Engaging Freshmen Women in Research – Feedback from Students and Best Practices for Faculty

Ms. Terri Christiansen Bateman , Brigham Young University

Terri Bateman is adjunct faculty in the Brigham Young University College of Engineering and Technology where she has worked with Women in Engineering & Technology at BYU, numerous mechanical engineering capstone senior design teams, and the Compliant Mechanisms Research Group. She received her bachelors and masters degrees in Mechanical Engineering from BYU, and also worked at Ford Motor Company as a manufacturing and design engineer in Automatic Transmission Operations. Terri is the mother of four children and loves to hike with her husband and kids in the mountains and canyons of Utah.

Ms. Lisa C Barrager, Brigham Young University

Lisa Barrager is the Assistant to the Dean and Coordinator of Women Student Initiatives for the Ira A. Fulton College of Engineering & Technology at Brigham Young University, where for the last 8 years she has worked to better the environment and increase opportunities for women students interested in pursuing degrees in technology and engineering. During this time these and other efforts have yielded both a significant increase in women student enrollment and a decrease in attrition rates for women students in engineering and technology majors at BYU.

Barrager is a BYU graduate with Bachelor and Master Degrees in Mechanical Engineering and an MBA from the Marriott School of Management. Her professional experience includes work in program management, strategy and marketing and business development for both large corporations and small engineering firms. Barrager spent 14 years in industry before returning to BYU. She currently serves as the Program coordinator for the WE@BYU – Women in Engineering Program, the co-advisor to BYU's Society of Women Engineers student chapter and is a member of the advisory board for the Women Technology Council.

Rebecca Peterson, Brigham Young University

Rebecca received her bachelor's in manufacturing engineering technology from Brigham Young University in 2013. She is currently a graduate student in manufacturing systems and will graduate this summer. Her research focuses on friction bit joining dissimilar metals for automotive applications. She is also involved in the women's programs in BYU's College of Engineering and Technology.

Dr. Spencer P. Magleby, Brigham Young University

Professor Magleby is a faculty member in Mechanical Engineering and the Associate Dean of the College of Engineering and Technology.

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Introduction

Increasing the participation of diverse populations in engineering and technology fields is a challenge for many universities. A significant means to address this issue is to increase the participation of women students. However, this can prove to be challenging. In a study conducted by Marra and Bogue,[1] it was found that although women engineering students enter the university with high levels of self-confidence and self-esteem, those levels decline quickly during the first year. They also found through their research, that the initial levels were never regained. One method to help retain diversity in engineering and technology majors is the implementation of support programs. Research literature on effective strategies to increase diversity in STEM fields generally describes support programs as activities crafted to help overcome factors that deter underrepresented students' from pursuing programs in STEM areas.[2] NSF supported research indicates that "Students that participate more frequently in support activities are less likely to leave engineering than those who do not participate or participate less frequently." [3]

Based on this hypothesis, Brigham Young University and other universities are implementing support programs at the undergraduate level to encourage and assist women in engineering and technology majors including mentoring networks, projects for freshmen, and research opportunities. For example, North Carolina State University has instituted a program for undergraduate women students in engineering that includes peer mentoring, industry professional mentoring, a parents' weekend activity for students and their parents, and other social and informative events.[4] Support programs such as this integrate the social and academic aspects of the students' experience.

The University of Colorado's First-Year Engineering Projects Course addresses the low levels of confidence and self-efficacy by exposing students to projects they might encounter in their careers. They found that students who take the course are "significantly more likely to be retained at the third, fifth, and seventh semesters than their peers who do not take the course." They suggest that reasons for this retention are the hands-on, real-life, social nature of the program. "These results imply the need to more broadly require and implement first-year engineering curricula embodying these characteristics."[5]

Another approach to increasing retention of women students in engineering and technology is research participation. A study conducted by SRI International showed that undergraduate research opportunities "increase understanding, confidence, and awareness."[6] Multiple universities such as UCLA and UT Austin have programs to increase the number of

undergraduates in research. The program at UT Austin is called GLUE: Graduates Linked with Undergraduates in Engineering. Through this program, undergraduates are matched with a graduate student mentor for one semester to work on research projects within the engineering college. The program is open to male and female students, and the majority of undergraduates are in their second or third year.[7]

A program implemented at Brigham Young University brings a unique approach to designing a research experience specifically targeted to first and second year women students in engineering and technology majors. The intent is to improve women student retention by helping students experience engineering, make connections, and gain self-confidence. While the program is unique from the authors' experience, it has parallels to programs at other universities.

This paper provides a detailed description of the Women's Research Mentorship program at BYU and its objectives with an evaluation of the effectiveness of the program. The benefits and challenges encountered in implementing the program are discussed, as well as lessons learned while implementing and administrating the program over the past five years. Based on program evaluations, student feedback, and faculty input, the paper suggests best practices for both faculty mentors and student mentees and summarizes the value of the Research Mentorship program to students' overall academic success.

Program Description

As with many institutions, BYU has struggled to retain women students in engineering and technology majors. The number of women who graduate in these majors is below the already low national norms of women in engineering majors. Nationally, ASEE reports that 19.1% of the engineering graduates are women, while at BYU it is 13.4%.[8] BYU recognized the need to focus efforts to change this trend, increase retention and recruiting, and provide more focused support for women students with a desire to study engineering or technology.

To help address this need, one of the programs that was created is the Women's Research Mentorship program. This program was initiated to provide a research-based experience to a group of freshmen and sophomore women students in the College of Engineering and Technology. The award, called a Mentorship, is designed to place students in a laboratory setting under the direction of a faculty member. Faculty members volunteer to be mentors, and the student mentees are expected to participate in their lab for one academic year.

A Mentorship award provides an opportunity for each student to earn $1,500 over the course of two semesters while doing research. The students are paid $10 per hour to work 5 hours per week and are expected to work approximately 15 weeks each semester over the course of two semesters. Mentees are paid by the college from donated funds.

A key aspect of the Women's Research Mentorship Program, which leads to its success, is that it works within the lab research assistant protocols that are already established in the college. Once

the awards are given and students are matched with mentoring professors, the mentees are hired through normal hiring processes and cared for in a manner similar to other research assistants. This makes it easy for mentoring professors to maximize the work experience and integrate the mentees into their lab processes.

Application and Award Process

The Women in Engineering & Technology office in the College administers the award process for the Women's Research Mentorship program. Freshman and sophomore women students who have declared majors in the college (approximately 240 students) are identified and invited to apply for the mentorship award. Over the past few years about half of the students have chosen to apply. Applications are essay-based and questions include what areas of research they are interested in for future work and what they hope to learn from a research experience. Applicants are evaluated based on their essay responses, grades and test scores, and on indications that they can successfully manage the added commitment of the research mentorship experience.

In early spring, the college polls each engineering department to find out how many faculty are willing and available to mentor women students for the upcoming academic year. There are approximately 110 full time male and female faculty in the college with 35-45 professors volunteering to mentor students each year. This and the amount of available funding determines how many awards are offered within each department. The college began by offering 9 mentorships its first year, but has increased the numbers over time and has been able to offer 32-33 mentorships for the last two years.

Newly declared freshmen are invited to apply very soon after they are notified of their acceptance to the university, and applications are due within a few weeks. These students are informed if they are receiving the award prior to the date they need to notify the university that they have accepted admission. Sophomore students who have registered for classes for the upcoming academic year are invited to apply during summer term and are notified if they are receiving the award approximately one month before the start of classes in the fall. Sophomore students who were mentorship awardees the previous year are not awarded a second mentorship, but are encouraged to work with their faculty mentor to continue participating in the lab group they worked with the previous year. Often funding is available through the faculty mentor for the students to continue working in the lab they were trained in as freshmen, but accurate data is not currently available to show what percentage do so. This will be tracked in further studies in the future.

Mentor-Mentee Matches and Start-up

Each department is responsible for matching the students who have received a mentorship award with an available faculty mentor and laboratory. Several weeks before school begins in the fall, each department receives a list of the mentees receiving the award, and a synopsis of the areas of research that she is interested in. The departments can then match students with faculty mentors,

aligning as best as possible the student's interests with faculty expertise and availability. The engineering departments are responsible for contacting the students, informing them of their mentoring professor, getting them hired as research assistants, and making sure they are trained in department policies and safety procedures.

The student then works with the faculty mentor and others in the lab to arrange their schedule and begin participation in the work of the research group. Mentoring faculty often also assign a graduate student to help directly supervise the student mentee. These graduate students are generally chosen based on the research they are working on and their willingness to work with the undergraduate mentee. Mentoring faculty try to find female graduate students to fulfill this role, but they are not always available.

Progress Reporting

The college office does periodic program evaluations to check on the progress of the student mentees, help resolve any concerns, and makes sure the program is working for the student mentees, faculty mentors, their lab groups, and the departments. A comprehensive program evaluation survey is done at the end of the mentorship experience and solicits feedback from both the student mentees and faculty mentors.

Program Objectives

As originally designed, the primary objective of the program has been to help increase retention of women students in engineering and technology majors. While this initial objective continues to be important, the program has had numerous other benefits to both students and faculty. With this overall objective in mind, sub-objectives were developed to support the mentorship experience to assist and encourage the student participants to:

- Form relationships with faculty and connect with upperclassmen and others within their departments and the college
- Gain confidence as they navigate their way through the challenges of obtaining an engineering degree
- Become involved in their departments and prepared for future leadership opportunities
- Participate actively in research earlier in their academic studies
- Excel as researchers and develop a desire to obtain graduate degrees

As the program has evolved and is running more smoothly (with faculty and administrators knowing how to hire and manage students and tasks), it is evident that these sub-objectives have merit on their own outside of the goal of increasing women student retention.

Study Group

The Women's Research Mentorship program has been operating in 2010 with 9 women student participants and has grown to 33 women students as of the 2014-15 school year. Evaluation data and student and faculty input presented in this paper reflect the experiences of the study group

over the 5 years in which the program has been operating. Figure 1 shows the participants by year and the mix of freshmen and sophomore students. Because of generous donations, the program has been able to increase the number of student mentees over the past five years.

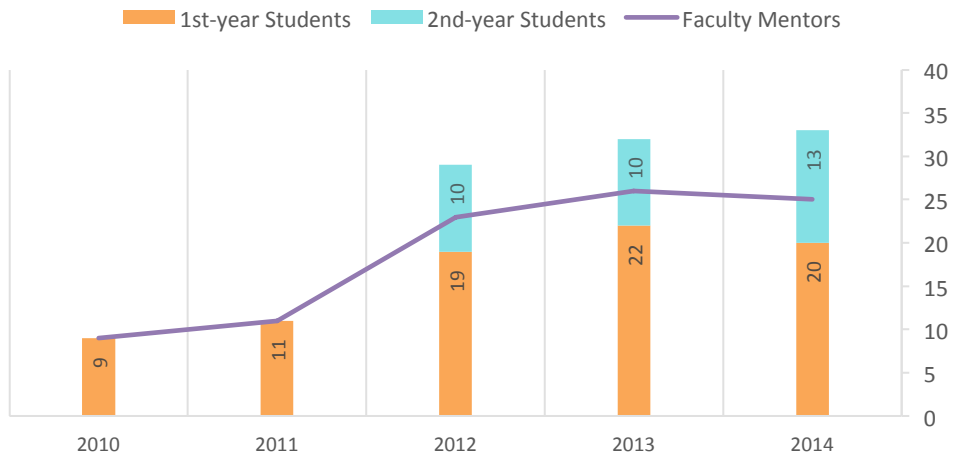

Figure 1. The number of first- and second-year student mentees and faculty mentors participating in the research mentorship program by year.

Program Evaluation

The Women's Research Mentorship program has provided a unique learning opportunity for everyone involved. Evaluation of the program includes quantitative and qualitative results from the student mentees and the faculty mentors, as well as observations from the program administrators. Results of the program have been largely positive, and improvements to the experience for the students and faculty are continually pursued.

Quantitative Results – Overall Experience

Student mentees and faculty mentors were surveyed at the end of the school year in April 2013. The goal of the survey was to obtain feedback and insight into the overall research mentorship experience. In general, the mentorship has been shown to be a positive experience for both students and faculty.

In the survey, faculty mentors rated the value of the program for the students who participated as well as the value of the program to the faculty mentor's lab group. Each was rated on a scale of 1 to 5, where 5 was excellent and 1 was poor. Nineteen of the twenty six faculty mentors responded to the survey.

- In response to the question "How would you rate the value of your mentoring experience for the student?" the average faculty rating for the program was 3.8, with a low rating of 2 and high rating of 5.
- In response to the question, "How would you rate the value of your mentoring experience for your lab group?" the average faculty rating for the program was 3.4, with a low rating of 2 and high rating of 5.

At the conclusion of the same year, the student participants were asked to rate the value of the program to themselves and their future success in their major. There were 24 student responses. Each was rated on a scale from 1 to 10 where 10 was "amazingly useful" and 1 was 'not useful at all'.

- In response to the question, "How useful was this mentorship opportunity for you. Will it help you in the future?" the average student rating for the program was 7.8, with a low rating of 3 and a high rating of 10.

Quantitative Results – Program Objectives

After tracking each of the students who have participated in the program, it is clear that participation in the year-long research mentorship experience does not guarantee that the students will stay in their originally declared engineering or technology major, as shown in Figure 2 below. Though overall retention of women students in the college is improving, the data shows, that the retention of the mentorship students is either on-par or slightly lower than the non-mentorship students in their class cohort group. The data in Figure 2 represent 1st and 2nd-year women students declared in an engineering or technology major in the academic year listed. A student is counted as changing their major if they declared as an entering 1st-year student and then changed to a major outside of the college at any time during the specified academic year.

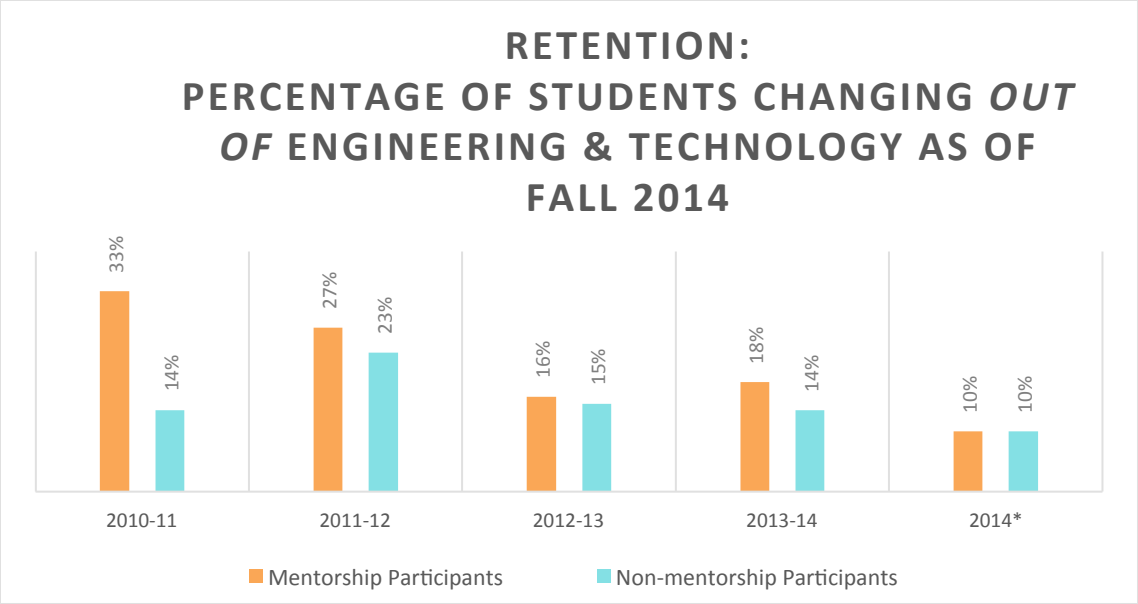

*Figure 2 - Participation in the research mentorship experience does not strongly indicate that the students will stay in an engineering or technology major. *2014 numbers have been doubled to reflect a projected full year of data (5% of students changed majors out of engineering during fall semester).*

Further analysis of the change of major data does show that research mentorship participants are more likely that non-participants to change their major to a different major *within* the college of engineering and technology, as shown in Figure 3. This may indicate some retention value to participating in the experience, even if the student decides that there may be a better fit for them in a different major.

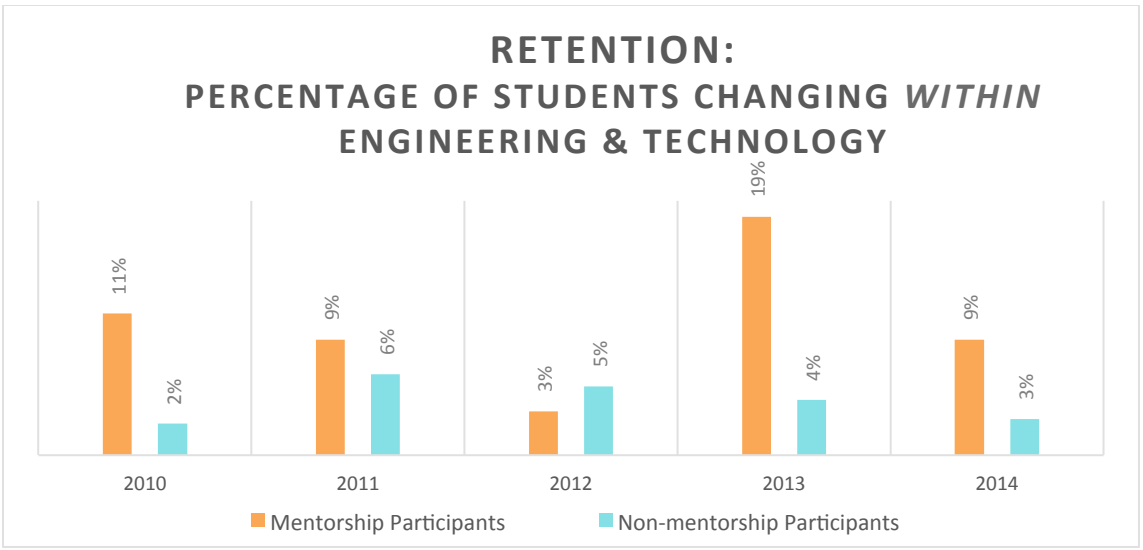

Figure 3 – 1st- and 2nd-year Research mentorship participants are more likely that non-participating women students in their class cohort to change their major to a different major within engineering and technology during a given academic year.

Qualitative Results – Value of the Program

The April 2013 survey yielded many useful qualitative responses. The faculty were asked about what they learned as they participated in the program, as well as what advice or strategies they would suggest to other faculty mentors. A sampling of faculty responses representing a variety of experiences in the program is summarized in Table 1 below. Each row of the table represents responses from a single faculty mentor.

What did you learn as you mentored the student?	What advice would you give other faculty mentors?
The program is a great medium to connect with students in the program at a higher level. It helped the student be involved in department research at an early stage which will provide a more fulfilling experience. It **helped me** as a professor **to accomplish several research objectives.**	I would strongly encourage participation and plan to participate again if given the opportunity. I would also encourage other faculty to have a **well-defined task list** for them to complete in the beginning so the experience is quickly rewarding for both the student and the professor.
It is critical to **connect the student to a graduate** or older undergraduate mentor.	**Outline a vision** early so that the student has clear guidelines.
The **thoughts of this student spurred some original ideas** in my PhD student that did most of the mentoring. This may lead the PhD student to an eventual journal paper.	Take a chance. The freshmen can do more than you think.
I had hoped that the student would be more willing to take ownership of her project. I needed to provide her with more structure and direction once I realized that **she was not going to be as self-motivated as I had initially expected**.	I would encourage faculty interested in the project to find out more about the available student's long term goals and current abilities and to **make sure that the project is a good match**.
Success depends heavily on the student. The previous year the student was not motivated or diligent, and finally dropped out. This student was very excited, learned quickly and produced results. I paired her up with two older female students and the matching group was a big positive factor.	**Pair up the student with a continuing woman student** in the lab so the young new student is not intimidated by working around PhD men.
It was important to put the student in **a group environment first** (rather than assigning research to be completed in isolation), so that she could gain confidence. Then she was able to become an independent and productive contributor to the lab.	**Sit down with the student** individually and help her identify her interests and strengths, then align the research tasks with those interests and strengths. Establish expectations and reporting mechanisms early.
Freshmen are enthusiastic and willing to learn but they also have very limited experience and knowledge. They are also learning how to manage their time and are adjusting to life as a college student. They require a **special research environment** tailored to their needs to thrive.	Prepare a binder with essential introductory information (Wikipedia articles, simple reviews of the research, lab safety, SOPs, etc.) that the student can study. **Keep expectations appropriate** for the student.

Table 1 – Faculty responses from the end of year program evaluations.

Student program evaluation responses from April 2013 were also insightful and useful for future mentees and faculty mentors. Students were asked to report on what their assigned duties and tasks were in the lab and to give suggestions on what could have made their research experience better and more valuable to them. A sampling of student responses, representing both positive and negative experiences, is summarized in Table 2 below. Again, each row represents a response from a single person.

Rating	What duties and tasks did you perform during your mentorship?	What could have made your research mentorship experience better?
9	I helped with **genetic engineering projects** in the professor's lab. I usually **assisted older students** with running tests and preparing experiments.	I wish I would have had a **better background with molecular biology and genetics** before jumping into my first month of college.
3	I feel as if I accomplished very little during my mentorship and was only given very general instructions on what I needed to do. When I got frustrated and couldn't find help, I assisted in various projects around the shop. After a while, I just stopped showing up. I rarely had contact with my mentor and only talked to him when I sought him out.	It would have been much better if I could have **worked with someone on their project instead of being in charge of my own**. Because I am a freshman, I know very little.
7	Lots of research on the web, gathering information and data for the program. I started with learning more about the CHP system and reading lots and went on to getting involved in doing calculations and formatting data for the program.	I wish I was given something **more to do** or was taught to do something more
10	I helped reorganize the lab, build a machine, and prep it to make isotrusses. I had different small tasks, such as going different places on campus to find out information or to get supplies. I was an **assistant to the professor's two primary undergrad researchers**.	I wish our project would have had better **funding**. We started the entire project, and it would be nice to have had the funding to keep our project moving along so we could have gotten the parts we needed.
8	Our lab focused on work with biofuels and I worked with **studies** to analyze the way that cells were affected by growing conditions. I would often prepare the experiments and care for the cells as they grew. I also did a lot of **calibrations** that needed to be done in the lab. Every few weeks I was also responsible for **presenting a piece of literature in lab meetings.**	I think if I had **known a little bit more about what kinds of experiments were being run** in the lab and what actually happened in a lab before I began it would have been helpful. It would have helped me not be so nervous when I started.

Table 2 – Student responses from the end of year program evaluations

At the completion of the experience students were asked whether or not they would recommend the research mentorship to future students. Comments were overwhelmingly positive. They are listed below and from the same students who evaluated the program in Table 2, in order.

"I would totally recommend the mentorship! It helped me feel comfortable and confident about pursuing an engineering degree. You also learn things about the department that you wouldn't

know until later (like where labs are, what resources are available). I also was able to pick the brain of my coworkers about the civil engineering program."

"I would definitely recommend it. It was a blessing for me. I learned a lot, met faculty, and was able to earn money. They were very flexible with my schedule and were patient with my learning."

"Yes. It is a good way to get to know professors and other engineering students. It is fun working on something for a long time with a group of students and professors."

"Yes! It gives the student a real world experience rather than just mundane school work. Being part of a research group so early looks amazing on applications to grad school, and the student's mentor may even want her to stay on the research project after the mentorship stipend is used up!"

"This was a really good experience for me because it gave me a different perspective. Sometimes classes are hard and you think you will never understand everything that is going on, but then you get into the lab and figure out how much you actually know."

Administrative Observations

A research mentorship experience that is perceived as successful from the student's perspective has been observed to have a great positive influence on the student's confidence and self-efficacy in engineering. Due to the responsibilities placed on each individual student in the program, the quality of the mentorship experience is largely dependent upon the students' dedication and willingness to stretch themselves. A student who has had a successful mentorship has made strong connections with their faculty mentor and the other students in the lab. They have often also had opportunities to meet and interact with other faculty and staff within their departments which helps them to feel a part of their major much more than other students in their age group. Most mentorship students have the opportunity to present their work both inside and outside of their lab group, some even as a co-author on a journal paper or presentation. This experience, though often stressful for the young students, helps to build confidence in their abilities and value to their contributions.

Administrators have also observed that in the years following their research mentorship experience, these students are more likely than non-participants to get involved in leadership and service opportunities within their major and the college. These students often become strong and enthusiastic mentors for the new entering students in the year following their mentorship experience. They are also more likely to be involved in club and society leadership positions than those women students who did not have a mentorship experience.

Lessons Learned

It is evident, particularly from the qualitative student feedback, that the research mentorship provides an experience to the participating students that they would not have on their own at this early stage of their studies. It is an intense experience that is either immensely positive or quite strongly negative for the student. Anecdotally, those who have positive experiences have a high likelihood of staying in a research setting, most often in the same laboratory or occasionally a different laboratory for the duration of their undergraduate studies. A negative experience correlates strongly to a student changing their major either to another major inside the college of engineering and technology or more often to a major outside of the college, though generally in another STEM related field.

Program Administration

These trends point to the importance of doing everything possible as program administrators to ensure a positive experience for the students. Over the course of the past five years, program refinements have included:

- Careful selection of student participants. Effort should be taken to evaluate whether the student is prepared and equipped to be successful in a research environment.
- Attention in matching student interests and personalities with available faculty and the research projects they are offering. Care in matching the student mentees with a faculty mentor and research project can be key in their engagement and successful experience in the program.
- A streamlined process to get the students started in the lab and trained very quickly at the beginning of the mentorship. A slow start-up degrades student confidence and can result in the student mentee dropping out of the program.
- Matching schedules to ensure that the mentees are able to participate in group lab meetings within their respective research groups. Students who meet with the whole lab as a group gain a greater understanding of their role in the overall research.
- Preparation and training of participating faculty, graduate students and others who may be directly supervising mentees. Advice on appropriate tasks and activities as well as how to help students feel included can increase the success of the mentee.
- Solicitation of periodic feedback from the mentees and faculty mentors to allow for any adjustments that might be beneficial to them. This is particularly useful in the first month of fall semester so adjustments may be made before students become discouraged with a poor situation.

Using the student and faculty feedback from the past several years, the program administrators have compiled the information and used it to categorize possible improvements to the program. The data and suggested improvements were presented and distributed at the annual college meeting to all faculty and administrators within the engineering and technology departments to help them better organize and run the program. Each year, the program has had smoother transitions and better participation from mentees and faculty mentors.

Operation of the Program

Mentoring faculty and graduate students can also be extremely important in helping young undergrad students gain perspective and understand how they fit into the lab experience. The student and faculty suggestions in Tables 1 and 2 led to the following conclusions on how a research mentorship program can best succeed:

- Freshman students need to know the context and framework of the work they will be doing. For most, the research process will be a completely new experience for them. Literature and books are helpful, but should be supplemental to one-on-one or group sharing to help the new student get started in the lab.
- Student researchers need to understand the importance of their individual contributions and how their efforts fit into the "big picture." Students are more engaged when they know the context of their duties and how they can contribute to the success of the research group and lab objectives.
- Women students most often feel more invested when they work with a group. Participation in lab meetings and sharing assignments with older student mentors help the mentees feel they have a core group to ask questions of and get help from.
- Regular meetings with their mentor give the student mentee a sense of accountability as well as way to ask questions and gain needed help.
- People like to feel unique, but feeling too different from the norm can have a negative impact. For example, placing a young female freshman student in a lab with all male PhD students will generally not help her feel part of the overall group. A better approach may be to place two or three new undergrad students together in a lab group so that they have other people they can relate to in the program.
- Lab culture has a huge impact on student satisfaction and ultimately success in the program. A welcoming, friendly atmosphere with people who are willing to teach, help, and answer questions is extremely important to the overall experience of the new student.

After reviewing the program at BYU, a few components should be included to make the process better for faculty, students, and administrators. Initial ideas include a start-up meeting to communicate expected outcomes, more frequent communication with participants, and grouping mentees together. Changes such as these will help e students better see the big picture, feel more comfortable, and ensure that the process is running smoothly.

Conclusions

While student retention was the initial focus of the program that has not necessarily been shown to be achieved. Additional study data is needed to draw solid conclusions, but a strong trend showing that students participating in the mentorship program are retained at a higher level than those students that have not participated has not been seen. This outcome has been surprising given the enthusiasm of the participants and the alignment of the program with recommendations

made in the literature. A variety of possible reasons for not showing a difference in retention have been put forward within the college and this area will be studied in the future.

There have been a variety of positive outcomes for the programs that are not associated with retention including:

- Faculty are now more comfortable having younger women students in their labs.
- Women students who successfully complete a mentorship are highly likely to go on to get graduate degrees. To date, four students who participated in the program have graduated with their undergraduate degrees and all are currently enrolled in either master or doctoral programs in engineering.
- A high percentage, greater than 65%, of mentorship participants continue to be involved in research in the years following their research mentorship.

The college intends to retain, refine, and expand the program. This is based on a continuing hope for increased retention, but also because of the other positive outcomes being generated by the program. Future evaluation will turn more focus to these outcomes.

The authors encourage other institutions to experiment with research mentorship programs for new students in engineering. These institutions may need to have moderate expectations relative to retention, but could expect other valuable outcomes for their women students.

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