

Lessons Learned Through Listening: Engineering Outreach with Community and Industry Collaboration

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Abstract - Efforts to link community resources and industry partners are vital to channeling the present K-12 students into our future engineering students. A program at The University of Memphis demonstrates that initial programs don't have to be large in order to be effective, and that program success is based on several key variables: (1) understanding the mindset and attitudes of your targeted audience; (2) providing a fast-paced, hands-on type of learning situation based on experimentation with engineering concepts through actual design; (3) and making use of community resources and relevant participants from industry in order to add credibility and depth to the program's content. This paper begins with a review of the dismal pattern of decreased enrollment nationwide in engineering programs, explores some key causal relationships, and presents the results from 2-years of data and experience in a two-week summer program for middle-school students designed to promote potential career opportunities in the transportation industry. This program is funded by a grant from Canadian National Railroad, and is supported at both the international level from Canadian National's headquarters in Montreal and the local level at the Canadian National Rail Yard located in Memphis, Tennessee. Instructional design for the program involves a mixture of transportation engineering content supported by active, team-based design challenges for the student participants. In addition, the program is supplemented with field trips to local sites of interest involving transportation and interactive discussions between the student participants and local professionals in the transportation industry. Results from the 2003 session led to modifications and expansion of the program for the 2004 sessions, and early analysis of the evaluation data is promising.

Keywords: K-12, industrial collaboration, instructional design, outreach

Introduction/Background

It is no secret in engineering education that the number of students choosing to study engineering at the undergraduate level is frighteningly low in a society that thrives on innovation and technology. What is even more frightening is the persistent levels of academic under-preparation for students who do qualify academically for any field that requires solid educational skills in math and science. In his introduction as Chair of the 2004 America Counts Report to the Secretary of Education, John Glenn presents a stark reality: Israel now has more start-up ventures involving technology than anywhere in the world with the exception of America's Silicon Valley, and possesses a ratio of twice the number of engineers per 10,000 citizens. Ireland now produces 60% of the computer software sold in European markets, and there are far too many similar statistics detailing graduates within the "globalized industry" that have outpaced and outnumbered American graduates. [Glenn, 1]

How does this relate specifically to engineering education? The basic reality is that educated people rely on proficiency in math and science skills for a variety of reasons which include an ability to navigate daily life from an economical perspective, an awareness of how the fields of math and science are intrinsically linked to our new global economy, and the resounding knowledge that understanding these skills leads to a more balanced perspective, individually and collectively. [The National Commission on Mathematics and Science Teaching for the 21st Century, 9] More specifically, the American educational system is under-equipped to prepare K-12 students for the anticipated increase in technologically-savvy jobs, a situation which is frequently linked to a combination of inadequate funding, inadequate teacher education programs, and poor learning skills of students. [The National Commission on Mathematics and Science Teaching for the 21st Century, 9]

Clearly, this is a problem—locally, regionally, nationally, and internationally for multiple reasons and there must be coordinated efforts from multiple perspectives to address potential solutions. As cited above, the recent “America Counts 2004 Report”, commissioned by Secretary of Education Richard W. Riley, strongly encourages a targeted approach to improving teacher education and teacher-preparedness in the fields of math and science, yet a widespread system of change in teacher education programs will yield few results for the students currently enrolled in American schools. [Commission on Mathematics and Science Teaching for the 21st Century, 9] Our study, therefore, focuses on a smaller-scale educational intervention aimed at current middle-school students AND their teachers. The study describes the design, implementation, and results from two-years of experience in a program that offers industry-supported supplemental student learning by combining specific pedagogical approaches that differ significantly from the curricular approach employed in most American schools. While our long-term goal is to promote awareness of the field of engineering as a potential career option, our short term goal is to establish solid connections between “knowing” and “doing” in science, math, and engineering with the expectation that these connections will have positive effects on our learners. Our own data collected from middle-school students over a five-year period suggests a variety of reasons that students do not elect to study engineering. For some, the perceived amounts of required math and science courses are daunting. For some, secondary academic preparation is not adequate for admission into engineering programs. But for the majority of others, data from potential students indicates a simple lack of awareness about the possibilities that exist in engineering.

What are we doing to solve it? Our research seeks to address an integrated audience targeting middle school students, their math and science teachers, and involving key industry representatives simultaneously through education and outreach initiatives at the middle-school level. The objectives for the Canadian National Youth Transportation Institute (CNYTI) program are as follows:

- To expand students’ and teachers’ knowledge base of math, science, and business principles involved in the transportation industry;
- To increase student and teacher awareness of the role the transportation industry plays in the Memphis economy and of career opportunities in the transportation field; and
- To increase the inclusion of transportation industry-related problem solving in mainstream math, science, and social studies classes.

The CNYTI program presents the results from 2-years of data and experience in a two-week summer program for middle-school students designed to promote potential career opportunities in the transportation industry. This program is funded by a grant from Canadian National Railroad, and is supported at both the international level from Canadian National’s headquarters in Montreal and the local level at the Canadian National Rail Yard located in Memphis, Tennessee. Instructional design for the program involves a mixture of transportation engineering content supported by active, team-based design challenges for the student participants. In addition, the program is supplemented with field trips to local sites of interest involving transportation and interactive discussions between the student participants and local professionals in the transportation industry. Results from the 2003 session led to modifications and expansion of the program for the 2004 session, and early analysis of the evaluation data is promising.

Lessons Learned

Understand the targeted audience

Considering the narrow window of time between the introductory skill set acquired in grades K-4 and the developmental chaos that accompanies grades 9-12, combined with the numerous studies demonstrating that students in grades 5-8 experience cognitive and developmental processes that yield high levels of interest and enthusiasm for unknown knowledge, our CNYTI program is targeting to students who have completed grades 5-8. [Pelligrino, 5; Sullivan, 8]

Data reported by the “Before It’s Too Late: A Report to the Nation from the National Commission on Mathematics and Science Teaching for the 21st Century” indicates that when compared with a total of 20 international countries, American students are leaving 4th grade with above-average levels of proficiency in science and math as compared to same-age children in other countries, yet when measured again at the 8th grade level, American children score just below the average when compared against similar peer groups. More alarming, data reported for 12th grade students in the same categories revealed a dismal downward trend: American students scored last in math skills at

the high school graduation point, and next to the last in physics. [The National Commission on Mathematics and Science Teaching for the 21st Century, 9]

When these statistics are considered in conjunction with cognitive and developmental processes for students in the same age groups, there is a clear time period between 5th and 12th grade where students need additional educational support.

Anticipate the expectations/needs of the target audience through educational research

Another benefit of reviewing existing literature and the growing database of K-12 programs focusing on math and science programs is that these studies suggest a clear pedagogical approach. Most successful programs offer one consistent tip for educators attempting to implement a new program: structure a fast-paced, hands-on type of learning situation based on experimentation with engineering concepts through actual design situations similar to those engineers face. [Symans, 8; Poole, 6]

Our CNYTI program was designed to meet the specific needs of our target audience by integrating a fast-paced, hands-on, active learning environment based around experimentation with engineering concepts through team-based design competitions similar to those “real” engineers face. [Higley, 2; Poole, 6; Mooney, 3]

Both team-based interaction and individual levels of reflection were integrated in the design competitions through writing and short presentations as a way of allowing students to practice team problem-solving strategies in a series of daily mini-competitions based on the day’s content knowledge. These types of curricular activities reinforce the cognitive processes between “doing”, “comprehending”, and “reporting”.

Each session met Monday-Friday for two weeks, with each daily program structured around specific activities designed to introduce multiple opportunities in transportation engineering, and each mode of transportation content was supported with the following activities:

- Brief content information followed by team-based design challenges that allowed each team of students to apply the content information on a small scale;
- Guest speakers representing career opportunities in the transportation industry who hosted 10-15 minute interactive sessions that allowed students to link the content and design applications to real-life opportunities and requirements associated with each type of job;
- Field trips designed to give students first-hand awareness of the breadth and importance of the transportation and logistics industry in Memphis. Field trips included visits to the CN Intermodal facility, the Port of Memphis, and Federal Express.

Specific daily instructional segments included individual journal writing, content-design challenges, and formal presentations of selected designs.

Individual journal entries were completed two to three times each day with students responding to specific questions. These entries were collected and reviewed by program faculty daily as part of the program’s evaluation

CNYTI Daily Schedule

8:00-8:15: Journal Writing about specified content or group-work questions.

8:15-8:30: Content Session introducing transportation and logistics concepts and content with short, hands-on examples related to each mode of transportation.

8:30-9:30: Content/Design Challenge with students divided into 3/5-person teams and presented with a challenge involving design, cost, logistics, and feasibility.

9:30-10:00: Data collection and Prototype Testing of alternatives for the Design Challenge culminating in selection of three development alternatives based on performance analysis.

Note: On two days of the program, the 8:30 –10:30 segment of the Institute involved Field Trips to local transportation business

10:00-10:15: Presentations of findings

10:15-10:25: Snack

10:25-10:45: Guest speaker

10:45-10:55: Journal Writing as thank you notes to speakers with follow-up questions

10:55-11:10: Content Session extending the content by adding a new variable such as cost or weight in preparation for the next day’s design challenge.

11:10-11:40: Content-Design Challenge

11:40-11:55: Data Collection/Observations concerning design selection and performance.

11:55-12:00: Journal Writing to record notes and observations related to problem-solving skills and group strategies for improvement.

strategy. Faculty members reviewed the journal entries and responded in writing each day. The participants looked forward to the instructor feedback that wasn't grade-based.

Make use of community resources and local professionals from industry in order to add credibility and depth to the program's content

A third important component of long-term success in a K-12 engineering education program involves a close relationship between the program faculty and local/regional industry professionals. The CNYTI program scheduled guest speakers to provide a more realistic link between the program content and the available opportunities in the transportation industry, yet planned these components with the earlier lessons in mind: keep it short, make it interesting, and make it hands-on wherever possible. Guest speakers included Mr. Lawson Albritton, from the Memphis Area Transit Authority, Ms. Amy Fowler, aviation instructor, Mr. Greg Dunavant, Director of Operations, FedEx, Mr. Eric Lambert, U.S. Army Corp. of Engineers, Officer Mike Bremner, Memphis Harbor Patrol, Officer Margaret Walker, Memphis Police Department, and Mr. Charlie Able, Canadian National. Each speaker was asked to describe his/her job briefly, discuss the relevant safety issues, and then each speaker hosted an interactive question-and-answer session from the participants.

Program Findings

2003 results (the ones that led to modifications)

In order to measure progress towards program objectives, a multi-focused assessment strategy was employed and included the following components:

- Pre-program and post-program surveys to secure quantitative and qualitative data of the students' background knowledge and interests in the field of transportation and attitudes towards engineering-related academic study;
- Daily evaluation of student journal entries with next-day written feedback from instructors;
- Group presentations were videotaped and evaluated by program faculty and students to offer suggestions for improvement;
- Teacher/mentor surveys completed at the conclusion of the program.

Based on analysis of pre- and post-program surveys for both 2003 and 2004, the program appears to have solidly met its objectives of expanding students' and teachers' knowledge base of math, science, and business principles involved in the transportation industry and of increasing student and teacher awareness of the role the transportation industry plays in the Memphis economy and of career opportunities in the transportation field. Initial program surveys indicated that 28 out of the 69 student participants could not identify a single career connected to transportation. The majority of the other students listed such careers as bus drivers, pilots, and car builders. At the end of program, all but two of the student participants were able to answer this question, and the post-program listing had expanded to include the more technology-intensive careers opportunities within the fields of engineering, aviation, rail, and water-based transportation.

In addition, experiences and attitudes about working in a group setting and making presentations—daily activities in the life of an engineer—revealed that 75% felt confident of their ability to organize and present information after program participation, and that they experienced both the benefits of idea generation and shared workload in their groups as well as the frustrations of dealing with different opinions and work styles and habits of their teammates. Prior to participation in this program, few had had the opportunity to independently develop and present information in front of a group or to work in a group setting that offered independent thought and action. Typical school group work and presentations were reportedly almost fully scripted with allocation of work responsibilities clearly defined. This type of group work was a new experience for most participants. Finally, observation of the daily design content challenges and journal entries clearly demonstrated growth in technical content knowledge and in the math and science principals with widespread application in the transportation industry.

In addition to specific progress towards program objectives, evaluation instruments sought to provide qualitative data on student experiences in the program. The data from the 2003 pilot program was integral for helping project directors/program faculty make appropriate design modifications for the 2004 program, and the combined data will be important for extension/expansion of the program in future years. Accordingly, students were also asked to identify what they considered as the most significant or interesting thing they learned during the program as well as what they liked best and least during their two weeks together. Students were also asked how the program could be improved in future years.

Input from 2003 program participants was strongly positive, as 14 of 17 respondents recommended that the journals be used in future programs, and all the respondents recommended that K’NEX continue to be used as the manipulative for engineering design. Favorite activities of the 2003 participants included the design challenges, building things with K’NEX, and the field trips. Least favorite activities included content lectures and field trips. When asked how they would make the program better in the following years, all the students agreed that the field trips be continued but suggested that the people conducting the tours could do a better job of connecting what they were seeing with the content being covered.

2004 evaluation of program

Based on the feedback from student, teacher, and faculty participants, the 2004 program was modified to reflect these suggestions. For example, program hours for 2004 ran from 8:00 a.m. to 12:00 p.m., with substitution of a mid-morning snack for lunch on Monday-Thursdays and pizza parties on Friday of each week. The 2004 session also incorporated guest speakers in an attempt to provide a more realistic link between the program content and the available opportunities in the transportation industry, and this addition was favorably rated by both students and teachers in the program.

Other findings from the 2004 evaluation data included information depicted below:

Figure 1: What Was Your Favorite Activity?

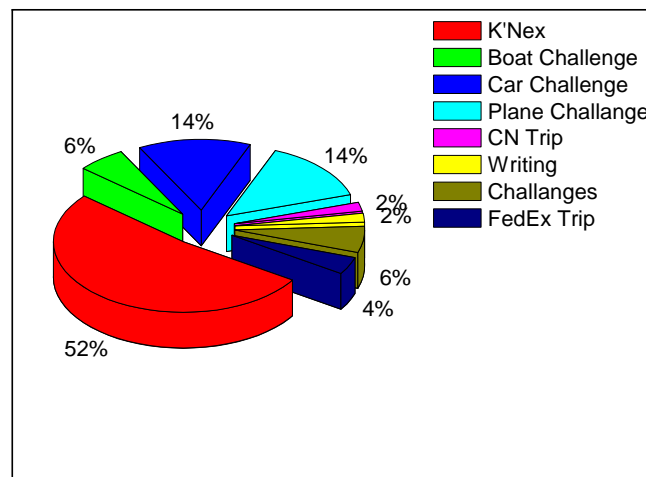
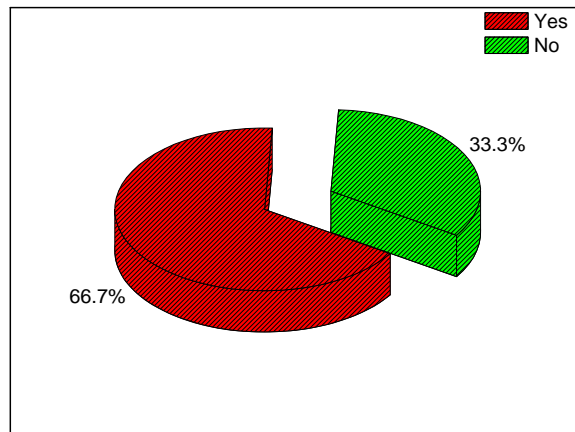


Figure 2: Have you learned anything that made you want to investigate transportation engineering as a potential career?



Importantly, 67% of student participants reported an increase in interest in the transportation industry following the CNYTI program, and 94% of respondents answered “Yes” when asked if they would recommend the CNTYI program to a friend.

Recommendations/Conclusions

Based on our results from this program in comparison with the anticipated results that the Secretary of Education seeks to achieve for all American students, we believe that a triangulated approach involving students, teachers, and industry representatives is a step in the right direction. Students gain essential knowledge and content reinforcement as applied to “real-life” engineering applications while teachers learn more about fun and interesting curricular modifications designed to reinforce grade-level concepts in science and engineering. In addition, in the CNYTI program, teacher participants leave the program with 2 complete sets of K’NEX manipulatives, a copy of the program’s activities, and faculty and industry representatives offer to conduct mini-sessions of similar activities in their own classrooms as a means of transferring CNYTI content to larger audiences. Industry representatives benefit by the interaction with the professionals of tomorrow: if they are able to present employment options in the fields of math, science, and engineering to students who have not yet made firm decisions about professional choices, perhaps the number of students entering these fields will increase. Because the CNYTI students are between 6 and 4 years of graduation from high school, long-term success rates will not be immediate, yet our results suggest that the program is successful in promoting both awareness levels and interest levels in the targeted areas of math, science, and engineering.

It is our hope that engineering educators at other institutions will perhaps modify and extend our CNTYI program at their own institutions as each small-scale success represents one step closer to the goal of widespread national proficiency in math and science. For further information about the CNYTI program or to receive copies of program activities and/or design challenges, please contact Dr. Paul Palazolo (ppalazol@memphis.edu) or Dr. Martin Lipinski (mlipinsk@memphis.edu).

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References

- [1] Glenn, John, "Forward in America Counts 2004 Report--Before It's Too Late: A Report to the Nation from the National Commission on Mathematics and Science Teaching for the 21st Century". Sponsored by Richard W. Riley, Secretary of Education, September, 2004
- [2] Highley, K.A. and C.M. Marianno, "Making Engineering Education Fun", *Journal of Engineering Education*, American Society of Engineering Education, 2001, pg 101
- [3] Mooney, Michael A. and Timothy Laubach, "Adventure Engineering: A Design-Centered, Inquiry-Based Approach to Middle Grade Science and Mathematics Education", *Journal of Engineering Education*, American Society of Engineering Education, 2002, pg 309
- [4] Morley, R.L., J. J. Havick, and G. May, "An Evaluation of the Georgia Tech Summer Undergraduate Program of Research in Electrical Engineering for Minorities", *Journal of Engineering Education*, American Society of Engineering Education, 1998, pg 321
- [5] Pellegrino, James W., "How People Learn: Incorporating Theory and Research into Instructional Practice", *Proceedings of the 2004 ASEE National Conference*, American Society of Engineering Education, 2004
- [6] Poole, Susan J., DeGrazia, Janet L. , and Sullivan, Jacquelyn, "Assessing K-12 Pre-Engineering Outreach Programs", *Journal of Engineering Education*, American Society of Engineering Education, 2001, pg 43
- [7] Sullivan, Jacquelyn, "K-12 Engineering: The Future is in our Hands", *Proceedings of the 2004 ASEE National Conference*, American Society of Engineering Education, 2004
- [8] Symans, Michael D. "Introducing Middle School Students to Engineering Principles Using Educational Bridge Software", *Journal of Engineering Education*, American Society of Engineering Education, 2000, pg 273
- [9] The National Commission on Mathematics and Science Teaching for the 21st Century. "America Counts 2004 Report--Before It's Too Late: A Report to the Nation from the National Commission on Mathematics and Science Teaching for the 21st Century", Sponsored by Richard W. Riley, Secretary of Education, September 2004

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