

Elementary and Middle School Engineering Outreach: Building a STEM Pipeline

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Abstract - The J. B. Speed School of Engineering is working to build a K-12 STEM (Science Technology, Engineering and Math) pipeline. Speed School is working with the local public school system and eventually the Louisville Science Center to expose young students to the world of engineering to prepare and encourage them to study STEM fields. Two successful bi-weekly programs are currently in place: (1) “Engineering Is Elementary” (EIE) program, offered in three local elementary schools and (2) “In the Middle of Engineering” (IME) clubs in two area middle schools. Both programs are coordinated by the Director of Outreach Programs at the Speed School and are supported by graduate and undergraduate students, faculty, and engineering alumni. Response to these programs has been very positive. This summer, the J.B. Speed School of Engineering participated in a unique training partnership with JCPS to provide teachers with training needed to support additional programs.

Keywords: Outreach Programs, Engineering is Elementary

BACKGROUND

The Need for a Pipeline

The creation of a robust K-12 STEM pipeline has been widely identified as critical to the future of America’s global competitiveness and is based on the research of experts who have produced concrete recommendations in the NAS Gathering Storm Report [19], Project Kaleidoscope Report on Reports II [18] and the President’s American Competitiveness Initiatives of 2007 [17]. Locally, the Kentucky Council on Postsecondary Education STEM Task Force [12] has developed a state-wide strategic plan to accelerate Kentucky’s performance within STEM disciplines. Both the STEM Task Force and the National Science Board [1] recognize the need to form strategic partnerships that inform K-12 students and parents about engineering.

The American Society for Engineering Education, (ASEE) published an analysis of current practices and guidelines for the future [Douglas, 9] and is involved in an ambitious effort to improve K-12 engineering education and outreach. The J.B. Speed School of Engineering is building a successful partnership with the local public school system, Jefferson County Public Schools (JCPS), which has more than 98,000 students. This partnership will soon include the Louisville Science Center. Through this partnership, young students will be exposed to the world of engineering and technology. The goal is to provide students with a foundation that prepares and encourages them for a STEM field of study in college, by elaborating and spreading the “Engineering Is Elementary” (EIE) and “In the Middle of Engineering” (IME) programs, discussed in the following section. Through its participation in this partnership, Speed School specifically implements four of the six published ASEE guidelines: 1) working with hands-on projects at the elementary level, 2) engaging young science teachers by providing them with good curriculum, materials, training and mentoring, 3) targeting minorities and females, and 4) strengthening the existing partnership between higher education (Speed) , K-12 (JCPS), and to an important community partner, the Louisville Science Center (LSC) who would provide important guidance on teacher training.

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Previous Outreach Programs for Engineering

The literature on outreach programs and outreach program assessment is vast. However, there is little information on assessment of K-12 engineering outreach programs [Poole, 16]. A review of K-12 engineering outreach programs [Jeffers, 10] describes several different models. The review notes that it has become clear to educators that students need to be introduced to engineering at an early age, and that K-12 teachers need assistance from engineers and engineering educators. It further states that all successful engineering outreach programs have a “do” or “hands-on” component, hearing or reading about engineers or engineering is not enough. Many universities are actively using outreach to promote STEM pipelines by offering workshops for students and teachers, hosting residential camps, competitions, conducting outreach activities at schools, conducting and sponsoring contests, developing materials and websites, and bringing students to campus for outreach activities [Jeffers, 10; Carlson, 3; Poole, 16; Rogers, 20; Sullivan, 22]. Websites for most engineering colleges indicate that they offer one of these K-12 outreach approaches.

What makes Speed School’s outreach program unique is that it “pulls” students into engineering in elementary school and mentors them through a pipeline that continues through high school. This is achieved by combining a nationally recognized curriculum for elementary students (EIE) with a locally developed middle school club program (IME) and the successful Project Lead the Way (PLTW) high school program. The Louisville Science Center, whose staff is skilled at teacher development and training, plans to join the partnership as funding becomes available. A focused partnership of Speed School of Engineering, JCPS and eventually LSC, will help build, support and sustain a STEM pipeline from elementary through the college level.

OUTREACH CURRICULUM

Engineering is Elementary

The most important part of any program is to have solid curriculum with hands-on learning activities, such as that provided by *Engineering is Elementary*, (EIE) developed by Dr. Christine Cunningham of Boston Museum of Science. EIE is a set of 20 modular units with hands-on activities that incorporate engineering and technology concepts with elementary science objectives. These units (currently 13 are available, with the rest due in 2009) align with the National Science Standards, the Kentucky Core Content for Assessment as well as the inquiry-based science module curriculum that JCPS is currently implementing. The EIE development process is research based and is clearly described in “Engineering is Elementary: An Engineering and Technology Curriculum for Children” [Cunningham, 7]. Cunningham recently reported [Boisseau, 2] that 9,306 teachers and 484,081 students in more than 1200 schools in all 50 states have used EIE lesson materials. JCPS is the only school system using EIE in Kentucky.

The EIE curriculum introduces each unit with a story about a child with a problem to solve. Activities introduce the engineering foundation of design, using science concepts as the students help the child solve the problem. Soft skills are learned as students learn to work in teams, deal with failure, and learn to “try again”. The next unit lesson focuses on helping students develop a broader perspective on the unit's engineering discipline involved. Through hands-on activities, students learn more about the types of work done by engineers in these fields, and the kinds of technology they produce. The third unit lesson is designed to help students understand the linkages between science, mathematics, and engineering. Children collect and analyze scientific data that they can refer to in their final lessons as they create engineering designs to solve their problem. Some lessons may take longer than others, especially the initial introduction to the problem and the design and build lesson. Explanation of lesson plans is available from the Boston Museum of Science website, http://www.mos.org/eie/lesson_plan_structure.php.

The EIE units are not an independent curriculum; but rather are designed to extend the learning that occurs in the existing curriculum. The units selected to be implemented in the after-school engineering program will be ones that best align with the JCPS science module curriculum. JCPS is in their third year of a district-wide inquiry-based science curriculum implementation. The EIE units use the same inquiry-based pedagogy; therefore, students will have additional opportunities to learn science by doing science. Students will also extend their learning by applying and connecting the science concepts they learn in the classroom to their problem solving experiences in the EIE units.

This is a rigorously researched and assessed program [Cunningham, 5, 6, 8; Knight, 12; Lachapelle, 13, 14; Shields, 21] with ongoing assessment. Their research has shown it not only improves elementary students’ understanding of science concepts, but their understanding of technology and of engineers and why their job is important. The Boston

Museum of Science is interested in having the Kentucky partnership participate with them as part of their ongoing formal assessment of EIE. They will provide the test instruments for teachers and students, and will also score the assessments and provide a copy of a database of information to the Kentucky partnership, as well as using the information for their own study. An initial assessment is planned for spring 2009, and formal assessment will start in fall 2009.

In the Middle of Engineering

Many students from the identified elementary schools will attend the two middle schools with “In The Middle of Engineering” programs: Carrithers Middle School and Newburg Middle School. At Carrithers, the IME after-school program supplements their Gateway to Technology Program. Gateway to Technology is the Middle School curriculum of Project Lead The Way, and consists of five independent nine week courses. Carrithers refers to this as their Technology Immersion Program and it is a pre-engineering curriculum required for all students. They use Inventor Autocad software and students take all five courses: Design and Modeling, The Magic of Electrons, The Science of Technology, Automation and Robotics, and Flight and Space. The IME programs are developed in coordination with the science teachers and use hands-on kits available from Slinky Science (<http://www.discoverthis.com/slinkyscience.html>), “Our Amazing Bridges”, “The Electro Lab”, “All About Gears” and “Solar Energy” to enhance topics covered in their Gateway to Technology and science classes.

Project Lead the Way

Project Lead The Way (PLTW) is a nationally accredited high school pre-engineering /engineering technology curriculum for aspiring engineers. It has been proven to prepare high school students for college/university engineering/technology curriculums, and is offered at Jeffersontown High School, the only high school with a PLTW program in JCPS. The program's academically challenging curriculum includes a four-year sequence of five technical, mathematics, and science integrated courses that compliment the honors/advanced mathematics and science courses required of pre-engineering/engineering technology students. The elementary and middle schools that are in the identified pipeline supply students to this high school. Speed has established a relationship with Jeffersontown High School and is working with them to coordinate more closely with the targeted middle schools. Speed's Outreach Director also worked with them to offer a summer camp in 2008 for their PLTW students that introduced them to Speed's campus. Plans for summer 2009 are underway, and will involve more of Speed's faculty in order to better introduce engineering education and the engineering disciplines.

PIPELINE PLAN AND DEVELOPMENT

Speed School, and its newly created Department of Engineering Fundamentals, is in an ideal position to initiate a new partnership for outreach, one that is both strategic and sustainable. One of the department's specific missions is to create outreach programs to elementary and middle school students. When the department was created in April 2007, the Dean established a term faculty position specifically for a Director of Outreach. This position was filled almost immediately. Through discussion and research, the best way to effectively perform outreach to elementary and middle school students was explored by the department, and this mission is part of the department's strategic plan. The goal is to have a lasting impact, to effectively make use of resources, and to have a sustainable model.

At that time, Speed had been working with Wheeler Elementary School (a JCPS school) since fall 2006 when Wheeler started an EIE Program at the direction of Wheeler's principal. At Wheeler, the EIE program is an after-school activity offered every two weeks. Wheeler solicited volunteer participation from Speed. They wanted the students to see and talk to engineers, and also wanted Speed's opinion of the program. Everyone, including the Dean (who participated regularly), faculty volunteers, the Wheeler teachers, principal, parents, and students all agreed it was an unqualified success. Students had fun, learned about science, and more importantly, learned what engineering involved and what engineers do.

First Year Activities and Planning

Wheeler had so much interest that a second “engineering group” was started, so that there were two EIE classes in school year 2007-2008, and there are also two programs in 2008-2009. The Department of Engineering Fundamentals' Outreach Director became involved with both groups and now has a cadre of Speed School student volunteers and Speed alumni that participate actively. The success of the program was highlighted in an article in the Courier Journal on March 3, 2008.

Speed's experience with Wheeler offered an obvious way to effect systemic change: develop a mechanism to allow the Wheeler teachers and principal to share their knowledge and enthusiasm within JCPS so that more elementary schools might start EIE programs with support and mentoring offered by Speed, and with teacher and informal science education training provided with guidance provided by LSC. It is seen as critical that Speed School take a lead role in this new partnership to "pull" more young students into the pipeline, giving them ample opportunities to see and talk to engineering faculty, alumni, and college students and to receive guidance early on concerning what types of courses they should take in middle school and high school. This plan is only partially implemented at this point, as additional funding is needed to fully integrate the LSC as a partner in the educational training. LSC is very interested, has participated in proposal preparation, and is anxious to formalize interactions.

The JCPS elementary schools (in addition to Wheeler) targeted for this pipeline are Jeffersontown, Watterson, Tully, and Bates. All of these feed the only middle school (Carrithers) in the county with a Gateway to Technology program which is the PLTW middle school program. In addition to providing the after-school IME program, discussions are underway with Carrithers as to how Speed can mentor and support their Gateway to Technology program. These elementary schools also feed Newburg Middle School which has a very successful engineering club started by Speed's Outreach Director in the 2007-2008 school year. These two middle schools feed Jeffersontown High School, the only high school with a Project Lead the Way pre-engineering program, but one that lacks the desired number of participating students.

Speed and Jeffersontown have started working together. In July (2008), Speed's Outreach Director, working with the director of the PLTW program, hosted a summer camp for middle school students from the two middle schools, encouraging them to enter the PLTW program at Jeffersontown. Students visited Speed's Clean Room, Nano Technology, Bio-mechanics, and Rapid Prototyping Facilities, and will work with Speed faculty and students as part of the summer camp.

Principals and teachers at Carrithers, Newburg and the five elementary schools are excited about this new partnership and the opportunities to enlarge the STEM pipeline. Thus, relationships exist currently between Speed and JCPS at all points in the pipeline, what is needed is a mechanism to ensure these informal EIE programs can be spread, thereby enlarging the flow by getting more students in at the elementary level. Furthermore, there must be a means to sustain and replicate these activities so that other elementary-middle-high-university pipelines can be created in JCPS and elsewhere in Kentucky. Creation of a new partnership with this focus will provide such a mechanism.

Advantages of a Partnership with Louisville Science Center

The Louisville Science Center is an organization dedicated to encouraging people of all ages to appreciate science, mathematics and technology in a stimulating and engaging environment that is educational as well as entertaining. Opened in 1977, LSC is uniquely situated as a cornerstone of the West Main Street Cultural District in downtown Louisville, Kentucky. Designated as the *State Science Center of Kentucky*, LSC serves over 500,000 persons annually, approximately two-thirds of whom are families. As the most visited school field trip destination in Kentucky, LSC annually serves more than 150,000 students and teachers. Completely revitalized over the past 10 years; LSC features 40,000 square feet of interactive permanent exhibit experiences including a celebration of creative thinking and the physical sciences, an exploration of the human body and the life sciences, and an investigation of environmental issues and the natural sciences. Other areas feature items from the natural science collection, a special area for young children, temporary exhibitions, and an IMAX theater.

LSC considers pre-K through 12 students and teachers its most important mission-related audience. In addition to school field trips, LSC's educational offerings include annual Teacher Institutes on both science content and inquiry methodology, workshops for early childhood educators, after-school science for middle-school students, an immersive program for schools with under-served populations, family science nights, a teen volunteer program, camp-ins, distance-learning links, traveling exhibits, outreach kits, and a website that reaches about 200,000 on-line visitors each year. LSC has an informal education staff with rich experiences in implementing hands-on projects of this nature. Through its membership and leadership in the Association of Science-Technology Centers (ASTC), LSC has cooperated or coordinated the implementation of many informal science model programs in Kentucky including GEMS (Great Explorations in Math and Science) with the Lawrence Hall of Science in Berkeley CA, Inquiry-based teacher training with the Exploratorium in San Francisco, CA and many NASA initiatives including the Virtual Space Community with Houston Space Flight Center. LSC and the developer of the EIE curriculum the Boston Museum of Science (BMOS) worked on a state-wide implementation of Science-by-Mail and other projects. Locally, LSC has over 30 years experience working in collaboration with JCPS and the Speed to jointly provides

excellence in STEM related programs, exhibits, films and teacher training. With the opportunity to have LSC manage and coordinate the teacher-training as well as coordinate meetings of the partners, pipeline sustainability and replication are greatly enhanced.

This partnership supports the pipeline and offers an opportunity for dialogue to develop ongoing plans for sustaining and replicating this STEM initiative with input and guidance from all. To bring together teachers from elementary, middle, high school and college levels (vertical integration) with a major community partner to address STEM issues in an integrated systematic way is critical to the success of the pipeline.

Impact and Sustainability of Partnership

Strategic attempts to enlarge the funnel of interested and prepared students has the obvious impact; if successful these students enlarge the pipeline of students able to pursue STEM studies at the middle, high school, and university levels. At worst, the result is a more technologically literate group of students and more technologically literate teachers. Of particular note is that Jefferson County, Kentucky has made national news with its school desegregation plans and its commitment to maintain diverse populations at its schools. All of the schools in this pipeline have diverse populations ranging from 24-50% minority and 40-50% female. Minority and female students are particularly encouraged to participate in the EIE and IME programs.

This pipeline system model is sustainable specifically because of the partners: a department with a strategic mission of elementary and middle school outreach, a county school system whose new superintendent, a cadre of elementary and middle school science teachers who are committed to STEM initiatives, and the Louisville Science Center, the State Science Center of Kentucky whose strategic mission includes education and training in science, math, and technology and who has established other successful teacher training programs in partnership with JCPS. The partners have experience working together on other initiatives and have a common interest in STEM. Working together, these entities can effect change that would be difficult to accomplish by any one of the partners working separately.

By sharing the enthusiasm and engagement of the teachers and principal from one very successful program, this partnership has already initiated new programs at the three additional target schools following a teacher professional development seminar held in July 2008. Eventually, this teacher training would become the responsibility of LSC.

As part of the partnership, principals and teachers from all participating schools, including the middle schools and high school will meet once or twice a year to share in modifying the overall plan, review where they fit in the pipeline, and decide how to move the joint effort forward. With the partnership fully in place, the EIE and IME programs can be replicated at more elementary and middle schools in the following years. Currently, JCPS and Speed are full partners, and LSC will become involved formally when more funding is secured.

Results to Date and 2008-2009 Activities

At the end of spring 2008, there were two successful EIE programs at Wheeler Elementary and one successful IME program at Newburg Middle School, and the plan for the pipeline and partnership was established. The Outreach Director, with support from JCPS administration approached the principals and science teachers at the other schools targeted for the pipeline. Response was very positive and in July 2008, the J.B. Speed School of Engineering participated in a unique training partnership with JCPS to provide these elementary and middle school teachers with the training needed to support the EIF or "In the Middle of Engineering" in their school. The teachers from Wheeler, the teacher from Newburg, and Speed's Outreach Director demonstrated the activities and showed how they supported the current science curriculum. In total, eighteen teachers participated with attendance from all the targeted schools. When additional funding is obtained so that Louisville Science Center can be fully incorporated as a partner, they will coordinate summer teacher training. The goal is to send a core group of teachers and an educator from LSC to the Boston Museum of Science, to participate in their formal training program for EIE, and then those teacher-educators would train other teachers.

Based on the successful training, more schools were added for the 2008-2009 school year. Two successful bi-weekly programs are in place for fall 2009: (1) the "Engineering Is Elementary" (EIE) program, currently offered in three local elementary schools and (2) "In the Middle of Engineering" (IME) clubs in two area middle schools. All of these schools feed Jeffersontown High School, the only JCPS high school that offers Project Lead the Way, an engineering preparatory program. The two programs for fall 2009 at Wheeler have 24 students total, of which 4 are female and 4 are minority students. There are two new EIE programs in place for fall 2009 at Jeffersontown Elementary, with 31 students total, of which 16 are male, 15 female and 5 are minority students. The new fall

program at Watterson Elementary has 15 students, of which 9 are minority and 7 female. The IME program at Newburg Middle has 24 students, 9 female students, and 8 minority students. The new program at Carrithers has 12 students, 3 female and 1 minority student.

Speed students help as young mentors and alumni have provided special assistance. An alumnus at the Core of Engineers comes to the school to give a presentation and answer questions during the modules on bridges, and an alumnus from the Louisville Water Company helps with the environmental module on clean water.

Table 1. Break down of participation in EIF and IME programs for fall 2009.

Program	Total Students Participating	Number of Female Students	Number of Male Students	Number of Minority Students
Engineering is Elementary (EIE)	70	26	44	18
In the Middle of Engineering (IME)	36	12	24	9

In the spring 2009 semester, two additional elementary programs will start, one at Tully Elementary and one at Bates Elementary School. Two additional IME programs are planned for Olmsted North and Olmsted South Middle Schools. These middle schools are close to Speed and have diverse populations; one is an all girls academy, and one is an all boys academy. The teachers at all these schools attended the summer training, but were unable to get programs scheduled in time to start in fall 2009. All of these programs are coordinated by the Director of Outreach Programs at the Speed School and are supported by graduate and undergraduate students, faculty, and engineering alumni.

Conclusions and Future Directions

To date, there is enthusiasm on the part of students, teachers, and parents. In fact, the superintendent of JCPS made it a point to share the current EIE program successes in his 2008 Annual Progress Report. Based on Speed's initial success with building one pipeline from elementary schools to middle schools to the high school with a PLTW program, it is obvious that building such a pipeline is possible. Sustaining the current pipeline and assessing the effectiveness of the program based on the students' understanding of engineering and technology is one of the next steps. Coordination with Boston Museum's assessment program will enable Speed and JCPS to get important information without too much overhead. Determining the increase in students applying for the PLTW program at Jefferson High School will be a true indicator of success. In order to sustain the pipeline, especially as more JCPS students participate, Speed and JCPS must continue their dialog and support of current programs and support the teacher training. The success of these programs depends on proper training; both for those teachers already in the program and for those who wish to enter. It is this aspect that we will aggressively seek to improve and to obtain funding so the Louisville Science Center can be fully incorporated as a partner and help manage this important element. More Speed students and alumni will need to participate; a process for expanding and managing this is being developed by Speed's Outreach Director. In the future Speed School hopes to replicate this process and build pipelines from elementary schools to other math or technology magnet high schools.

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