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Making Engineering Appealing for Girls: Programmes for Grades 6–12*

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The Rochester Institute of Technology's Women Engineering programme (WE@RIT) has developed a continuous series of outreach programmes to stimulate an interest in engineering as a career for girls in grades 6–12. Events include: Park and Ride*, a 6th and 7th grade amusement park design programme;* Expanding Your Horizons*, an 8–10th grade engineering and science conference; the SWE* Overnight and Shadow *Programme, an introduction to Engineering at RIT for 11th grade women;* Colleges and Careers*, a summer recruiting workshop for 12th graders; and* WE@RIT Weekend*, a three-day experience for young women who have been accepted to RIT, but who have not yet decided whether or not to enroll. In addition, WE@RIT has developed and piloted several travelling engineering activity kits (TEAK) to bring engineering experiences to students unable to come to campus for an organized workshop. Although these programmes are still new and limited, long-term survey data have been collected; preliminary results show that the activities do help girls to take a broader view of what engineers do and portray RIT as a friendlier engineering campus.*

Keywords: pre-engineering programmes; diversity; women in engineering; K–12; outreach; retention

BACKGROUND

INCREASING THE DIVERSITY among those who graduate with engineering degrees is essential for providing a strong workforce for the nation's high technology industries. In particular, women comprise 50 per cent of the population, but fewer than 20 per cent choose to major in engineering; NSF recently reported that the percentage continues to decline [1]. At RIT, the percentage of women engineering students graduating each year from the Kate Gleason College of Engineering is approximately 11, significantly below the 2004 national average of 20.3 per cent [2]. However, unlike the national trends in engineering student attrition, the overall retention rate for this relatively small group of RIT engineering women is actually higher than the retention rates associated with their majority male peers, although both groups fall below RIT's long-term student retention goals. A demonstrated ability to keep women here once they decide to come means that RIT is an excellent place to work at bringing more women into engineering.

The lack of academic preparation is generally not the reason students choose to leave engineering. Many studies have attempted to identify factors that relate to students' decisions to leave: lower confidence, anxiety, isolation, missing the 'big picture' of how maths and science relate to engineering, finding that their reasons for initially choosing engineering as a major proved incongruous with what they actually experienced once they matriculated in an engineering programme, all contribute to attrition of women in engineering programmes [3–7]. High school experiences in maths, science and technology may lead to perceptions about engineering that affect students' willingness to pursue, persist and succeed in an engineering curriculum. This is especially relevant for engineering students since many do not possess a clear idea of what becoming an engineer entails [8]. When an unclear vision combines with lower self-confidence levels, the potential exists for young women to choose not to pursue engineering or to depart shortly after entering the major.

In response to the relatively low number of women enrolled within engineering at RIT and the desire to improve retention, a comprehensive series of outreach events have been offered to increase the local pipeline of women interested in pursuing engineering education upon high school graduation [9]. WE@RIT has consistently involved RIT's existing women engineering students during outreach programme design and administering.This involvement provides an excellent means to improve communication, leadership and teamwork skills among the students, which are essential for today's engineering workforce [10].

PROGRAMMES, OBJECTIVES AND ASSESSMENT

RIT's outreach programmes are an effort to address these issues and increase the number of

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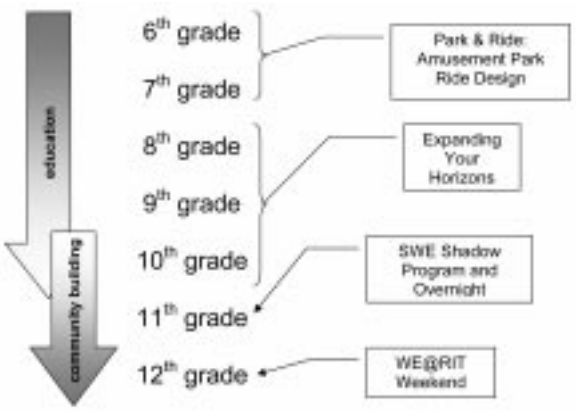

Fig. 1. Goals and target age groups for WE@RIT programme offerings.

women entering engineering fields. The programmes illustrate the ways that engineering impact everyday life, so that the young women participating can start to see the applications of maths and science to engineering before entering college. By doing this, WE@RIT hopes to dispel many of the misconceptions regarding what engineers actually do by showing these young women that there is engineering involved in most things we depend on every day. The programmes also provide a friendly environment, where girls are free to try out new ideas in a 'safe' environment where there is no penalty for failure. Programmes for older girls also focus on mentoring and community building, to ensure that young women interested in engineering do not feel isolated.

The overarching goal of the programmes offered by WE@RIT is to recruit more young women into engineering schools, by showing them that an engineering major is a fun, rewarding and feasible option with a wide variety of different career choices after graduation.To that end, a continuous series of programmes are offered, each with slightly different objectives, to track young women towards choosing an engineering major in college as shown in Fig. 1.

To date, most assessment has been done in the form of post-event surveys and some pre-event surveys. Participants are not identified by name, but for events with pre- and post-event surveys, the young women are either assigned numbers or asked to draw a picture [11] so that their pre- and post-event surveys can be matched. Post-event surveys relating to programme development have not been included here; this paper only presents assessment results pertaining to each outreach programme's objectives. Some longitudinal data have been collected from participants in the SWE Overnight and Shadow Program, since this event has now been offered for five years. The following includes a description of each outreach activity with relevant assessment information.

Travelling Engineering Activity Kits (TEAKs)

TEAKs are created and administered by senior engineering design student teams to area K–12 students. To date, several TEAKs have been developed and tested, with more planned. During development of the kits, RIT engineering students conduct workshops with the Genesee Valley Girl Scout Council and groups of students from several area middle schools. RIT engineering seniors design each TEAK as a portable learning device used to introduce children to engineering. The first kits, funded by RIT's engineering departments, has a general introduction to an engineering theme. The second kits, developed with funds from the American Society for Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE), introduces students to concepts relating to energy and the environment. Programme objectives, assessment and outcomes for the TEAK Workshops are listed in Table 1.

The Introduction to Engineering TEAK includes activities from the fields of Biomedical, Electrical, Industrial and Systems Engineering.The Biomedical Engineering Activity revolves around an RIT-student-built electrocardiograph. Workshop students learn how the heart pumps blood and how measurements of the heart's actions help physicians determine the health of a patient's heart. Participants view their own heart rates after resting, jumping and exaggerated breathing to see how the device registers their activity. The

Table 1. TEAK Workshop objectives

Objective	Assessment	Outcome
Encourage girls to continue taking math and science classes throughout their schooling	Survey students before and after workshop on their interest in science and engineering	91/102 students (middle school boys and girls) reported an increased interest.
Teach K–12 students selected basic engineering concepts	Quiz students before and after activities	Student performance on activity related quizzes improved: worst case showed 5/17 students improving, best case showed 17/28 students improving.
Expose K–12 students to the scientific method *and* the design process	Observation of students following procedure, versus 'guess-and-check' approaches	Students successfully use a design procedure within various TEAK activities.
Create a mechanism to bring engineering activities to students off the RIT campus	Portability of TEAK	Kits fit into clear plastic storage bins that can be transported in a car boot.

Electrical Engineering Activity revolves around the theremin, an electronic musical instrument popularized by The Beach Boys and Star Trek. Students learn about their body's electrical properties by standing in different positions near the theremin and observing the change in pitch and volume of the sound emitted. The Industrial Engineering Activity involves the students in a workplace competition; using simulation software, the students try to optimize the production of chocolate by purchasing various pieces of equipment and hiring workers, assigning the workers and equipment to bottleneck areas to improve yield.

The Energy and Environment TEAKs were developed as a set of activities that could be used in NY State classrooms to meet various science education standards [12]. Activities include selection of insulation for a 'house' to retain heat given off by a light bulb; comparison of conduction, convection and radiation to transfer heat; competition to see who can generate the most power using water, and a similar competition using wind power; competition to see who can find the best site to collect solar energy; and cooking a frozen pizza in a solar oven. Table 2 shows how representative activities map to the NY State Math, Science, and Technology Standards.

Assessment

The Energy and Environment TEAKs have been piloted with several groups of middle school students; due to scheduling difficulties, the kits have not yet been piloted with a group of only girls. Results indicate that the kits are successful in increasing participants' interests in science and engineering, and that they gained technical knowledge during the activity. For example, after participating in TEAK activities, most participants were able to explain the difference between heat and temperature, explain what a fuel cell is and calculate the cost of the electricity required to run different home devices. While anywhere from 25–50 per cent of participants were able to answer questions before participating in the TEAK activities, some students were either able to correct their answers afterward or come up with an even better response. Table 2 shows highlights of the survey results.

Park & Ride: an Amusement Park Ride Design Workshop

This is a three-day event for 6th and 7th grade girls. The girls are at the critical age where they can choose to follow an education path that will enable them to pursue a technical college degree. The theme for the programme is amusement park design, and the engineering activities programmed for participants centre around constructing and programming Lego Mindstorms© robots for a final competition. Many other outreach programmes nationwide incorporate Lego© robotics [13–16] because the kits are straightforward to use and have a high impact on students. One of the event highlights is a guest visit from an RIT alumnus who is an industrial

Table 2. Representative Energy and the Environment TEAK activities mapped to NY State science standards

Energy/ Environment Kit	Heat Transfer and Energy	Electrical Energy	Wind and Water Energy	Solar Energy
NY State Standard				
Analysis, Inquiry, and Design (NYS1)	Use scientific method to identify the best insulator	Use scientific method to identify which type of circuit produces brightest lights	Use scientific method to identify the hydroelectric configuration with the most power	Identify some everyday devices that could make use of solar energy
Information Systems (NYS2)	Learn to read gas/ electric bill	n/a	n/a	n/a
Mathematics (NYS3)	Calculate heat transfer rate	Calculate cost to power a variety of home appliances	n/a	n/a
Science (NYS4)	Observe differences between radiation, convection, conduction	Explain what insulators and conductors are	Identify examples of renewable and nonrenewable energy sources	Draw the solar energy cycle
Technology (NYS5)	Use design process to design optimally insulating house	Use electrical engineering tools to measure current, voltage	Design the most efficient wind and water turbines	Evaluate several solar collection sites and select the best
Interconnectedness, Common Themes (NYS6)	Discuss why gas/electric bill might change throughout the year	Recognize models that are simplified representations of objects, identify patterns of change	Identify interrelationship between our power needs and the environment	Identify interrelationship between our power needs and the environment
Interdisciplinary Problem Solving (NYS7)	Work in groups to determine the best insulators	Relate issues of science, technology, and society, work in groups to realize ideas	Compete to generate the most wind and water power	Compete to collect the most solar energy

engineer working for Disneyworld in Orlando. She visits the event each year to discuss her experiences as a Disney engineer and the sorts of jobs that engineers can hold at Disney. This helps to divert attention from the robotics aspect of the workshop to thinking more about the different types of engineering required to make a place like Disney operate. In addition, the girls interact extensively with volunteer engineering undergraduate students during the workshop, as well as engineering faculty.

Participants in Park & Ride spend most of their workshop time learning how to use the robotics kits in order to design and build robots for the culminating design competition. The theme of the competition is to design an amusement park ride cart that will drive passengers along a predetermined ride track. Amusement park management wants to move riders through quickly, to reduce long queues and keep the patrons happy, as well as to be able to handle more paying park visitors. However, they also want each rider to see as much as possible, so they feel that they have their money's worth out of the visit. The objective given to the girls is to have their passengers see the most 'attractions' inside the ride in the shortest time. The robot carts are required to be autonomous, but the girls can nudge their robots within certain guidelines in exchange for a point penalty. The programme also provides sessions on the last day for parents to learn more about engineering and watch their daughters' robots compete. Table 3 lists programme objectives, assessment and outcomes for Park & Ride.

Assessment

The biggest surprise found from participant surveys was that most girls had a good idea of what sorts of things engineers can do. The responses before and after participating in the programme all indicated that engineers could do a wide variety of things, ranging from amusement park design, cell phones and MP3 players to pollution reduction, medical equipment, and devices to make our lives easier. All participants succeeded in building functional robots that could navigate the amusement park ride, using software that was new to (most of) them. This success in a comfortable environment will help to reinforce participants' confidence in their abilities.

Expanding Your Horizons (EYH)

EYH is part of a nationwide conference series [17] designed to encourage young women to pursue careers in science and engineering. The RIT conference, an all-day Saturday workshop, is in its second year. The workshop includes two tracks, one for students and one for parents. The student track is for 8–10th grade women, who participate in four different activities designed to teach them about different fields of engineering and science. While specific activities may change yearly in order to draw repeat attendance, a sample programme is as follows:

- Robotics—attendees were able to build some simple Lego models and control them, both by using prewritten programs and by modifying existing programs to see what changes occurred.
- Aeronautics/Industrial Engineering—after a brief discussion on the history and science of flight, the attendees constructed paper airplanes for a flight competition. Students also learned about aspects of reliability, repeatability and some aspects of probability.
- Materials Science—attendees watch polymer crystals absorb water as they discussed properties of polymers and different applications of the different materials. They compared water absorption characteristics of polyester fleece, Elmer's Glue and commercially available soil additive.
- Civil Engineering—after hearing about career opportunities in Civil Engineering, attendees used survey equipment, bridge simulation software and test concrete cylinders to failure.

The attendees spend about an hour in each of the activities. The parent track includes informative sessions on the history of engineering, tips for helping their daughters to succeed in math and science, a tour of the engineering facilities, a panel discussion with engineering faculty, students and professionals. Parents also have the opportunity to participate, separately from the young women, in some of the activities. As with the Park & Ride,

Table 3. Park & Ride programme objectives

Objective	Assessment	Outcome
Create awareness of career options in Engineering	Pre- and post-event surveys—ask participants what engineers do	Number of participants responding, 'build machinery' dropped from 8 to 2.
		Number indicating that engineers follow design-analyse-build-test system increased from 0 to 3.
Build participants' confidence that they can solve STEM problems on their own	Overcome obstacles to complete design	100% of teams learned to use software well enough to programme cars.
Help participants develop basic programming and logic competency	Complete a functional robot car design and build project	100% of teams built functioning robot cars.
Begin long-term recruitment of future RIT students	*Requires future longitudinal studies*	Data not yet available, due to newness of programme.

Table 4. Expanding Your Horizons programme objectives

Objective	Assessment	Outcome
Create awareness of career options in Engineering	Pre- and post-event perception of engineers and what they can do	Number of participants indicating bridges/cars/machinery *dropped from 30 to 18*. Number of participants indicating design/create/problem-solve/everything man-made *increased from 17 to 32.*
Build participants' confidence that they can solve STEM problems on their own	Completed experiments in four different technical areas	All participants successfully completed four activities independently.
Encourage parents to learn more about career/educational options for their daughters	Parent/counsellor attendance at parent-track sessions	13 adults attended; all survey responses indicated that the programme had met their goals of learning more about engineering.
Begin long-term recruitment of future RIT students	*Requires future longitudinal studies*	Data not yet available, due to newness of programme.

there is an emphasis on interaction with college students and faculty members for both parents and students. Table 4 lists programme objectives for EYH.

Assessment

EYH participants are surveyed before and after the workshop, and the parents, teachers or Girl Scout leaders who accompanied the girls are surveyed after the workshop. In the two years during which EYH has been offered, more than 50 per cent of girls attending were accompanied by a parent, teacher or Girl Scout leader who spent the day at RIT with the participant. The most interesting responses came when programme participants were asked, before and after the programme, what they think an engineer does and what they think an engineer creates. Table 4 above shows the summary of results. Participants left the event with an expanded view of what engineers might create, as shown in the table. Additionally, only seven out of 19 pre-event responses indicated that the girls thought that engineers were problem solvers, but 14 out of 21 of the post-event responses listed problem solving. Clearly, the girls learned about career options in engineering that they had not thought about before EYH.

SWE Sleepover and Shadow Programme

The SWE Sleepover and Shadow Programme is an annual programme, held each spring, for 11th grade women. The programme has been held for five years, and is planned and run almost entirely by RIT's Society of Women Engineers student section. Since it is a recruitment event to demonstrate RIT's engineering programmes to young women in high schools around the Northeast, it is centred on providing an RIT experience. Attendees spend a full day on campus, where they participate in a series of laboratory activities provided by students and faculty in the departments of Electrical, Industrial and Systems, Mechanical and Microelectronics Engineering. The young women also spend the night on campus with RIT students. Attendance has grown in recent years, and RIT is now regularly hosting approximately 60 participants per year for the event. Programme objectives for the SWE Shadow Programme are listed in Table 5.

Assessment

Programme participants are surveyed before and after the two-day workshop that is designed for 11th grade women who have expressed an interest in engineering. Not surprisingly, when the women are asked questions like 'What do

Table 5. SWE Overnight and Shadow programme objectives

Objective	Assessment	Outcome
Create awareness of the variety of engineering and technology majors available at RIT	Pre- and post-event perception of engineers and what they can do	Survey data indicate that these women already know what options are available.
Introduce young women to a community of engineering students	Number of respondents stating that the most important thing they learned related to engineering community	7/53: community of students 4/53: enthusiasm about engineering at RIT
Introduce young women to a university environment	Number of respondents stating that the most important thing they learned related to the university environment	14/53: college life
Direct recruitment of future RIT students	Participants' eventual choices of college and major	Through each event offering, approximately 10–15% of the participants become RIT students

engineers create?' and 'How many disciplines within engineering can you list?', the pre and post survey responses are very similar. Other responses indicate that most participants felt that the most important things they learned related to the engineering community at RIT and life at a university. Some respondents (8/53) cited details that they would have learned within the various sessions, such as engineering career options, soldering basics, co-op information and how a heart-reader works.

WE@RIT Weekend

The WE@RIT Weekend is an event for accepted women engineering students, intended to convince them that RIT is a great place for a young woman to pursue an engineering career. WE@RIT Weekend coincides with the RIT's Accepted Students Weekend; after participating in the Institute-sponsored events, accepted women engineering students remain on campus for an additional two days. Participants are teamed with current women engineering students for the entire weekend, providing time to get to know the students who may be their future RIT classmates. During the weekend, participants have time to use the recreational facilities, talk with current students about co-op experiences, participate in a panel discussion with RIT alumnae and interact with engineering multidisciplinary senior design teams. Since teaching undergraduate engineers how to create innovative designs is within the college's mission, the young women participate in a design competition of their own. Ample time is also provided for socializing with current RIT engineering students (both men and women). WE@RIT Weekend programme objectives are listed in Table 6.

Assessment

Twenty-six young women completed pre-event surveys and 25 completed post-event surveys during the first offering of the WE@RIT weekend. In addition to the responses detailed in Table 6, some interesting results were:

- 14/26 attended to learn more about RIT in general, but only 2/26 attended to learn more about RIT engineering offerings;
- The most common questions for current students were about how hard RIT is (5/26), what they do for fun (5/25), how classes are (6/26), and about their overall opinion of RIT (8/26).

This information indicates that the young women attending were more interested in learning more about RIT as a whole—things to do, people to meet and life on a day-to-day basis—than in learning about specific engineering options. This confirms the thinking that the best way to recruit women into RIT's engineering programme is not to show lab facilities and classrooms, but to show off a friendly, fun and supportive environment for women. By the end of the weekend, the young women participating in the programme were clearly very comfortable around each other and with the RIT students.

Student-Led Programmes

All of the WE@RIT activities are led by student volunteers; hired co-op or part-time student employees contribute a great deal to the planning process. While the primary objectives of the WE@RIT outreach programme series are centred on increasing the numbers of young women pursuing engineering degrees in college, these programmes also benefit RIT's current women students. By hiring women engineering students

Table 6 WE@RIT Weekend programme objectives

Objective	Assessment	Outcome
Create awareness of the variety of opportunities available at RIT	Changes in participants' surveyed knowledge of opportunities	Respondents came to the programme well informed, and indicated that this is not the reason they came.
Convince participants that RIT is a warm and welcoming place for women engineering students	Changes in participants' surveyed perceptions of RIT	7/26 pre-survey and 17/25 post-survey respondents used words like fun, friendly and supportive to describe RIT.
Convince participants that RIT's engineering women are a vibrant community that eagerly welcomes new members.	Number of surveyed participants citing RIT's students as a strength of the programme	All respondents: intelligent, creative, geeky, etc. 0/26 pre-survey and 10/25 post-survey respondents describe engineers as fun, cool, or awesome.
Bring together the next year's potential first year students so that they meet each other and begin bonding prior to enrolment at RIT.	Number of programme participants, number of participants citing peer bonding and socializing time as 'favorite parts of program'	10/26 respondents attended to meet future classmates; 5/26 attended to meet future *women* classmates. 5/25 post-event respondents felt better about RIT having met potential future classmates.
Direct recruitment of future RIT students	Participants' eventual choices of college and major, number of students indicating that the programme made them more likely to enrol at RIT	22/26 women who attended the first offering of this event became RIT engineering students

as full-time co-op employees or part-time workers at the WE@RIT Centre, each of these outreach programmes is a leadership opportunity for one or more of RIT's women engineers. These students gain experience with major event planning, supervision, mentoring and teaching the 'softer' skills that are lacking in many engineering programmes, but important for their careers as engineers. Past research [18] has found that women and minority engineering students are less likely to attain experiences that build these types of skills during their undergraduate education. From the participants' point of view, RIT's enthusiastic and energetic women engineering students are outstanding role models and are much closer in age to the participants than the faculty members. This successful model has been described elsewhere [19].

CONCLUSIONS AND PLANS

Over several years, while creating and administering a comprehensive array of pre-engineering outreach programmes for girls from 4–12th grades, approaches that work have been identified and duplicated while those that do not have been identified and eliminated. Effective programme planning approaches are:

- Strong women in engineering programme leadership, so that volunteer involvement is seen as a positive experience by faculty, staff and students.
- Electronic advertisement and web postings in lieu of mass mailings.
- Low registration fees which cover event direct material costs.
- Build a network of elementary, middle and high school teachers and administrators who understand your programme offerings.
- Press coverage—both at university and local/national levels.
- Involving college students in the conceptual design of overall programmes and individual sessions.
- Faculty design of pre-engineering sessions and session administration.
- Faculty creating valid assessment tools, such as pre and post event surveys.

Effective program implementation approaches are:

- Expand interested faculty involved in outreach to include representation from all engineering departments within college.
- For programmes directed at younger girls, involve elementary or secondary school teachers in programme implementation.
- Involving parents strategically throughout the programmes, in such as panel discussions, design challenge or closing/awards ceremonies.
- Integrating college students into pre-engineering programmes as mentors.
- Limiting lectures in lieu of more hands-on activities.

Unsuccessful planning approaches include:

- Mass mailings to school principals.
- Registration fees that attempt to cover direct salary costs.
- Failure to produce press releases.
- Involving faculty in detailed event planning and administration—waste of valuable resource.
- Last minute creation of assessment tools.
- Over-involving undergraduate college students in detailed design of sessions, events, assessment tools, etc.

Future plans for the WE@RIT pre-college programmes fall into two categories: programme improvement and assessment improvement.

WE@RIT uses the current feedback to modify/add/subtract programmes from this portfolio. Based on student feedback relative to programme objectives, some programmes require modification. In general, these are limited to logistical issues (programme registration, transportation, food), but there is also an ever-present demand to 'entertain me' and students repeatedly respond that they do not want lectures, just hands-on activities and fun time. It is a challenge to develop an appropriate balance of fun and learning, and the objectives to expose young girls to engineering need attention in addition to making the activities fun.

Simultaneously, the assessment plan for these programmes is still evolving, as several of them are only one to two years old. Future assessment plans include:

- Specific survey questions to address each programme objective, eliminating the need to assess by observation.
- Reduce the number of objective survey questions and rely more on checking off items on a comprehensive list.

Since many of these programmes are new, it has not been possible to track attendees through multiple events. Over the next several years, we anticipate having many repeat participants and will then be able to assess long-term impact.

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