EXCITING CHILDREN FOR STEM ACTIVITIES: THE POWER OF THE GRAPE

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Abstract

It is acknowledged that engineering suffers from an image problem: "Engineering is not attracting enough people to the field, and is often not attracting the diversity of backgrounds needed. A central issue is the way that engineering is perceived by prospective students, teachers, guidance counselors and parents." ("Moving Forward to Improve Engineering Education," (National Science Board Report No. NSB-07-122, 2007). UT Tyler has undertaken an outreach program aimed at 5th Grade Students at a local elementary school in order to build excitement for STEM activities and change some of the existing attitudes and anxieties about math, science and engineering. The program, termed herein the 5th Grade Reading and Activity Program for Engineering (5GRAPE), was conducted during the 2008-2009 academic year and consisted of a sequence of visits by faculty and current undergraduates to the elementary school. Each visit consisted of 2 university faculty members and several undergraduate volunteers coordinating hands-on engineering themed activities with two 5th grade classes for a duration of 1.5 hours per visit. Pointing out the technical content hidden within well-loved stories during read-a-loud sessions illustrated to verbal learners that math and science concepts are everywhere and not intimidating. The visits were designed to tie-in with the 5th grade science and math curriculum that focuses on the physical world, and to build bridges between the 5th graders and potential undergraduate student role models. Female undergraduates were part of all visits to show girls that they could be vital members of the engineering community. The culmination of the program was a visit by these classes to the UT Tyler campus, where the students participated in hands-on experiments in CE laboratory spaces (e.g. concrete cylinder crushing, soil liquid limit testing, traffic congestion modeling and fluid dynamics studies in a flume chamber), a design competition, and then toured the UT Tyler campus on the way to an informal lunch in the University Student Center with undergraduate volunteers. The power of this activity to build enthusiasm for university study and engineering in particular were crystallized for the PI when he overheard a girl say to a female undergraduate volunteer at lunch "You are just like me…we like the same things!"

The current paper discusses this program, outlines the lessoned learned, and presents a potential assessment plan that will be incorporated as part of Phase 2 of the program.

1. Introduction

It has been noted that STEM activities are not generally positively perceived by the public in all cases [1. UT Tyler has undertaken an outreach program aimed at 5th Grade Students at a local elementary school in order to build excitement for STEM activities and change some of the existing attitudes and anxieties about math, science and engineering. The program, termed herein the 5th

Grade Reading and Activity Program for Engineering (5GRAPE), was conducted during the 2008-2009 academic year and consisted of a sequence of visits by faculty and current undergraduates to the elementary school. The specific objectives of the 5GRAPE program were to: (1) Build enthusiasm for math, science and technology topics in 5th grade students reached, (2) Reduce anxiety about math and science in 5th grade students reached, and (3) Build excitement, camaraderie and likelihood of retention in undergraduate student volunteers who aided in the delivery of the outreach efforts. This paper provides an overview of the program activities, a proposed assessment plan to be incorporated in Year 2, and preliminary results of this assessment plan that suggest new directions for the program as it moves forward. The paper concludes with lessons learned from this experience with hopes that others can use 5GRAPE as a framework for building their own outreach activities.

2. 5GRAPE Activities

As noted, 5GRAPE consisted of a sequence of visits to a local elementary school. Each visit noted in Table 1 consisted of 2 university faculty members and several undergraduate volunteers coordinating hands-on engineering themed activities with two 5th grade classes. During each visit, the 5th grade classes were engaged with one faculty member assisted by several undergraduate volunteers leading discussions in each room at the same time. The program was conceived in a civil engineering (CE) department and many of the activities have a link to the CE field. However, the topics were generally chosen based on their appeal to children and their relationship to the 5th grade curriculum. Although simultaneously executing the program in two classrooms was a logistical challenge, this increased the time efficiency of the program greatly while increasing the number of students that could be reached. Each visit was structured around four sub-tasks: (a) a brief introduction that highlighted the major ideas of the day's visit; (b) a reading of a short engineering themed children's book; (c) a focused, hands-on activity that allowed the elementary students to apply some of the abstract concepts that were introduced in the reading of the day in a concrete way; and (d) a concluding question and answer wrap-up session where the children could ask questions that were inspired by the day's activities. Three important features of the overall program are discussed below, and then specific details of each of the visits are given so that others can modify the activities for their own use.

It is noted here that the method of interaction was structured to follow the ASCE Excellence in Civil Engineering Education (ExCEEd) [7] model for civil engineering instruction: (a) structured organization of presented material based on learning objectives and pitched toward varying learning styles, (b) material presented in an engaging fashion with a high degree of instructor contact with students and incorporation of physical models and demonstrations; (c) instructor enthusiasm; (d) positive instructor-student rapport ; (e) frequent assessment of student learning , and (f) appropriate use of technology. Because the exact technical content of 5GRAPE was deemed less important than the excitement and rapport building that took place during visits, the ExCEEd model was a perfect fit for the exercise. Key inspirations for the ExCEEd model were Lowman's ideas regarding the key role of intellectual excitement and interpersonal rapport in exceptional teaching [8]. Thus, even though the ExCEEd model was created to describe college teaching, the ideas regarding organization of activities (having and executing a well thought-out plan each day), using physical models, modeling excitement and enthusiasm and building rapport, were particularly germane here. Although this is viewed positively as linked with UT Tyler 5GRAPE, it may be a hindrance to using this style of program elsewhere – the faculty energy and time commitment are considerable in this approach, which may impact the scalability of this type of program to and at other institutions.

Table 1: 5GRAPE Activities

Module	Topics	Book Title	Activity
What Does a CE Do?	introduction, excitement	"Mike Mulligan and His Steam Shovel [2]" by Virginia Lee Burton	Hands-On with CE Materials (beams, steel shapes, concrete cylinders, bridges, etc.)
Bridges	tension and compression	"Pop's Bridge [3]" by Eve Bunting	K-Nex Bridge Building Contest
Heat and Energy	energy, conduction, convection, radiation, thermal imaging	"Seeing Heat - The Magic of Thermal Imaging [4]" by Barbara L. O'Kane / "Goldilocks and the Three Bears [5]" by Jan Brett	Thermal Imaging, melting cheese cubes, incandescent versus flourescent light bulbs
Will it Float?	bouyancy, density, weight	"Scuffy the Tugboat [6]" by Gertrude Crampton"	Will it Float? (pineapples, concrete, etc.), aluminum foil boat building challenge
UT Tyler Lab Field Trip	CE experiments		concrete cylinder breaking, soil liquid limit tests, flume water studies, traffic simulation, design competition, campus lunch

A second point of emphasis with 5GRAPE was the incorporation of read aloud sessions of beloved, topical children's books. As initially conceived, this feature was intended to engage students who experience apathy or apprehension about science and math topics and to provide links for those more interested in reading and literary aspects of learning. Illustrating that scientific concepts are all around the children and embedded in everyday activities was also a positive contribution. What amazed the author (although perhaps it shouldn't have) is the growing body of literature [9,10,11] which suggests that reading aloud can be an important part of science education, and that experts suggest even through high school it can play a valuable role. Reading aloud meshes perfectly with the 5E (engage, explore, explain, extend, evaluate) K-8 science instruction model [9,12]. "In the engagement phase, the teacher initiates the learning, determines what students already know about the topic, and provides motivation for learning about the scientific concept." [9,12] Thus in the 5GRAPE program, the reading activities comfort students and build enthusiasm, and children's pedagogical literature shows that these activities provide value in the engagement phase of learning.

A third global point that is noted here regards the general curiosity of 5th grade students regarding college and university life. It was surprising to the author how many questions were directed at undergraduate student volunteers or others that were directly related to what the university is like, what a typical college student does every day, what facilities the engineering department has, etc. A positive outcome of the 5GRAPE program thus is simply the ability to further spark this curiosity about college and university pursuits. It would seem that the more interest that elementary school students have regarding college, the more likely that they will be inspired to seek this educational experience when the time arrives. Even students who don't ultimately engage in STEM activities in the future can still be positively impacted by the extra motivation to pursue a college education.

3. Activity Specifics

3.1 First Visit – Civil Engineering Introduction

This visit was an introduction to what civil engineers do. The visit began with a dramatic reading of Mike Mulligan and his Steam Shovel [2], which includes building canals, roads, highways, airports and skyscrapers, and also deals with issues of environmental impact, recycling and technology (among others). Although some might feel this book is "young" for 5th grade, as noted, there is a comfort in reading aloud [9] and this story is teeming with CE projects of all kinds [13]. Afterward, many physical models (several K'nex bridges, light and heavy concrete cylinders, rubber shapes representing steel beam cross sections, several foam beams, asphalt cores, steel wide-flange cross-sections, examples of bolted connections, etc.), were used to provide hands-on objects as the faculty members led discussions of the roles of engineers (and civil engineers in particular) in society. Brightly colored safety vests and college themed hard hats increased the energy level. The fifth grade classes were beginning their unit on earth science at this time, so the physical nature of the civil engineering projects described here fit right in. Fig. 1 is a picture of one of our faculty members interacting with elementary students and represents the activities that were performed on that day (although captured at another, similar visit).

Figure 1. An example of the types of interactions fostered during first visit

3.2 Second Visit: Bridges

While spending several minutes discussing the basic engineering design cycle with the children (emphasizing the need to iterate, sometimes based on trial and error), a 5-10 minute slide show was played in the background simultaneously, depicting many different kinds of bridges (suspension, stringer, arch, steel, bamboo, timber, etc.) to incorporate visual images [7]. The hands-on activity for this visit was a K'nex bridge building competition. Fig. 2 shows the challenge sheet handed out to the children. The children were divided into groups of 3 or 4 and although the groups needed some help, a goal was for the groups to creatively brainstorm their own ideas and learn by trial and error. Enough K'Nex were provided to ensure that each of the two classrooms had at least 4 large toolboxes full, and all groups had adequate materials. At the end of the build each bridge was tested in front of all the students using steel manuals from a steel design class. The author feels that one of the roles of the faculty facilitator during the bridge testing is to build drama by announcing the proceedings with enthusiasm and flair. The kids were super excited and the winning bridge held 9 steel manuals. It was coordinated so that this visit coincided with the 5th grade unit that was beginning to discuss forces. Fig. 3 shows testing of one of the bridges, and Fig. 4 shows discussion of basic structural concepts.

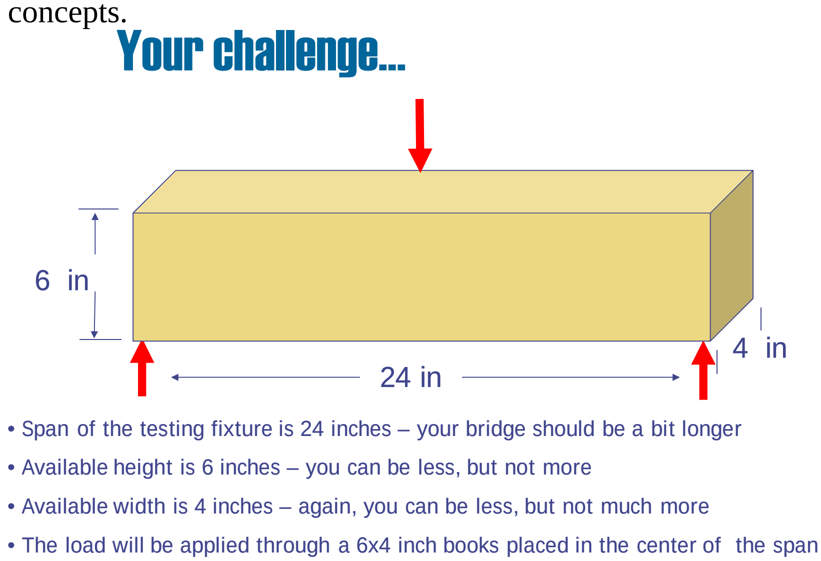

Figure 2. The Challenge

Figure 3. Testing Bridges

Figure 4. Discussing bending and torsion with foam models

3.3 Third Visit: Heat and Energy

The visit centered around activities with a laser thermometer and a thermal imaging camera. In one room, Goldilocks and the Three Bears [5] was read and then the students used a laser thermometer and bowls of 'porridge' to try to determine which of the three bowls was Mama's, Papa's and Baby's based on cooling rates. This portion of the visit was inspired by the Reference [14] study guide. The children were introduced to simplified explanations of convection, radiation and conduction to do this. In the second room, Seeing Heat: The Magic of Thermal Imagery by Barbara L. O'Kane [4] was read. This book describes thermal imaging cameras as a way to visualize heat, and shows many interesting pictures that illustrate these concepts. Using a thermal imaging camera, some of the scenarios in the books were recreated, such as allowing the children to walk across the floor and then look at their own footprints in the camera, or see their handprints on the wall. A microwave and a hot-plate were used to melt cheese cubes of different sizes, following the work in the Reference [15] paper. The melting behavior was explained in terms of the convection, conduction and radiation concepts that were introduced. Finally, the difference in heat output from regular (incandescent) light bulbs and energy saving (fluorescent) light bulbs was illustrated using the thermal imaging camera, and concepts about sustainability were discussed. Excitement abounded during this visit as even the six undergraduate volunteers exclaimed that they had learned several new concepts regarding energy during the activities.

3.4 Fourth Visit: Bouyancy

This visit centered around the ideas of mass, density and buoyancy. Hands on activities included a game of "Will it float?" and a design build competition where students competed to build boats from aluminum foil. Both activities were inspired by 'Fetch with Ruff Ruffman' [16], an educational television program on American public television sponsored (in small part) by ASCE. Objects included in "Will it Float?" included grapes, a watermelon, a pineapple, concrete cylinders (regular and extremely low density floating concrete used for making canoes), and other plastic figurines, and the goal of this activity was for students to discuss concepts of mass and volume. This portion of the visit concluded with an advanced discussion of why boats don't generally tip over, using a two by four pine board to illustrate the concept of the metacenter [17].

Building boats from aluminum foil followed the Reference [16] activity guide and emphasized iteration and trial and error in design. An important aspect of this activity was ensuring that each group had a 'test platform' – many plastic basins were brought and filled with water. The read aloud book for this visit was "Scuffy the Tugboat [6]."

3.5 Fifth Visit: UT Tyler Lab Field Trip

After demonstrating to the school district the value of the activities in Visits 1-4, administrators were convinced to schedule a field trip to the University as the culmination of the 5GRAPE program. Activities were set-up in four of the civil engineering laboratories: concrete cylinder crushing in a structural laboratory, liquid limit testing of clays in a soils laboratory, flume water experiments in a hydrology laboratory, and traffic simulations in a transportation laboratory, see Fig. 5. The two classes were divided into four groups and participated in a round robin fashion, visiting each laboratory for approximately 20 minutes. With conclusion of these activities, an egg drop competition was conducted where children could test their own designs that had been assembled in the days prior to the visit. Again, the faculty facility built drama during testing by assuming the role of an enthusiastic announcer. This visit concluded with a campus tour followed by lunch in the university student center. During lunch, undergraduate student volunteers ate with the children and fielded rapid fire questions about college, life, and STEM topics. This visit provided an excellent capstone to the 5GRAPE experience , and was especially powerful for generating excitement about college and university life. Undergraduate students throughout the civil engineering department also seemed energized by having elementary aged students working in "their" spaces for the day.

Figure 5. Modeling intersections with transportation software

4. Moving Forward: A Proposed Assessment Plan

The key differences between the program piloted by UT Tyler last year and that proposed herein are the development of an appropriate assessment plan (we *know* last year worked, now we must *show* that it worked). Proposed assessment activities include those noted in Table 2. In Year 2, the survey questions depicted in Table 3 were intended for use as a pre-survey to be given to the students prior to participation in any 5GRAPE activities. The questions were modeled after the assessment vehicle of Ref 18. The initial results have been scaled such that higher values denote a "more negative" response for all questions. No trends in this data are noted here except that these two classes do not have strong apprehensions regarding math or science (which may be associated with the high socioeconomic status of the school district visited, or with the fact that the 5th Grade teacher involved is a recent district teacher of the year winner). Comparison with end of program survey results may prove enlightening, although it will be difficult to separate 5GRAPE impacts from teacher impacts and the impacts of nearly a year of fifth grade science and math instruction. The most interesting aspect of the initial surveys was the relative count of free form comments linked to math versus science anxiety. Table 4 shows the comments attributed to positive and negative feelings about math and science from students, and shows a two to one disparity in positive responses for science over math. The author attributes some of this difference to the hands-on, active nature of significant portions of the K-8 science curriculum (note the action verb "do" strongly associated with science in the comments) and notes the greater difficulty in presenting many math concepts in this engaging manner. This initial result has inspired the author to build a new 5GRAPE module centered around the transportation CE sub-discipline. Using car counting equipment and speed radar guns, the module will explore percentages with students in an interactive way. The module will be piloted in 2010. Other portions of the assessment plan are funding dependent, and the author is actively soliciting additional assessment strategies.

Table 2. Proposed Assessment Plan

Pre and post surveys to probe: (a) knowledge of engineering role, (b) excitement for STEM activities, (c) anxiety for math and science
Comparisons of matched sets of standardized test scores (Texas Assessment of Knowledge and Skills (TAKS) or equal as TAKS is phased out
To provide a longitudinal view, in Program Year 5 will survey 9th grade students to compare particpants to non-participants to probe: (a) intention to pursue STEM career, (b) anxiety regarding math and science

5. Conclusions and Lessons Learned

In conclusion, the author hopes that others can use the outlined activities as roadmaps or springboards for their own outreach activities. The following general lessons learned are noted:

(1) There are wonderful resources available to aid university engineering faculty in building outreach activities for children [14,16,19, etc.], and many have acknowledged the importance of inspiring passion for math, science and engineering in the next generation of students [1].
(2) Outreach activities do not have to focus solely on the transmission of technical information – building excitement and engagement through enthusiasm is perhaps more important
(3) Read aloud activities in science and math outreach programs are often overlooked, but are valuable components of sound educational approaches that follow published K-8 pedagogy.
(4) A good working relationship with elementary school teachers can improve programs.
(5) Undergraduate students can serve as mentors for elementary students and are valuable assistants in outreach programs. Furthermore, participating in these activities seemed to energize the volunteers as well.

Table 3. Student Attitudes Survey Questions and Responses from Pre-participation Survey

Question	Average Response
When the teacher says that he/she is going to ask you some questions to find out how much you know about math, how much do you worry that you will do poorly?	2.30
When the teacher is showing the class how to do a problem, how much do you worry that other students might understand the problem better than you?	2.48
When I am in math class, I usually feel	1.32
When I am taking math tests, I usually feel	2.89
Taking math tests scares me	2.46
I dread having to do math	1.78
It scares me to think that I will be taking advanced middle school math soon.	3.07
In general, how much do you worry about how well you are doing in school?	3.48
If you are absent from school and you miss a math assignment, how much do you worry that you will be behind the other students when you come back to school?	2.93
In general, how much do you worry about how well you are doing in math?	2.73
Compared to other subjects, how much do you worry about how well you are doing in math?	3.07
I like helping people	0.75
I like math and science	0.73
I like using math and science to solve problems and puzzles	1.58
I think that by solving problems with math and science we can help people have better lives	1.40
I know what an engineer does	1.78
I know what a civil engineer does	2.00
I want to be a scientist when I grow up	2.07
I want to be an engineer when I grow up	2.61
Math and science are fun!	0.73
Math and science are exciting!	0.74

Table 4. Free Form Survey Responses from Pre-participation Survey

Math	Negative Responses	4	Positive Responses	7
Science	Negative Responses	2	Positive Responses	14

Example Comments
I think that math and science are kind of fun and not so hard. I like science better because we get to do projects.
I do not like math. I like science.
Math is fun because we always learn new things. Science is exciting because we learn new things and do experiments.
I love math and science because you're always thinking a lot. Science is very fun about learning and doing things.
Well math I kind of feel scared when we do it because I'm not very good at it. And science sometimes I'm good at it and sometimes I'm not.
I like science more than math.

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