an inviting and comfortable atmosphere to learn engineering concepts in the classroom and throughout the school. During this time, the engineering specialist took the teachers on a 'field trip' around the building to strategize on how to change the physical setting to make it clear from the entrance that the school was about engineering and success. The school's new name and motto were already chosen by administration: The Rachel Freeman Elementary School of Engineering: Gearing Young Minds for the Future. First, the staff decided to install display cases and shelving in the lobby to highlight student generated engineering projects for visitors. Another decision was to install real street signs to name each hallway and central area (such as the cafeteria and media center) relevant engineering and problem solving phrases. Some examples are Problem Solving Place and Creativity Circle. Next, the entire group participated in the development of a school vision statement that would be displayed on a large banner in the lobby and on smaller posters in each classroom and hallway. The final statement was:

> "We are a community of student engineers who use team work, communication, and creative thinking to solve problems as we build dreams and become lifelong learners in a global society."

Finally, the staff decided it was important to cultivate the climate of an engineering school by prominently displaying the motto, vision statement and EiE design process graphic abundantly throughout the school. In each classroom, hallway and common area there are copies of these as well as pictures of teams at work and their completed projects.

The plan for ongoing support is for monthly visits from the university specialist, while the technology specialist at the school handles the day-to-day needs. The first specialist visit consisted of grade level meetings to discuss progress made and challenges faced in the first month. The outside viewpoint is very valuable, since the teachers in the day to day work tend to be very hard on themselves. Nearly all grade levels felt they were not implementing enough of the engineering ideas, yet every grade level had done at least one engineering project, even if it was not from EiE. For example, in kindergarten, students study animals in science, so, using an 'animals as engineers' theme, the classes studied beaver dams and ant farms.

Each classroom had a see through gel ant farm to monitor the progression of the sophisticated tunneling system that ants dig. Using their engineering notebooks, the students wrote and drew pictures about what they observed and what they thought would happen. When the specialist arrived at the school that day, one kindergarten teacher brought her class's farm to the office because she was so excited about how it was made! First grade students designed projects around books they were reading. For one book about a man constantly losing his hat, the children designed and built hats that would stay on. Fourth graders were keeping detailed engineering notebooks and diligently taking them to specials to write entries there. And the fifth grade, working with volunteer engineers from the nearby GE Nuclear plant, designed and built Lego robots for an inter-grade competition.

The next visit in October included a Family Math Night, using activities developed under an NSF GK-12 grant at the university.[9] The staff and administration promoted the event heavily in the weeks prior, but were very concerned about the potential attendance given their experience with low income families. However, over 200 parents and students showed up and worked side by side with teachers on activities and games that reinforce basic math skills. The feedback from parents was extremely positive and the turnout provided a much needed morale boost for the staff.

Challenges

When students are assigned to schools in the area in which they live, the school demographics of course reflect those of the surrounding community. In urban areas, this often results in student populations with high needs. This is the case with Rachel Freeman. The unintended consequences of such an assignment policy are numerous and daunting. The simultaneous implementation of an engineering curriculum with a predominantly new staff takes a strong administrator and huge support. The principal of Freeman is a very experienced administrator who is well regarded by her staff, colleagues and central office personnel.

The biggest challenge was in acclimatizing the students to a disciplined environment with high expectations for behavior and academics. As stated, the children who lived in the neighborhood had not attended the same school before, and neighborhood tensions were often brought into the school. In addition, it seemed to the staff that previous academic and behavioral expectations for these students had been low. Finally, the emotional needs of high poverty children are enormous[10,11] and require a lot of energy from the teachers. The task of addressing these issues at the same time as they were implementing a team oriented, project based engineering curriculum was enormous. Staff morale remains a key concentration area for administration as well as the specialist supporting the engineering implementation.

Another major unexpected hurdle has been presented by the rules of NCLB. The Freeman principal has funding for an engineering coordinator position. However, as the central office human resources department interprets the rules of NCLB, this position must be filled by a 'highly qualified' elementary math or science specialist. The issue of elementary teachers receiving a more generalized content background means that such a person is rare, if it even exists. Discussions are underway to address the divide, but until then the technology specialist is doing both engineering and technology coordination.

Consistent support and feedback is necessary to meet the needs of the staff and students. Teachers email our university's engineering education specialist with questions and requests for help with research, activities and STEM content. Providing this electronic support is an important link between the two educational institutions. The principal is also supporting visits by key staff members, along with the university specialist, to other elementary schools who have established engineering programs in their elementary schools, for example the Raymond Academy of Engineering in Aldine, Texas. Raymond is a K-4 school with a high minority and high poverty student population. However, student achievement on the Texas Assessment of Knowledge and Skills is extremely high under the engineering magnet theme. In their seventh year, Raymond students study engineering with projects in the Mechanical, Civil, Electrical and Chemical disciplines. (http://www1.aldine.k12.tx.us/schools/websites/raymond/index.html) The school has support from many business partners but no direct university collaboration in recent years.

Freeman staff members and the engineering specialist will also visit Douglas L. Jamerson Elementary Center for Mathematics and Engineering in Tampa, Florida. Jamerson is in its fifth year as an engineering magnet school and enjoys a very close collaboration with the University of South Florida and Professors Dr. Marilyn Barger and Dr. Richard Gilbert. Drs. Barger and Gilbert conduct ongoing professional development in STEM content, write parent newsletters and support staff in the engineering implementation. (http://www.jamersones.pinellas.k12.fl.us/).

Through visits such as these, the Freeman staff hopes to learn how others are dealing with similar student populations and the implementation of engineering.

For the remainder of this year, the university engineering education specialist will continue to make monthly visits to the school to provide ongoing support and half-day professional development workshops focusing in science, engineering and math integration. The leadership team at the school has already decided to again bring the staff back early to undergo another week of professional development, this time specializing in science and math content and methods of integration into the engineering curriculum.

At the beginning of the school year, teachers administered the Boston Museum of Science's "What is an Engineer?" and "What is Technology?" surveys as a pre test of knowledge. These will be compared to those administered in June, 2008 as a post test to evaluate whether students have a better appreciation for engineering and technology. While teachers are using the engineering notebooks as formative assessments of individual student growth, the administration and specialists will examine them for general growth and content knowledge understanding. This allows teachers to make changes in the way units are presented or to remediate during a unit and to also gather summative data to assess student learning authentically. Finally, math, reading, science and writing state assessments given by the state will be followed year to year to assess knowledge gain.

Early Observations and Teacher Reports

Through the monthly visits and regular email contact, the specialist has developed positive and supportive relationships with the teachers at Freeman. The dynamic nature of this first year implementation requires that ineffective practices be stopped or changed and new ideas

evaluated carefully. One of the things the staff requested was a resource document of easy to organize and deliver hands on stand alone engineering activities that would give them additional opportunities to get both themselves and their students more comfortable in the implementation. Using well researched and documented resources such as TeachEngineering.com, as well as numerous university and National Science Foundation GK-12 outreach sites, plus the multitude of activities already being used by our university, this was a relatively simple resource to assemble. The teachers have used it heavily and proudly display the products of their students in classrooms, hallways and the front entry hall.

One of the teachers of Students with Disabilities (SWD) requested help in the development of an engineering newsletter idea she wanted to use to prepare her students for the upcoming fourth grade state writing assessment. They used the engineering design process to develop the newsletter idea to a workable plan. Each student and his/her family have been lent a laptop computer to take home to work on the project and training was provided to both adults and children.

Teachers report remarkable changes in student behavior when engineering projects are being done. The ability to get the children to work effectively in teams has been a real challenge. One fifth grade teacher allots time periods for each step of the design process when doing engineering projects. If students have trouble working together or are disruptive, she has the entire team take five minute breaks from that part of the process, thereby losing some of the time the other teams have to work. The competitive spirit vies with peer pressure to behave and the teacher has seen great improvements in team work.

Others report about students who have not demonstrated their academic abilities in the traditional classroom setting showing a high level of critical thinking and problem solving ability during engineering projects. These up to now unseen skills, in turn, have resulted in increased confidence during direct instruction subjects as well as improved behavior overall.

Another fifth grade teacher reports:

“All the students, no matter what academic level, have been motivated to work on all the engineering tasks we have completed. They also have been brought to about the same level as far as working and solving problems and creating things together, where in say Reading class it is evident who is the better reader and their academic levels. During engineering all the students are on an equal playing field.”

She continues with information about two particularly challenging students:

“The main students that stand out are two of my lowest students academically. One, Omar, is on a First Grade academic learning level. He has not been able to function in the fifth grade class work, but does wonderful with the science and EiE curriculum. He stays engaged and motivated where with other subjects loses attention and falls asleep. He has helped contribute with his groups and given helpful problem solving strategies in building and completing tasks. .....During one project where the object was to have the tallest tower that could hold a full crayon box, Omar was able to show his group how to stabilize their structure to withstand the

weight longer. He showed them also that they could flip their tower upside down since the top of their tower was wider and larger to be able to sit sturdier on the desk.

Another student, Marlon, as on an Individualized Education Plan (IEP) and is very low academically. He is at a second to third grade reading level and has been diagnosed with ADHD. During EiE tasks he is very motivated, engaged, and his attention remains on task. He has shown interest in every task where he has wanted to excel and give his knowledge and helpful participation to the group." She goes on to tell about his assuming a leadership role in a roller coaster building activity that resulted in his team successfully completing the task.

Finally, she comments "engineering and the science activities appeal to all the different levels of the students and especially with the population of socio economic issues and troubles that we have seen here at Rachel Freeman. I look forward to the EiE kit for the third nine weeks coming up."

Teachers in other grade levels report similar stories of engagement and interest in doing the activities taking precedence over a child's behavior choices. This is an area of great interest to the team and will be a subject of future evaluation.

Conclusion

Our university continues to receive requests from K-12 schools at every level for assistance in implementing engineering processes, ideas or curriculum in their schools. The rapid growth of the K-12 division of the American Society of Engineering Education (ASEE) supports our belief that engineering is being looked at in a new way by the K-12 education community. At the Rachel Freeman School of Engineering, we believe it is an effective tool to not only apply and integrate the core subjects, but also to appeal to a broad range of students and learning styles to increase student achievement. This paper reports on the groundwork and early implementation of a university/K-12 school partnership to create a K-5 engineering magnet school. Due to the burgeoning interest in the K-12 system as a whole in engineering magnet, these early results are presented as a guide to others considering implementing such a magnet program. Assessment results and progress will be offered in a future publication.

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Appendix A: Rachel Freeman School of Engineering Staff
Development Agenda Week of August 13, 2007

Date	Time	Activity
Monday, 08/13/07	12:153:15	Facilitator Introduction and Background Goal Statement and Participant goals for week Introduction of engineering notebooks with guide for use Problem Based Learning Principles and Process (with best practice video)
Tuesday 08/14/07	8:0011:30	Introduction to Engineering Presentation Engineering Principles Engineering Design Process (including the elementary version utilized by EiE) Engineering Team Activity
	11:3012:30	Lunch
	12:303:30	Engineering, Science and Technology: What's the difference? Discovering the engineering in Science kits (presentation and hands on activity)
Wednesday 08/15/07	8:0011:30	Engineering is Elementary program introduction Overview of EiE units and structure EiE correlation to the North Carolina Standard Course of Study Science Objectives Engineering Team Activity
	11:3012:30	Lunch
	12:303:30	Engineering is Elementary Unit exploration with GE Nuclear Engineering Partners Classroom walk to observe grade level EiE projects
Thursday 08/16/07	8:0011:30	"A Private Universe" video Integrating Inquiry throughout the curriculum
	11:3012:30	Lunch
	12:303:30	Planning for implementation: creating the environment, mission statement, making it happen
Friday 08/17/07	8:0011:30	Engineering in Action in the Classroom Engineering Design Challenge (water filters, egg drop)
	11:3012:30	Lunch
	12:303:30	Engineering Notebooks: Review and Assessment Assessment: How do you know its working? Where do we go from here?