ASSESSING THE EVOLUTION OF ENGINEERING SATURDAY ACADEMIES FOR MIDDLE SCHOOL AND HIGH SCHOOL WOMEN

Arline H. Inman[1], Mary R. Anderson-Rowland[2], Marcela Castro[3], Donna Zerby[4]
Arizona State University

Abstract *– The Women in Science and Engineering (WISE) Investments Engineering Saturday Academies introduce engineering to young women in middle school and high school. The WISE Investments (WI) Summer Institute gives middle and high school teachers the opportunity to develop engineering lessons, which they present to the girls at the Saturday Academies. The teachers and the WI team work with 30-75 girls in each academy. The program has been evaluated for the past four years. Feedback and observations from the evaluation have been used to implement changes in the program and will be discussed in detail. This paper will describe the Saturday Academy challenges, their solutions, and the lessons learned. This project, sponsored by a National Science Foundation grant, also promotes gender equity in engineering activities.*

INTRODUCTION

WISE Investments (WI) is a National Science Foundation funded program HRD 98 72818 that introduces middle school and high school teachers and counselors and their students to engineering and computer science. During a two-week Summer Institute, the teachers and counselors attend hands-on engineering and computer science laboratories given by the engineering college faculty [1]. The institute also includes gender equity [2] and a follow-on optional one-week industry internship [3]. General descriptions of the program can be found in previous papers [4, 5]. Various assessments of the program have been conducted through its existence, including an assessment of attitudinal change in the teachers and counselors [6].

The Summer Institute gives middle and high school teachers the opportunity to develop engineering lessons that they present to young women at the Saturday Academies. The Saturday Academies consist of eight engineering workshops in biomedical, chemical, aerospace, civil, electrical, industrial, materials science, and computer science. The teachers and the WI team (program staff, faculty, and students) work with 30-75 girls in each academy. The Saturday Academies and assessment methods also have been described in detail [7]. These assessment methods include the use of pre- and post- questionnaires on the students' educational background, engineering knowledge, and their engineering career interests.

The plan of this paper is to examine the evolution of the Saturday Academies for the past four years. A program evaluator external to the program evaluated the Saturday Academies using a Theory-Driven Qualitative Evaluation to evaluate the attitudes and opinions of the middle school and high school students who attended the program. As a result of the evaluations, changes were made to the academies. The following sections will 1) describe the Saturday Academies; 2) describe the Theory-Driven Qualitative Evaluation methodology; 3) the key elements of the Saturday Academies; 4) assess the evolution and improvements in the academies; and 5) summarize the results and make recommendations for similar programs.

THE SATURDAY ACADEMIES

The goal of the WISE Investments program is to encourage young women to pursue a career in engineering. The WI Saturday Academies are designed to introduce middle school and high school girls to engineering, show them examples of engineering as a helping profession, and to increase their awareness of the value of the engineering profession. Together, the hope is that girls will "get excited" about engineering. The students met one Saturday morning each month to participate in the engineering academies. Each three-hour Saturday Academy focused on a different area of engineering: biomedical, chemical, aerospace, civil, electrical, industrial, materials science, and computer science One component of the Saturday Academies was the "hands-on" engineering activities that focused on finding a solution to a technical problem. The girls experienced how engineers help people by creating products or applying engineering principles.

Another component of the Saturday Academies was to provide these young women with female engineering role models. The engineering mentors are women enrolled in undergraduate engineering programs at ASU (Arizona State University). Being regularly exposed to engineering mentors helps to dispel negative perceptions of engineers as "nerds, boring, or antisocial" [8]. The mentors provided the

[1] Arline Heil Inman, Inman Consulting Group, 29 East Kelly Lane, Tempe, 85284, arline@asu.edu
[2] Mary R. Anderson-Rowland, Arizona State University, College of Engineering and Applied Sciences, Office of Student Affairs, P.O. Box 875506, Tempe, AZ 85287-5506, (480) 965-3815 0r (480) 965-8251, mary.anderson@asu.edu
[3] Marcella Castro, Arizona State University, College of Education, P.O. Box 870211, Tempe, AZ 85287-0211, cmarcela@asu.edu
[4] Donna Zerby, Arizona State University, College of Engineering and Applied Sciences, Office of Student Affairs, Office of Student Affairs, P.O. Box 875506, Tempe, AZ 85287-5506, (480) 727-7505, donna.zerby@asu.edu

girls with information about "what to expect in college" which may allay fears of pre-college girls who are transitioning to college. The Saturday Academies also provided access to female engineers in industry through tours of local businesses.

In a third component, the Saturday Academies gave the teachers who attended the WI Summer Institute an opportunity to practice their engineering skills. By presenting the material in a girls-only environment, the teachers are more likely to be aware of making their presentation of interest to girls. Teachers gained experience presenting engineering activities and developed more confidence before presenting engineering activities to students in their classroom.

THE QUALITATIVE EVALUATION

A program evaluator external to the program evaluated the Saturday Academies using a Theory-Driven Qualitative Evaluation. A Theory-Driven Evaluation (TDE) uses the program theory as its starting point. Program theory is defined as the way the program plans to address a "problem," the activities it uses to "treat" the problem, and the outcomes it hopes to obtain [9].

In this case, the "problem" is the small percentage of women who choose engineering as a career. Based on research and experience, WI theorizes that this is in part because women are less familiar with engineering and less likely to see it as a helping profession. Program activities "treat" this problem by exposing young women to female engineers, by providing hands-on engineering activities in a same sex environment. The expected outcomes are that middle and high school girls will become "excited" about careers in engineering, knowledgeable about the many areas of engineering, and envision these career options for themselves.

The theory of the program is then compared to the actual results of the activities as determined by the evaluation. An evaluator looks at program implementation, activities, and outcomes, as well as strengths and weaknesses of the program.

The results reported in this paper concentrate on evaluation of the middle school and high school student participants. The results of the evaluation are formative, summative, and cumulative. The evaluations provided information to improve the ongoing program (formative) and provided accumulated information from four years of the program (cumulative). This type of evaluation can provide decision makers with information about the how well the program is performing, the strongest elements of the program, how the process could be improved, how changes in personnel and activities affect the program, unnecessary program components, and unanticipated benefits [10].

The data collection instruments in this evaluation are qualitative. The two primary instruments are ethnographic observations and focus group interviews. In each instrument, the goals of the program and its intended outcomes are used to form hypotheses to be tested.

Ethnographic Observations

Ethnographic observations are one in a series of measures used in qualitative research. These observations focus on the program operations, relationships among stakeholders, and the ways the program meets its objectives [11]. The observations take place in the natural setting of the program and the observers are usually not associated with the program.

Ethnographic observations were used to evaluate the Saturday Academies and activities with the engineering mentors for the past four years. Observations were structured and focused according to a systematic guide to elements associated with the objectives for the WI program and Saturday Academies [12]. The evaluator used an Observation Checklist that included: the behavior of students, teachers, and mentors, organizational elements such as registration, timing of activities, and interest of activities to students. The evaluator noted whether the teachers are interacting with the whole group or how they behave toward individual students. Behaviors included nonverbal interaction, positive reinforcement, and how activities are introduced.

Observations of student behavior included if the students appear attentive, how they used program materials, interactions with other students, and teamwork. Observations also included types of vocal expression such as helpful communication, questioning, hostile or withdrawn actions, and with whom.

Observations of each of these elements contributed to the knowledge base about the outcomes of the academy. In addition, each element was used as material for focus groups or used in other aspects of the evaluation.

Focus Group Interviewing

Focus groups are another data collection instrument used in qualitative research. The purpose of a focus group is to elicit feelings, perceptions, and ways of thinking from participants in a relatively natural environment. The permissive and nonjudgmental environment tends to encourage self-disclosure and increase participant candor. Questions are usually open-ended and the moderator has an opportunity to probe participant responses [13, 14].

Information from participants was elicited about any change in their behavior or interests since starting the program. This included an increased interest in science or engineering programs on television or the value of science or mathematics.

As participants became more comfortable and open, the evaluator asked key questions. Participants were asked if they could use information from the academies in their classes at school, if they had a greater interest in engineering

as a career, and how engineers help people. Participants also were asked which elements of the program they liked the best. Finally, they were asked what change they would make, if any, to improve the program.

For the past four years, participants gave their candid opinions about the success of the program and about elements that did not impact them positively. Participants, including the younger ones, made suggestions. The WI staff implemented many of these suggestions to improve the academies.

OUTCOMES: KEY COMPONENTS OF THE SATURDAY ACADEMIES

Information from focus groups, discussions with staff, ethnographic observations, and parent surveys were used to evaluate the outcomes of the Saturday Academies. The information revealed the key components of the academies as well as areas that might be improved.

The key components of the academies were: 1) the interesting information and hands-on activities provided to increase the girls awareness of engineering; 2) examples to illustrate engineering as a "helping profession"; and 3) a same sex environment with activities geared for girls. Other important elements included the opportunities for girls to socialize with other girls "like them" and to meet women engineering students who served as mentors. Meeting the engineering mentors gave the girls an opportunity to picture themselves as an engineering student in the future.

The girls are more interested in engineering and science as a result of attending the Saturday Academies. They began to relate things around them to engineering and found they were more interested in the engineering field.

Participants' comments about the academies included:

- I'm more interested in science now (general agreement by other participants).
- I'm doing more science at home now.
- If I see an article (on engineering), I understand it more now.
- I started to do independent stuff on science.
- We don't get engineering at school or anything.
- The more we learn about things (like engineering specialties), the more interested we become.

The most popular aspects were the hands-on engineering activities and making familiar products such as perfume or a telegraph. The academies increased their awareness of how engineering affects daily life. Participant comments about engineering included:

- Everything uses engineering: cars, houses, TV, music, micro fiber clothing, medicine, and construction.
- I don't think there is anything that engineering doesn't touch.
- We like hands-on things. We don't want them to tell us what's going to happen. We want to figure it out ourselves.
- I liked making the bridge and the rockets and the roller coaster best.

The social aspect of the program for the girls was an important factor of the academies enhanced by the same sex environment. The girls shared that boys in the classroom are "pushy" and tend to "hog" some of the equipment

Another program element was to group the girls in similar age groups. The girls liked to work in groups and often formed their own teams after attending a few academies. The participants often sought one another out as they arrived, worked in the same team, and congregated together at break time. Participant comments about working with each other included:

- I like working with girls like me.
- I like working with other girls my age who are interested in the same stuff I am (not everyone is at school).
- Well, I come to the academies all the time because I get to do interesting hands-on stuff, and work with girls like me who are smart, and use all the interesting equipment and stuff.

The girls also placed some importance on ancillary aspects of the academies. For example, they wanted food, especially a snack in the morning (not all girls eat breakfast). They also suggested that the program provide some social activity (also with food). Furthermore, the girls liked to receive prizes – not just prizes for the "best" in a competition, but little prizes for everyone to show that they made a good effort. As one participant said, prizes for everyone proclaimed: "Good job, you tried."

Finally, the girls like meeting with the women engineering students who volunteered as "mentors." This gave the girls a chance to meet young women of diverse ethnicities and interests with whom they could talk. This mentor relationship was ineffective at first and was part of the evolution of the academies.

EVOLUTION AND IMPROVEMENT IN THE SATURDAY ACADEMIES

One of the strengths of the WI program has been the responsiveness to stakeholder needs and suggestions. Each year changes were made to improve the Saturday Academies.

Presenting Information and Choosing Engineering Activities

A major change in the academies was altering the tendency of teachers (who were full-time 6-12 math and science teachers) to head toward the familiar. The first change was with the lecture. In the beginning the teachers began the academy with a lecture, then presented the hands-on activities. The girls objected to this school-like format. A participant comment stated:

> We sit and listen to lectures like six or eight hours, five days a week. That's enough.

The second area of change was with the activities. Many of the activities were those that were familiar in science classrooms – and which might not be related to engineering. In response, the WI staff encouraged the teachers to develop a specific engineering activity for each of the eight areas. The WI team worked with the teachers to develop these engineering activities and to identify the connection between the activities and engineering. The teachers then presented these engineering activities in the academies.

The evaluations revealed that the girls wanted activities that allow them to solve problems, to figure out puzzles, and to think for themselves. The process of discovery is important to girls interested in science and engineering.

The WI team helped the teachers shorten their lectures, incorporate information into handouts, and create short PowerPoint presentations. Information about how an activity related to a human need or engineering as a "helping profession" was often done in a Socratic format. Although the girls were supplied with the information they needed, the girls were also encouraged to discover much of the information themselves.

The changes brought the academies closer to program goals, still supplied needed information, and made the academies more enjoyable for the girls. In addition, the teachers learned how to introduce engineering activities and information to their classes.

Timing Activities and Challenging a Range of Ages

The first year of the academies there were challenges related to managing a large group of girls for an engineering activity. One challenge was using the same activities to challenge girls who ranged in age from 10 to 18. The second challenge was timing the activities in a way that permitted a large group of girls to move through the activity and still use all the equipment.

One solution proved effective for both of these issues. The girls were divided into groups by age and the activities were done in separate rooms. Rotating the girls through the activities gave each girl an opportunity to use all the equipment within a specified time period. They worked in teams with girls of a similar age and intellectual development. Teachers could easily plan activities for the young participants and expand activities to be more difficult for the older girls. The timing of each activity became less crucial because teachers could adjust one activity for their group easily. Each rotation usually lasted 40-50 minutes.

Social Time

As mentioned previously, having social time was important to the girls. They objected to the rigid rules and format of a school and wanted more time to meet and to talk with "girls like them." They asked for opportunities to get to know one another and to talk about the things they were learning. Participant comments about social time included

- It's been pretty difficult to make friends here.
- It might be nice to have friends from the same class in the program.
- We don't know one another in the beginning because we come from different schools.
- That'd be really good – if they had some (social) time -- that way you aren't stuck by yourself.

The program staff listened and responded to the needs of the girls. A break time was added for the girls to talk and to process information. The atmosphere of this break was more relaxed and they received a mid-morning snack and drink. A result of this activity was that girls got to know one another better and began to form their own teams.

Prizes

The prizes changed over time too. Early in the program, the teachers chose the token prizes. Initially, prizes were given for the "best" in a competition. The girls suggested that prizes be given to everyone, to show them, "Good job, you tried." Acting on this suggestion, the WI staff then gave a small prize to everyone, usually candy. During the last year of the program, all prizes were chosen as a learning instrument related to the engineering activity.

Selecting relatively inexpensive prizes that are connected to a particular area of engineering takes a little creativity. After the girls made cosmetics at the Chemical Engineering academy, they were given a small bottle of hand lotion called: Scent of an Engineer. For the Materials Science Engineering academy, the students were given a bracelet fashioned out of several materials including: a crystal, wire, and a magnetic clasp. The properties of these materials were discussed in the academy. For the Electrical Engineering academy, the prize was a Nose, Ear, or Belly Button light that flashes three colors and displays the electronics, including the IC chip. A description of an IC was included in the academy. For Industrial Engineering, the students received an ergonomic, mechanical pencil in ASU's school colors. The mechanical pencil displayed the brand "PhD"

which then was the basis of a discussion of the advanced study needed to earn a PhD degree. Prizes serve as a reminder of the academies and the engineering concepts discussed.

Relationship with Mentors

The original program proposal had envisioned a complex and comprehensive relationship between mentor and student participant. It envisioned matching girls on ethnicity and having the mentor and participant get in touch with one another outside the program.

Although both the mentors and the girls enjoyed the time they had together, there were some problems actually getting the groups integrated as originally planned. The first year, neither the mentors nor the participants had a good mentoring experience. There were difficulties in recruiting, in matching interests and ethnicity, and in communicating with time-challenged engineering students. The solution was to recruit a smaller number of mentors and to plan a series of pizza parties between girls and mentors after five of the eight academies.

Both the mentors and participants rated the new arrangement "excellent" (on a five-point Likert Scale). In addition to time to socialize and to get to know one another, the mentors developed a program for the girls that stressed engineering games, fun puzzles, and "field trips" to interesting campus sights.

Mentors reported an unexpected fringe benefit. They found that in mentoring the young participants, their own enthusiasm was renewed. Several female engineering students volunteered as a mentor for more than a year.

The Saturday Academy Engineering Agenda

Part of the Summer Institute for teachers required that they prepare a draft academy agenda. However, the final agenda frequently was altered from the original. WI staff members began working with teachers about six weeks before they were scheduled to teach an academy. The most challenging part of the Saturday Academy for the teachers was to make the connection to math or science and to find examples of engineering as a helping profession. Staff and faculty helped here by providing teachers with instructional media, websites, ready-made handouts, and posters.

The students in this program are talented in math and science. Their teachers recommended many of them to the program. because of their abilities. Even the younger girls performed hands-on activities quickly. Teachers commented on the ability, sharpness, discipline, and enthusiasm of the girls in the WI program. The teachers found that the girls finished activities faster than students in their regular classes. Because of the acuity and discipline of the WI participants, teachers had difficulty allotting an optimum time for activities. Guidance by experienced program staff was often valuable. A back-up activity or game was helpful when participants had finished early.

An important part of ensuring successful workshops was to problem check the entire presentation, especially if computers are involved. Being able to access the Internet when needed cannot be assumed and a backup plan needs to be ready.

Presenting the Engineering Lessons in the Classroom

As the years passed, there was more of an emphasis on the Saturday Academy information being directly linked to engineering and the current science standards. The program directors realized after the first two years, that if the teacher could understand how hands-on engineering activities could satisfy science standards already demanded in the classroom, there would be a greater chance that the engineering activities would be incorporated into the regular classroom.

In talking to teachers who have gone through the program, it is clear that many of them might not have applied their newfound engineering understanding after attending the institute if they had not been "forced" to develop lesson plans and activities for the Saturday Academies.

Miscellaneous Factors

WISE Investments had originally intended to have the girls apply information from the academies to their schoolwork (and vice versa). This had mixed results. Some girls were able to apply information from the academies if their coursework was in reasonable time proximity. Frequently, however, their courses did not coincide with the academies.

The tours of local engineering-related industries were very popular with participants and mentors. They gave the girls a view of women in professional engineering careers. More recently, many industries have increased security concerns and do not allow public tours.

SUMMARY AND RECOMMENDATIONS

The WI program is intended as a pilot project that can be replicated by others. It has demonstrated particular success in its Saturday Academies. In addition, the program has evolved and improved since beginning four years ago. Over the years, pre-college girls have come out of the program with more information about college and an increased interest in engineering. The girls are able to see more connections between engineering and the world around them and to see engineering as a "helping profession."

Both experience and a theory-based qualitative evaluation showed that some portions of the program are quite strong. Particularly successful with pre-college girls are hands-on activities and opportunities to solve problems and to think for themselves. The process of discovery is

important to girls interested in science and mathematics. They want activities to emphasize investigation and problem solving rather than the ability to follow instructions or follow a cookbook format. Girls enjoy working in teams with participants of similar age and strongly favor the same-sex environment.

Gradually, the academies have taken on an atmosphere similar to an engineering club. Here the girls learn about engineering and do interesting and challenging activities without "boring" and lengthy lectures. The incorporation of a mid-morning break with a snack filled the need to socialize and process information.

The pizza parties held after the academies enabled participants to get to know young women engineering mentors. The contact was rewarding to both parties. They also had an opportunity to tour some of the university with the mentors. This helped participants to become more comfortable with a university environment.

Teachers need considerable coaching and assistance from program staff. They need to be guided out of the familiar and to learn to deal comfortably with a new subject and a new type of student. They were given guidance, support, and direction, as needed, when they presented in the Saturday Academies. Some teachers tried academy activities in the classroom before conducting a Saturday Academy. It helps to separate girls into age-similar groups and to keep each activity in a separate room. Similar programs might limit participants to a narrower age range so their social and intellectual needs are similar.

In the early years, teachers followed their familiar school format of lectures and demonstrations. This proved very unpopular with the girls, since they attend school "eight hours a day, five days a week" and they don't want a continuation of school on Saturday mornings.

Rather than lectures, a more effective method was for teachers to give a brief introduction to the engineering specialty and to reinforce important points with Power Point presentations, handouts, and brief posters. They used examples of engineering as a helping profession for each area of engineering. A brief "ice-breaker" game or activity started the program each Saturday to set the tone of cooperation and teamwork. Several teachers reported changing their classroom practices as a result of experiences at the WI Saturday Academies.

A recommendation for developing a similar program is to have a multidisciplinary team for the program staff that includes an education curriculum specialist, an engineer who has performed technical instruction, and a person trained in gender equity. Each of these professionals brings the needed knowledge and skills, which together enable the development and support of a strong engineering program for middle and high school girls.

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