

# EXCITING CHILDREN ABOUT ENGINEERING THROUGH INTERACTIVE EXPLORATION OF BRIDGES AND DAMS

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**Abstract** — *K-12 outreach programs commonly face difficulties in attracting adequate staffing and financial support. This paper discusses curriculum and materials developed to facilitate engineering outreach visits to 2<sup>nd</sup> and 3<sup>rd</sup> graders in Montana. The program involves two-hour hands-on workshops that explore bridge and dam design to excite children about engineering and to emphasize the real world connectivity of science and math. The evolution of the program since its inception offers a good case study for creating, funding, and sustaining K-12 outreach programs. The bridges and dams program has successfully attracted government, private foundation, and private sector financial support as well as human resource assistance from university staff and students as well as professional engineers.*

**Index Terms** — *funding, K-12 outreach, recruitment, retention.*

## INTRODUCTION

A number of studies have shown that women remain significantly underrepresented in all fields of engineering, making up only 10% of the engineering workforce and about 20% of enrollment in engineering colleges. [1-2] If the under-representation of women in all fields of engineering is to be remedied, it is generally acknowledged that significantly better recruitment and retention of women in engineering is needed.

The problem with recruitment lies in the fact that long before college (during elementary and middle school), girls begin to lose interest in math and science, show a greater lack of confidence in these subjects than boys, and start dropping out of math and science tracks by the time they reach high school. [3] In order to reverse present trends, early intervention is needed as research shows that by age nine, girls already lag behind boys in their hands-on experiences of science. [4]

For those girls who do persist through high school math and science classes and enter undergraduate programs, whether or not they continue in engineering through graduation depends in large part on the academic climate they encounter at individual institutions. Support programs for female engineering students are demonstrably effective in increasing retention rates, particularly programs that

involve women students in social enrichment activities. [5] Involving female students in community service programs fosters their sense of importance within the engineering community and serves to increase their commitment to their academic programs. [6]

Although both the needs and the remedy are clear, outreach and support programs aimed at increasing recruitment and retention of women face chronic funding shortages, and personnel to manage such programs are in equally short supply. The history of the bridges and dams program at Montana State University provides an excellent case study for establishing sustainable outreach efforts that meet both recruitment and retention goals.

## HISTORY OF BRIDGES AND DAMS OUTREACH: FIRST STEPS

Anders Larsson, an instructor in the Civil Engineering Department at Montana State University (MSU) in Bozeman, successfully obtained funding from the National Science Foundation's *Science and Engineering for All* program in 1999 to develop and implement a pilot outreach program for second and third grade students. The program was developed in response to a perceived lack of exposure to engineering as a profession at the elementary school level and was designed to foster children's understanding of the real-world connectivity of math and science.

The initial NSF funding allowed the project team, which included Anders Larsson and Professor Jerry Stephens (Civil Engineering) as well as two engineering students, Heather Estvold and Gretchen Iman, to develop the curriculum and materials for an outreach program and to test them at a number of Montana elementary schools. The project team developed all materials for a two-hour workshop on bridges and dams that incorporates various hands-on activities.

Bridges and dams were selected to introduce children to engineering because they can be touched and seen, are familiar to children, and the scientific principles behind their design can be simplified to an appropriate level for elementary school-aged children. The bridges and dams workshop begins with a 25-minute interactive presentation that introduces the reasons for building bridges and dams, common design types, key construction elements, and some basic terminology. The presentation uses PowerPoint to

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display pictures of what is being discussed and to demonstrate some bridge mechanics (like tension and compression). The children are encouraged to ask and answer questions throughout the presentation.

Following the introductory presentation, the class is divided into two groups for the hands-on discovery portion of the program. One group is given a kit of miniature bridge building supplies (balsa wood, string, straws, tape, etc.). Each student works independently or with a partner to design and build a bridge using the given materials. Once they have completed their bridge, the children test their designs. The bridge is laid across a test area and a hook and washer is put through the center of the bridge from which a bucket is hung. The children slowly add water to the bucket to see how much weight their bridge can hold before it breaks. If there is time, they can then redesign and retest.

In a second room, the other half of the class is again divided into two groups. These groups then rotate through three discovery stations. The first uses an aquarium and a recycling pump to demonstrate various spillway designs. Students then use foam balls and toothpicks to build waterwheels that they test in the aquarium. A second station involves exploration of bridge types and elements by rearranging boxes, beams, and rope in various combinations. The students test the various designs by walking across each bridge type. In the third station, the children use play doh and gravel to build miniature dams in artificial canyons and test their designs using water. The children rotate through each of the three stations over a 30-minute period. They then switch with the other group to build miniature bridges for the next 30-minutes and vice versa.

Once everyone in the class has gone through all of the stations, the entire group is reconvened for a concluding presentation. During this 15-minute presentation, children are introduced to the concept of bridge design using West Point Bridge Designer software, shareware designed by engineers at West Point Military Academy for educational purposes. The bridge design software is projected onto the screen and the facilitator demonstrates how a computer can be used to design and test the most economical bridge possible.

The pilot Bridges and Dams outreach program received a very favorable response from teachers and students. From its inception, the program emphasized increased participation of women and minorities in engineering. Heather and Gretchen were specifically chosen to participate because of their active involvement in student organizations, their communication skills, and their outgoing personalities. Their involvement in the workshops demonstrated to the children that women can also successfully pursue engineering as a career. NSF funding also allowed the project team to travel to Native American schools on Montana reservations to conduct the outreach program. The program brings all necessary supplies with it so a trailer was built to facilitate hauling workshop materials to various schools across Montana. Children from

Hawthorne Elementary School in Bozeman volunteered to paint the trailer with a colorful bridges and dams mural.

## **MONTANA CIVIL ENGINEERING OUTREACH**

School interest in the program quickly outgrew facilitators' availability as well as available funding. In response to increased demand and the desire to expand the program to reach more schools throughout Montana, local members of professional organizations, including the American Society of Civil Engineers (ASCE), the Montana Society of Engineers (MSE), and the Institute of Transportation Engineers (ITE), were approached about conducting workshops at local schools.

Under the auspices of the Montana Civil Engineering Outreach Program, a how-to manual was developed and distributed to professional engineers who expressed interest in participating in the program. The manual describes each part of the workshop in detail and provides tips for classroom management and on working with schools and teachers. Included with the manual is an electronic copy of the introductory presentation, a list of materials needed and directions for constructing or assembling them, and shareware bridge design software.

The professional partnership encompassed by the Montana Civil Engineering Outreach Program is mutually beneficial in a number of ways. It provides needed volunteer power to the outreach program while at the same time expanding its geographical reach. In addition to volunteers, MSE, ASCE, ITE and the Billings engineering firm Kadrmas, Lee & Jackson provided financial contributions to support continued program development. Finally, professionals are often approached to visit schools, but may lack the time necessary to devise engineering-related activities for children from scratch. The program provides them with ready-made activities as well as a network of fellow professionals who can assist them with school visits.

The efforts of the Billings Engineers Club (BEC) provide a great example of the potential of this type of partnership. The BEC, made up of professionals from a number of engineering firms in Billings, Montana, collectively assembled and built the necessary workshop materials and props as well as an outreach trailer for hauling them to schools. The trailer provides a mobile resource to anyone in the club interested in making an outreach visit to a group of children in the Billings area, something that could only be done at considerable expense by the project team in Bozeman.

## **EXCITING YOUNG GIRLS ABOUT ENGINEERING**

The Western Transportation Institute (WTI), a research institute at Montana State University dedicated to advancing transportation research, education, and outreach, obtained funding from the Engineering Information Foundation in

2003 to implement an outreach effort aimed at increasing the recruitment and retention of women and minorities in engineering. A primary goal of WTI's education program is to increase the diversity of students pursuing degrees and careers in transportation engineering. The grant, entitled "Bridges and Dams: Exciting young girls about engineering through interactive exploration with women engineering students," was a collaborative effort between WTI and the Civil Engineering Department at MSU. The program builds on the success of the ongoing Montana Civil Engineering Outreach Program and utilizes the bridges and dams curriculum and workshop materials with the specific goal of increasing young girls' and minorities' interest in math, science, and engineering.

The Western Transportation Institute provides graduate fellowships, involves over thirty undergraduate and graduate students in transportation research projects, and maintains a close working relationship with the Institute of Transportation Engineers (ITE) Student Chapter. The Department of Civil Engineering is the largest department within MSU's College of Engineering, with 620 undergraduates, 70 graduate students, and over twenty faculty members. Utilizing this student base, WTI and the Civil Engineering Department recruited and trained eight female engineering students enthusiastic about K-6 outreach to conduct bridges and dams workshops.

The outreach program fulfills two needs simultaneously: recruitment of future female students to engineering and retention of current female engineering students. The project aims to increase the retention of women engineering students by fostering a sense of community among undergraduate and graduate students involved in the outreach program. In addition, students gain networking opportunities with professional engineers also active with the program and receive a stipend for their participation. Second, by involving women engineering students from MSU as presenters, the program provides positive female role models to young girls, mitigates the sexual stereotyping of engineering as a male profession, and increases available information about career opportunities in engineering to elementary school-aged children.

The engineering students recruited to the program completed a comprehensive training seminar, which covered the purpose of the program, program expectations, as well as effective classroom techniques. Each workstation and presentation was then set up and demonstrated. At the conclusion of the training, the students indicated that they had a clear understanding of the outreach program goals and that they were comfortable with the bridges and dams curriculum and materials.

Local girls clubs were targeted for participation in the outreach effort. A presentation was made to Girl Scout troop leaders, which solicited considerable interest in the program. Workshops were scheduled during regular troop meeting times after school or as a special program on Saturday. Depending on convenience, the workshops were scheduled

either on MSU campus or at the regular troop meeting location (usually a school).

In addition to working with local girls clubs, grant funding supports travel to Native American schools in more remote tribal regions across Montana that do not have as much access to these types of outreach programs.

## PROGRAM EVALUATION

Although the program is still in its early stages, initial response has been overwhelmingly positive with enthusiastic endorsement on the part of participants at both the university and primary school level. Six workshops were held from February to May 2003. Over a hundred second through fourth graders have participated in workshops so far (92 girls, 13 Native Americans, and 14 boys).

School teachers and Girl Scout troop leaders gave favorable assessments of the program. On evaluation forms given to them following the workshop, all indicated that the activities were appropriate for the age-level, that the children found the activities to be interesting and fun, and that the facilitators were knowledgeable and well prepared.

In response to a questionnaire following the first semester of the program, all of the MSU students who facilitated workshops indicated that they considered their participation in the program worthwhile, that they felt more a part of the broader community, and that they thought community outreach was important in the engineering field. They also responded that through participation in the program they got to know other women engineering students better. Half of the university students involved in the outreach effort met engineering professionals through the program.

The outreach program will continue in the Fall of 2003 with both continuing facilitators and new recruits among female engineering students at MSU. Several more trips to tribal schools are also planned.

## CONCLUSION

The history of the civil engineering outreach program exemplifies a flexible approach to program staffing and funding. Development of the curriculum and materials for the program was initially made possible with NSF funding. The program was designed to excite young children about engineering as a profession and to emphasize the real world connectivity of math and science. Special attention was paid to diversity issues and reaching underrepresented groups during the implementation phase.

The Western Transportation Institute currently has funding from a private foundation to specifically address recruitment and retention of women and other underrepresented groups in engineering. The program utilizes student and university personnel to implement bridges and dams workshops for girls clubs and at Native American schools.

Concurrently, the program has gained volunteer and financial support from professional firms and organizations. Thanks to the development of the manual, these professional groups are able to independently introduce the program at local schools in their respective areas. In addition to volunteers, firms and professional organizations have contributed financial support to further program development.

Simultaneous involvement of both professionals and students opens up opportunities for networking, recruitment, and developing mutually beneficial relationships generally. In addition, student participants who graduate and enter the work force will have the experience and resources to implement similar programs in their new workplaces. This provides them with opportunities to establish leadership roles early on in their careers.

Overall, the flexibility of the program has opened up new opportunities for funding and support and provides a good case study for creating, funding, and sustaining successful outreach programs.

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