GLUE: Sticking with Engineering through Undergraduate Research

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Abstract
The Women in Engineering Program (WEP) at The University of Texas at Austin (UT Austin) is in the third year of developing, managing and expanding a hands-on, seminar-based undergraduate research program, Graduates Linked with Undergraduates in Engineering (GLUE). GLUE undergraduate student participants are matched by major and interest area with a graduate student for the spring semester. The undergraduate participant works with the graduate student on a research project three to five hours per week and attends a weekly seminar focused on research opportunities, graduate school issues and career development topics. Undergraduate students gain engineering and research experience while earning engineering course credit. Graduate students participate in mentor training and skills development workshops while gaining teaching and supervisory experience and enhancing their communication skills.

The GLUE program has been very successful at UT Austin and has expanded rapidly from 13 undergraduate student applicants and $4,500 in funding in 2003 to 68 applicants and $53,000 in funding in 2005. Although the program is open to both male and female students, the program has successfully attracted a high percentage of female participants. Feedback from pre and post-program surveys indicates that the program has increased the proportion of undergraduate participants interested in pursing a graduate education. As for the graduate students who serve as mentors in the program, over 60% of the participants report an improvement in their teaching and communication skills as a result of the program. The GLUE program has become an integral retention and career development initiative for WEP and the College of Engineering at UT Austin and several improvements are planned for the Spring 2005 program.

Introduction

Although The University of Texas at Austin has an excellent graduate program in engineering, many of our undergraduate students know very little about the research going on at our university. Misconceptions about graduate school and research careers are common among the undergraduate population. This lack of knowledge proves to be a real barrier that prevents many undergraduate students, and female and minority students, in particular, from considering graduate school. The Graduates Linked with Undergraduates in Engineering (GLUE) program provides an innovative opportunity to expose undergraduate engineering students to research by linking them with graduate engineering students working on research projects in the College of Engineering. The program consists of a semester-long research experience in the laboratory that is coupled with a structured interdisciplinary seminar course for the undergraduate participants. The program is primarily intended for undergraduates with little to no previous research experience. Specific objectives of the GLUE program are as follows:

1. Involve undergraduate engineers in the engineering research being conducted at The University of Texas at Austin;
2. Increase the number of female and underrepresented minority engineering students pursuing graduate degrees and research careers;
3. Introduce undergraduate students (male and female) to engineering graduate students, faculty and research practitioners in industry;
4. Expose students to real-world issues of importance to engineers; and
5. Provide mentoring and teaching opportunities for graduate students in engineering.

A successful pilot of the GLUE program was completed in Spring 2003 with a total of 26 undergraduate and graduate participants (13 pairs) and two sponsors providing $4,500 in funding. A formal course for the program was established in Spring 2004 with a total of 42 participants (21 pairs) from six engineering departments and sponsorship of $23,400 from five companies. The Spring 2005 program will encompass all UT Austin College of Engineering departments with 68 participants (34 pairs). Sponsorship for the 2005 program totals $53,400 from six corporate sponsors and one government-funded consortium sponsor.

Program Components

Graduate Mentor Recruitment. Graduate student mentors are recruited prior to opening the applications for undergraduate participants. All female graduate students in the College of Engineering are emailed and encouraged to participate and faculty are notified about the opening of the graduate mentor applications. With a target enrollment of 30 students, WEP presents to graduate student organizations, communicates with female graduate students and seeks assistance from faculty to recruit at least 30 graduate students as mentors in the GLUE program. Graduate students participate on a volunteer basis, receiving no compensation for their efforts other than access to graduate mentor workshops.

Undergraduate Participant Selection. Undergraduate students are initially recruited by WEP through targeted email advertisements to second and third year engineering women. If the targeted number of students is not reached after the initial advertising campaign, advertisements broaden to non-graduating senior women, followed by minority male students and eventually include all engineering students. Students are selected based on the following criteria:

1. Application order (first come, first served provided the remaining criteria are met)
2. Research interests match with a graduate mentor's project
3. Second or third year classification (priority over first year and senior level students)
4. No prior research experience

With the targeted advertisement campaign, the percentage of female and underrepresented minority engineering students applying to participate is greater than the pool. Undergraduate students accepted into the program are given clearance to enroll in the seminar course.

Research Projects. The undergraduates participating in the GLUE program work 3 to 5 hours per week on a research project with their graduate student mentor for one semester. Topics for the research experience are arranged at the beginning of each semester and are developed by matching the undergraduate student's stated interests with a graduate student working in that

area. A key component of the GLUE program is the relationship that develops between each undergraduate student and their graduate student mentor as a result of working together on a research project of mutual interest. The undergraduate participants keep written logs throughout the semester to document their work and to reflect on their research experience. These logs are turned in weekly and reviewed by the GLUE coordinators to make sure that each project is evolving smoothly and that no problems have developed.

Participating in a research project under the supervision of a graduate student has many advantages. Because the undergraduate and graduate students are working together toward a common goal, it provides a comfortable atmosphere in which the undergraduate student can ask any questions he or she would like of the graduate student. It also demystifies what it is like to be a graduate student. For women and minority students in particular, it can sometimes be quite a revelation that someone just like them can be highly successful in graduate school and beyond.

Interdisciplinary Seminar Course. To supplement the experience that the undergraduates receive working with their graduate mentors in the laboratory, all of the undergraduate GLUE students participate in a structured weekly seminar course throughout the semester. The reason for formalizing the program into a course is twofold: (1) undergraduates are used to working within the structure of a course and thus understand the responsibilities involved; and (2) the course codifies the program which will contribute to the longevity of the program since it is now "in the catalogue". The course description for the two unit course is as follows:

> *Research Experience for Undergraduates:* Undergraduate students work 3 to 5 hours per week with graduate students on engineering research projects. Topics for the research experience are arranged at the beginning of each semester for each undergraduate/graduate student pair and may include conducting laboratory experiments and developing computer models. Mandatory seminar meetings related to the engineering profession, engineering ethics, as well as research career tracks in industry and academia will be held weekly. Students keep written logs documenting their research experience and reflections on weekly seminars and regularly present their research experiences and projects to the interdisciplinary class.

Each GLUE student formally presents their research project to the rest of the class at least two times during this course. A discussion period follows each presentation so that the other students can ask the presenter follow up questions. In this way, the students learn to present their work to a broad, interdisciplinary audience and are exposed to wide variety of research currently underway in the College of Engineering.

In addition to the student presentations, a formal seminar series is incorporated into the course. Outside speakers are invited to provide a broader perspective on topics relevant to engineering students who are considering pursuing an advanced degree (See Table 1).

Table 1. Seminar Topics for the GLUE Program.

Seminar Topic	Presenter(s)
Keys to Success ~ *Past GLUE Participants Panel*	GLUE Undergraduate Participants from Previous Year's GLUE Program
Beyond the BS Part I~ *A Graduate Student Panel*	GLUE Graduate Mentors
Career Options Part II: Research and Faculty ~ *A Faculty Panel*	UT Austin Engineering Faculty
Career Options Part I: Research and Industry ~ *An Industry Panel*	Representatives from Local Industry Who Work in Research
Beyond the BS Part II ~ *Graduate School Applications*	UT Austin Engineering Faculty
Next Steps: REU's and other Undergraduate Research Opportunities	Undergraduate Research Program Coordinator, College of Natural Sciences, UT Austin

Outreach Activities. In addition to the research experience and seminar course, the GLUE program is being expanded for the Spring 2005 class to include outreach activities. This spring, the GLUE undergraduate and graduate students will have the opportunity to participate in either Introduce a Girl to Engineering Day, the nationwide effort during National Engineers Week to introduce pre-college girls to engineering, or Explore UT, the university-wide open house during which the College of Engineering shares projects, research and hands-on activities with the public. Students will participate by giving tours of their research labs and describing their projects, presenting posters on their projects, or conducting hands-on experiments or demonstrations related to their projects.

Graduate Mentor Workshops. Graduate students participate in GLUE on a volunteer basis. The program gives the graduate student participants the opportunity to improve their teaching, communication and project management skills. In order to further increase the value of the program to the graduate students, WEP and Dr. Kinney will be implementing two Graduate Mentor Workshops for the Spring 2005 program. These workshops are in addition to the mentor training conducted at the beginning of the semester aimed at detailing the program to the graduate students and answering questions.

Program Assessment

In order to evaluate the GLUE program and to determine if the goals of the program are being met, a variety of survey instruments and sources of data were used as described below.

Undergraduate Assessment and Evaluation. Undergraduate participants complete pre-surveys to assess their level of research experience, exposure to graduate students, faculty, research and the graduate school process, current career plans and expectations for the program. At the conclusion of the program, undergraduate students complete a post-survey to assess their satisfaction with the program, exposure to graduate students, faculty, research and the graduate school processes and current career plans.

Sample Questions from the Undergraduate Participant Pre-Survey

- Have you had previous undergraduate research experience?
- Have you interacted with a female engineering graduate student while in college?
- Have you interacted with any female engineering faculty while in college?
- Have you been mentored by a graduate student?
- What are your career plans? Grad school? Industry? Etc.

Sample Questions from the Undergraduate Participant Post-Survey

- Do you plan to do undergraduate research in future semesters?
- How do you feel your perception of graduate school has changed over the semester?
- How often did you interact with other graduate students besides your mentor?
- How often did you interact with your graduate mentor's faculty advisor?
- What are your career plans after graduating with your BS degree?

Graduate Assessment and Evaluation. Graduate mentors also completed pre-surveys to assess their previous mentoring and undergraduate research experiences and their current career plans. At the conclusion of the program, graduate students completed a post-survey to assess their satisfaction with the program, perceived increase in teaching or mentoring and current career plans. Graduate mentors also completed pre-surveys and post-surveys for each training session offered to gather feedback on the merits of the training sessions.

Sample Questions from the Graduate Mentor Pre-Survey

- Have you participated in the GLUE Program in the past?
- Have you had previous experience mentoring undergraduates?
- Were you mentored by a graduate student when you were an undergraduate?
- Did you participate in undergraduate research as an undergraduate?
- What are your career plans? Grad school? Industry? Etc.

Sample Questions from the Graduate Mentor Post-Survey

- What skills do you feel that you have gained, if any, during your participation in the GLUE program?
- As an experienced GLUE mentor, what advice would you give to a new GLUE mentor?
- What are your career plans after graduating with your graduate degree?

Undergraduate Participants

Participant Demographics. Demographics of the undergraduate participants in the GLUE program over the three years of the GLUE program (2003, 2004 and 2005) are summarized in Table 2. Women are participating at a rate of 76 percent compared to the overall College of Engineering undergraduate enrollment of approximately 22 percent. Minority students (African American, Hispanic and Native American) are participating at a rate of nearly 18 percent matching the overall College of Engineering undergraduate enrollment.

Table 2. Undergraduate Participant Demographics.

	Women			Men			Total		
Major	Non-Minority	Minority	Total	Non-Minority	Minority	Total	Non-Minority	Minority	Total
Aerospace	7	0	7	0	0	0	7	0	7
Biomedical	1	0	1	0	0	0	1	0	1
Chemical	3	3	6	1	0	1	4	3	7
Civil	9	3	12	2	1	3	11	4	15
Electrical & Computer	14	4	18	10	1	11	24	5	29
Mechanical	8	0	8	0	0	0	8	0	8
Petroleum	0	0	0	1	0	1	1	0	1
Classification									
1st Year	3	0	3	0	0	0	3	0	3
2nd Year	16	2	18	8	0	8	24	2	26
3rd Year	15	3	18	4	2	6	19	5	24
4th Year +	8	5	13	2	0	2	10	5	15
TOTAL	42	10	52	14	2	16	56	12	68

Pre-Survey Data. Undergraduate students completed an application form that contains questions assessing their research experience. Sixty-eight student participants have been surveyed to date from the 2003, 2004 and 2005 GLUE programs. Survey highlights are below:

- 10 percent had previously participated in research;
- 49 percent had previously interacted with a female faculty member;
- 37 percent had previously interacted with a female graduate student;
- 3 percent had previously been mentored by a graduate student; and
- 32 percent have interned or co-oped previously.

Students were also asked on the pre-survey about their career plans upon graduation. Below are the results from the sixty-eight participants:

- 38 percent plan to attend graduate school and then head into academia or industry;
- 32 percent plan to head into industry and then get an MBA or attend graduate school;
- 25 percent are undecided;
- 3 percent plan to head into industry; and
- 1 percent plans to head into medical school.

Post-Survey and Graduation Data. Thirty-four undergraduate students have completed the GLUE program to date (Spring 2003 and Spring 2004 participants). Post-survey results from completed surveys as well as graduation information are below:

- 47 percent have graduated with an engineering degree (the remaining students are still in the engineering program);
- 26 percent have taken the GRE and either have applied to graduate school or are attending graduate school in engineering;

- 63 percent plan to attend graduate school and then head into academia or industry;
- 25 percent plan to head into industry and then get an MBA or attend graduate school; and
- 13 percent are undecided.

These survey results indicate the GLUE program increased the proportion of the undergraduate participants planning to attend graduate school following graduation (i.e., from 38 percent prior to the GLUE program to 63 percent following the GLUE program). Another 25 percent plan to seek a career in industry first before getting an MBA or attending graduate school, a value which is similar to the pre-GLUE levels.

Participant Feedback. The program is currently in its third year and feedback from previous participants in the program has been overwhelmingly positive. A sampling of quotes from previous participants is provided below.

> "After the faculty panel, I actually thought what it might be like to become a professor; something that I've never done before. The student and industry panel also helped me realize that there is more than one way to go through graduate school, either the research route, or the non-research route. I had never realized there was a choice, but having the option to make it through school more quickly if I needed to was very comforting."

> "The GLUE program gave me a great chance to get deeper into my interest in computer engineering, as well as useful advice to plan for years after my graduation. The research project I was involved in not only strengthened my knowledge for what I have learned in class but developed my skills for research."

> "I am incredibly thankful because GLUE has not only given me the opportunity to work on an interesting project, but it has also encouraged me to pursue graduate school. My graduate mentor has been a wonderful source to ask questions and express my concerns about graduate school. I have been motivated from listening to her experiences and observing how much she enjoys her research, courses and professors."

> "I really got to see first hand how versatile studying electrical engineering could be and how it could be applied in various ways of research. GLUE has opened the door to many other opportunities for me and has made a positive impact on my semester and my decisions for the future. The exposure that I have gotten to graduate students, professors, and research is not something that all of my peers get to experience, and I am very grateful that GLUE gave me the opportunity to get the most out of being an undergraduate student in engineering."

Graduate Participants

Participant Demographics. Demographics of GLUE program graduate participants from the three years of the GLUE program (2003, 2004 and 2005) are summarized in Table 3. Women are participating at a rate of 62 percent compared to the overall College of Engineering graduate enrollment of approximately 21 percent. Minority students (African American, Hispanic and

Native American) are participating at a rate of 4 percent matching the overall College of Engineering graduate enrollment.

Table 3. Graduate Participant Demographics.

	Women			Men			Total		
Major	Non-Minority	Minority	Total	Non-Minority	Minority	Total	Non-Minority	Minority	Total
Aerospace	6	0	6	1	0	1	7	0	7
Biomedical	3	0	3	1	0	1	4	0	4
Chemical	1	0	1	2	0	2	3	0	3
Civil	7	2	9	7	0	7	14	2	16
Electrical & Computer	14	0	14	8	0	8	22	0	22
Mechanical	7	1	8	6	0	6	13	1	14
Petroleum	1	0	1	0	0	0	1	0	1
Classification									
Master's	12	2	14	7	0	7	19	2	21
Ph.D.	27	1	28	19	0	19	46	1	47
TOTAL	39	3	42	26	0	26	65	3	68

Pre-Survey Data. Graduate students complete an application form that contains questions assessing their research and mentoring experience. Sixty-eight student participants have been surveyed to date from the 2003, 2004 and 2005 GLUE programs. Survey highlights are below:

- 60 percent have mentored undergraduates previously
- 18 percent were mentored by a graduate student during their undergraduate studies
- 63 percent participated in undergraduate research during their undergraduate studies

Students were also asked on the pre-survey about their career plans upon graduation. Below are the results from the sixty-eight participants:

- 47 percent plan to head into academia
- 26 percent plan to head into industry
- 27 percent are undecided

Post-Survey Data. Thirty-four graduate students have completed the GLUE program to date (Spring 2003 and Spring 2004 participants). Post-survey results from completed surveys:

- 20 percent indicated an increase in confidence regarding their skills and abilities
- 33 percent indicated an increase in their planning and project management skills
- 60 percent indicated an improvement in teaching and communication skills

Participant Feedback. A sampling of quotes from previous graduate student participants is provided below.

"I have learned a lot about teaching what I know about my research to someone else with much less experience. That is invaluable to me."

"I realized how much I like teaching; I realized how much I actually knew about my topic and how much I have learned thus far in graduate school. I got help from her in asking questions that were really good and I hadn't thought of yet."

"Last Spring, I participated in the GLUE program, and it was one of the best experiences I have ever had in college (grad or undergrad). I was at a point in my studies where I both didn't have the confidence in my knowledge I thought should, yet I was having an increasing number of days where I couldn't remember why my research was interesting. Everything just seemed tedious and a bit overwhelming. GLUE changed that. Since everything was new to my undergrad, she found everything interesting. Her enthusiasm renewed my enthusiasm, and I think it was a kind of snowball effect. Also, the more I explained things to her, the more confident I felt about my knowledge. If I struggled some to explain things, she never gave me that "You should know this," look. And rather than being discouraging, my not knowing things was actually positive, because it showed her that you don't have to know everything to be a grad student (a misunderstanding that discourages many from applying to grad school). My renewed enthusiasm helped me get a lot done this past summer. And, I think this fall might be the first time I've truly enjoyed graduate school."

"You get to teach and encourage an undergrad the same way you wanted to be encouraged when you were an undergrad. Also, you get to solidify and gain confidence in your knowledge by teaching someone else."

Partnerships

GLUE has become one of the most collaborative programs administered through the Women in Engineering Program (WEP) at UT Austin, reaching across the College of Engineering and UT Austin as well as including corporate and government partners. GLUE was born out of collaboration as WEP worked with Dr. Kerry Kinney who developed the concept for the Graduates Linked to Undergraduates in Engineering (GLUE) mentoring program while still a doctoral student at the University of California. Dr. Kinney serves as the faculty instructor for the interdisciplinary course associated with the GLUE program and works with the WEP to recruit the undergraduate and graduate students for the program.

University Partnerships. GLUE has expanded from a pilot program with 13 undergraduate applicants to the current program with 63 undergraduate applicants of which 34 were accepted into the program. This dramatic growth in just three years is due to the partnerships developed across the College of Engineering and UT Austin. Partnerships enhanced the marketing of the program to students, contributed to the involvement of students from all College of Engineering departments, and added to the seminar content and management.

Marketing the program to both undergraduate and graduate students takes place electronically through the College's and University's Research Web sites in addition to the WEP Web site and

E-mail newsletter. In addition, student organizations such as the American Society of Engineering Educators and the Vector, the College of Engineering student-run newspaper, promoted the program encouraging student participation.

In addition to the partnership with Dr. Kinney, WEP works with faculty and department chairs from across the College of Engineering who encourage their graduate students to participate as mentors in the program. For the 2005 GLUE program, the partnership with the Aerospace Engineering and Engineering Mechanics Department is strengthened through a grant from the Texas Space Grant Consortium with Dr. Robert Bishop, Chair of the Aerospace Engineering and Engineering Mechanics Department and co-PI on the grant, identifying and recruiting graduate students throughout the College of Engineering who are working on space based research. At a minimum, we aimed have five to eight space based research projects involved in the Spring 2005 GLUE program and seven such projects are confirmed through collaborative efforts with the Department of Aerospace Engineering.

The GLUE seminar is a stand-alone General Engineering (GE) course listed in the spring course schedule thanks to the collaborative efforts with the Associate Dean of Student Affairs for the College of Engineering, Dr. Alvin Meyer. For the pilot program in 2003, the seminar was administered through special projects courses in the departments of Mechanical Engineering, Electrical and Computer Engineering, and Civil Engineering, requiring collaborations with department advisors for course enrollment and grade posting.

Corporate and Government Partnerships. Corporate and grant support for the GLUE program has increased twelve-fold since the pilot program in 2003. Initial program sponsors included Applied Materials and BP with $4,500 in funding. With the establishment of the formal course for the program in Spring 2004, sponsorship increased to $23,400 from five corporate sponsors. The Spring 2005 program will encompass all UT Austin College of Engineering departments and sponsorship totals $53,400 from six corporate sponsors and one government-funded consortium sponsor. Sponsorship includes funding for tuition scholarships to cover the tuition cost of the two credit hour course for a number of the participants, materials and supplies including lab books for each undergraduate participant, undergraduate and graduate student coordinators, WEP staff salaries, seminar refreshments and an end of semester celebratory dinner.

Project Sustainability

From 13 undergraduate student applicants and $4,500 in funding in 2003 to 68 applicants and $53,000 in funding in 2005, the GLUE program has rapidly become an integral retention and career development initiative for WEP and the College of Engineering at UT Austin. The GLUE program has successfully attracted corporate support and has gained the attention of students across the College of Engineering. The program has been formally institutionalized in the College of Engineering as a General Engineering course, allowing faculty such as Dr. Kinney to teach the course every year as part of their regular teaching load and greatly improving the sustainability of the program by combining faculty time with corporate support and the resources of WEP. WEP and Dr. Kinney plan to continue this program indefinitely.

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The expansion of the GLUE program is due in part to the partnership with Dr. Robert Bishop, Chair of the Aerospace Engineering and Engineering Mechanics Department and the support of faculty and administration across the College of Engineering at The University of Texas at Austin. In addition, past and present GLUE undergraduate and graduate participants have contributed to the success through continual feedback, honest assessment, word of mouth marketing and continued involvement.

Biographical Information

TRICIA BERRY is the Director of the Women in Engineering Program (WEP) at The University of Texas at Austin. Prior to this role, Tricia was Engineering Scholarship Program and Undergraduate Recruitment Director. She came to UT in 1999 after six years at The Dow Chemical Company in Freeport, Texas. Tricia received her BS Chemical Engineering degree from UT in 1993 and her MBA from the University of Houston – Clear Lake in 1999.

DR. KERRY KINNEY is an Associate Professor in the Department of Civil Engineering at The University of Texas at Austin. Dr. Kinney's research in the field of environmental engineering is focused on biological treatment processes and air pollution control.