

IDENTIFICATION OF STRATEGIES OF THE ERC FOR PARTICLE SCIENCE & TECHNOLOGY AT THE UNIVERSITY OF FLORIDA TO ATTRACT FEMALE UNDERGRADUATE STUDENTS IN ENGINEERING RESEARCH

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Abstract - The Engineering Research Center for Particle Science and Technology (ERC for PS&T) at the University of Florida is one of 20 National Science Foundation (NSF) ERCs across the country that are dedicated to fostering a new paradigm of engineering education that embraces multidisciplinary approaches to engineering education and research. The NSF Centers program has been committed from the start to increasing the diversity of the scientific workforce and has been successful in attracting a significant number of women to this type of research experience. The ERC for PS&T has exceeded even the NSF Centers performance, consistently including over 35% women students in its undergraduate research program. The purpose of this qualitative study was to investigate the reasons for this success and to make these strategies available to other programs wishing to increase the diversity of their participants. Focus groups and surveys were designed to identify the students's perspective of the ERC experience and to elucidate what program components attracted and retained these women researchers. Initial results indicate that ERC sponsored research experiences helped participants develop intrinsic motivation, responsible behavior, and a sense of increased self-efficacy.

Index Terms – Engineering climate, diversity in engineering education.

INTRODUCTION

The report of the Congressional Commission on the Advancement of Women and Minorities in Science, Engineering, and Technology Development (2000) [3] put a spotlight on the “critical shortage” of workers prepared to meet the needs of an increasingly technological society, and detailed the need to remedy the under representation of women and minorities in engineering. WEPAN noted that given projected trends in the workplace coupled with declining enrollments, identification of issues faced by women in engineering programs is crucial if the United

States is to remain competitive [2]. Research has documented that male and female students report different educational experiences and levels of self-confidence in engineering [2, 4, 11, 14].

The National Science Foundation has recently celebrated 16 years of fostering a new paradigm of engineering education through the Engineering Research Centers (ERC) Program. Thirty-six ERC's have been established as National University-Industry partnerships focused on improving American competitiveness in leading-edge multidisciplinary research. Through these Centers, NSF has served as a catalyst to the development of an interdisciplinary, team-based education program that focuses on systems-level, industrially relevant research. NSF has also held ERC's accountable for encouraging/including women and minority students in Centers Research. Nationally, women represent 19.5% of the total undergraduate enrollment in engineering. Due to the leadership of the NSF ERC Program, ERC programs nationally have been able to exceed this level, reporting 29% undergraduate women enrolled in these programs in 2000 [12].

The ERC for Particle Science and Technology at the University of Florida was established in 1994 to promote research and education in a critical core technology important to the microelectronics, mining, pharmaceutical, chemical, agricultural, and consumer products industries. The Center has established a multidisciplinary Undergraduate Research Program that has placed over 500 students from 14 different departments in research projects across campus. The Center has exceeded even the strong record of ERC's on the national level in attracting both women and minorities on all levels. The subject of this study was the high level of participation of undergraduate women in the research program, currently 38% out of a pool of 81 students. This compares to the enrollment of women in engineering at the University of Florida of 20%.

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WEPAN conducted a Pilot Climate Study in 2001 [2] and called for institutions to determine why male and female students have different perceptions of their educational experiences. It was appropriate therefore for the Center to undertake a study to try and pinpoint why it has enjoyed this success with female students so that it could share this information with other programs seeking to increase participation of women. Reference [10] determined that women are not as successful in the laboratory as in the classroom, so the success of a research program in attracting and retaining women is of additional significance.

POPULATION AND SAMPLE

The population consisted of 50 male and 31 female undergraduate students who are currently a part of the ERC Undergraduate Research Program. A total of five focus groups (two male and three female) included 7 male students (9% of the total male population; including 1 Hispanic, 3 African American, and 3 Caucasian students) and 8 female students (26% of the total female population, including 1 Hispanic, 1 African American, 1 Asian, and 5 Caucasian students), or 19% of the total sample population. Students participated in only one focus group.

A survey was developed that included multiple choice, 5-point scales and open-ended questions. It was e-mailed to all 81 ERC Undergraduates and 40 were completed for a return rate of 49%. 25 men (50% of the total male population) and 15 women (48% of the total female population) were in the respondent pool. These students came from 10 departments.

METHODOLOGY

This study employed a mixed methodology as data was collected through focus group interviews as well as a survey. Focus groups were used to collect detailed qualitative data as well as to collect information that was used to develop a survey instrument. The focus groups were conducted by a graduate student from the UF College of Education to encourage candid and open responses. The focus groups solicited information regarding students' perceptions of their experiences at the ERC, why they have remained part of the ERC, and their satisfaction and dissatisfaction with the ERC's programs. The interviews were audio tape-recorded and the recorded interviews were transcribed. Specific methodological guidelines [17] informed the coding and analysis of students' responses.

Additional information from a larger number of ERC students was collected through use of a survey. The instrument was sent via email, followed up by reminders through email. The instrument was developed following several of the focus groups and was reviewed by the ERC Associate Director of Education for content validity. Survey items sought to elicit information from students about their ERC experience, particularly with regard to

climate and level of support they experienced, as these factors have repeatedly been shown to be important but male and female students rate them differently.

Given the limitations of the focus group and survey methodologies [13] data was also collected on the percentage of students that return after their first semester to allow for triangulation of data on the degree of satisfaction with the Center.

FOCUS GROUP INTERVIEW RESULTS

In this section we will present findings from the male and female focus groups under five headings: (1) Variables influencing choice of the field of engineering, (2) Satisfaction with the ERC (3) Dissatisfactions with the ERC, (4) Perceptions of the ERC climate, and (5) Reasons for continued affiliation with the ERC for PS&T.

1. VARIABLES INFLUENCING CHOICE OF ENGINEERING

Focus group responses to variables that influenced their choice of engineering fell into three categories: interest/ability in math and science, money, and influence of others. For the majority of participants, both male and female, interest in the sciences was a major motivator in choosing engineering. As one male participant observed, *"I was always pretty great in math and physics and I like to be a thinker and I thought engineering would be a good choice for me."* The female participants' realization that they were *"good in math and science"* was influential in their choice of engineering.

For two males in chemical engineering, this particular field was perceived as having the potential for *"making money."* Females did not mention money as influencing their choice of engineering.

One half of the male participants had parents who had careers in the sciences. These participants felt that had some influence on their choice of engineering. One participant said, *"My father's an engineer, so that's a factor, and my mom's a biochemist so I guess materials is somewhat in between engineering and chemistry."*

The females reported that different people influenced them in their choice of engineering. One recalled being a junior in high school and *"a teacher came to the Materials Science department here at UF and she came back with information and I liked what Materials Science was about."* For another female, *"FSU did a presentation on engineering at the school"* which caught her attention. For another, the academic advisor in Materials Science *"steered me into materials science."*

2. SATISFACTION WITH THE ERC

All participants, spoke positively about their experiences at the ERC. A major theme that emerged from the interview

with the males was the cross-disciplinary nature of their experience at the ERC and the exposure this provided to different fields in engineering. As one participant shared:

Well, for instance it's cross-disciplinary right, so you get to do things like what materials science would do and so other people get a look at the field to see where you want to go if you actually do go into the industry. Or if you want to pursue graduate school what field would you want to pursue. Otherwise ...you don't have that insight into the other fields.

And another,

I'm working with the mechanical engineering department. So, it's actually not really my department at all and all of the projects we are working on are not terribly materials related. So, I get a lot of knowledge in that department that I otherwise would not have.

In the interview with the females, only one person mentioned the fact that the research was interdisciplinary.

Participants, both male and female commented on how much they appreciated the expertise demonstrated by faculty in their department. As one male commented:

I think that everyone I have worked with is well versed in his or her area of study. Obviously, he knows what he's talking about and if we had any questions he was able to answer them.

Faculty was perceived as not only possessing the expertise in their fields, but as being willing to help students. One male participant shared,

I am pleased with the faculty here. If you need to find some instruments or find some materials they can help you find it or how to use a machine. And up here, people like [ERC Administrators] are really helpful and really communicative.

For female participants, one explained,

"I have no problems, they [faculty] are extremely helpful, there's one machine that I didn't get a chance to work on and so I have come to the faculty member who showed me how to work the machine."

Males also emphasized their appreciation for the expertise and knowledge demonstrated by faculty members.

Another major theme that emerged was participants' observations about their work schedules and the flexibility and autonomy that working at the ERC provided them. The sense that this was highly appreciated and provided motivation for them to work even harder was apparent in many of their comments. As one male participant shared:

Generally a lot of us put in a lot more than that [ten hours a week] probably. And they're flexible about it. I usually come in really late because he knows I like to do it when no one else is using the computer that way I don't have to keep getting interrupted.

Another perceived the flexible schedule as vital in lowering the stress experienced by students, "Yes, it's much less stressed than other jobs. I basically get to choose my schedule and work on my own time."

Another reason for satisfaction with the ERC was the fact that all participants were working with other students as a team. As one male shared,

"...so, not only are you working with your group members but you are working with a larger team also. So it's a little more goal oriented and you actually see how your results affect others."

For one of the female students,

"I am learning something. I feel sort of important. I am working on this big project that a lot of other graduate students are working on. I am actually learning something. I am networking by meeting people and asking questions—not only about the project but also about graduate school."

Another female explained, "I am getting a good experience because I am working on a real project. It is something that I can talk about during an interview." The females seemed to focus on the opportunity for networking and advancing, and the importance of the feeling of inclusion felt more than did the males. For another male, "the overall friendly environment" was a source of satisfaction with the ERC.

In sum, all participants expressed great satisfaction with the ERC because of the flexibility of the scheduling, the cross-disciplinary exposure within the field of engineering, expertise and helpfulness of faculty, and the exposure to the different equipment/machines at the ERC. One male participant saw the research as "benefiting people and...helping out in a greater cause," as they enjoyed the opportunity to "apply what [they] learn in class in an actual setting." Both males and females perceived their ERC experience as helping to build their resume.

3. DISSATISFACTION WITH THE ERC

When asked about their dissatisfactions about the ERC, all the males expressed their satisfaction with their experience and said they were not dissatisfied at all. Some of the comments were, "nothing comes to mind," "I pretty much have been pleased with my entire interaction with the ERC." The females expressed some dissatisfaction. The female who was new to the ERC expressed apprehension about the novelty of the ERC experience, as she explained,

"I have my group and they are all grad students and it is really intimidating....I wish there was another new person with me and we could work together. Everyone is a lot older than me."

Another female felt out of place at the group/thrust meetings she attended because at these meetings "all these big people...they talk over your head." One student wished she had access to the work site on weekends so she could "come and use the machine." Another discussed her desire to be involved more extensively in the design of the project. She explained that times where "they are changing design and they are deciding what course to take", she hoped to be "a

part of the analyzing process” that went on to decide on the direction of the research project.

4. PERCEPTIONS OF THE ERC CLIMATE

As far as the climate of the ERC, terms like “friendly,” “encouraging,” “supportive” were used by both male and female participants. As one male explained,

They are interested in us because they give us jobs also. They mention a lot about interview people coming in and they tell you, "have your resume ready." And they are interested in getting you out there, I guess, in the spotlight.

Females described the climate as “professional.

5. REASONS FOR CONTINUED ERC AFFILIATION

Participants remained in affiliation with the ERC for various reasons. Some saw this broad exposure to differing engineering fields as helping them prepare for future employment. As one explained,

I would say it's a good learning experience and it helps being well-rounded not just knowing one area of industry or engineering. It exposes you to a lot of other things. It shows you have a lot to offer to employers. And I guess it's a good resume builder.

For both male and female participants, the funding from the ERC was important. As one male participant candidly shared, the ERC “Pays my tuition. That's why I keep coming back,” and a female, “The \$1,000 per semester is a very good reason actually.” However, for neither was this the major reason for being at the ERC, as the same female explained further, “I feel like I am finally beginning to learn a little more about particle science,” and for one of the males, “I could work some other job. I would just rather come here and I'd rather do this.”

Other reasons included the perception that the ERC was a welcoming place. One male student appreciated “the open arms” with which he felt he was accepted. Both males and females mentioned the desire to complete the projects they started as a reason for remaining with the ERC. Both males and females mentioned the fact that they liked the “atmosphere” as a factor why they remained at the ERC.

To sum up in the words of one male student, “You don't get this experience anywhere else.”

When asked the final question about whether they had anything else to say about the ERC, one participant summed up the general feeling by saying, “Keep it going.”

RESULTS OF THE SURVEY ANALYSIS

Procedures in the Statistical Package for the Social Sciences (SPSS) were used to analyze the survey results on ten of the 5 point scaled survey items. Six of these items asked students to rank their perceptions on their research participation, support from faculty, mentors and administrators, and the flexibility of the schedule. Four other items measuring overall climate factors were included since the literature indicated their importance. They included measures of the climate as positive/negative, supportive/non-supportive, participatory/ non-participatory and “girl-friendly”/“not girl-friendly.” The reliability of the instrument was established through an alpha reliability test of the ten items ($\alpha=0.79$.) Principal components analysis showed that the four climate items had high factor loadings (>0.7), indicating that climate factors are strongly related to ERC students' reported level of satisfaction, which is consistent with the literature.

The response categories were coded from one (strong disagreement) to five (strong agreement). For all respondents, both male and female, the mean score for each item ranged from 3.82 to 4.85 as shown in Table 1.

Results showed that the mean score on the majority of items was higher for females than for males. The only statistically significant difference in perceptions of the climate was that the females rated the climate of the ERC more positive than did the males ($t(33) = -2.067$, $p = .047$, $\alpha = .05$)

Further examination of the data showed that those students who had been at the ERC for a longer period of time scored higher on the majority of items when compared to those who had been at the ERC for fewer semesters. Those who had been at the ERC for four semesters showed greater appreciation for the cross-disciplinary nature of the research project than those who had been at the ERC for three semesters ($t(7) = -2.414$, $p = .049$, $\alpha = .05$)

TABLE 1
DESCRIPTIVE STATISTICS OF MALE AND FEMALE ERC UNDERGRADUATE RESEARCHERS

Variable	Gender	N ¹	Mean	SD
Involvement in research project	Male	24	3.98	.94
	Female	15	4.10	.83
Level of faculty support	Male	24	4.29	.76
	Female	15	4.33	.83
Level of grad/ mentor support	Male	19	4.13	1.05
	Female	12	4.38	1.05
Level of ed. office support	Male	22	4.09	1.05
	Female	14	4.18	.85
Flexibility of work schedule	Male	24	4.85	.40
	Female	15	4.80	.37
Imp. of cross- disciplinary research	Male	24	3.83	1.19
	Female	15	4.20	.65
Climate: positive/negative	Male	24	4.06	1.12
	Female	15	4.60	.47
Climate: supportive/not supportive	Male	24	4.10	1.14
	Female	15	4.53	.65
Climate: participatory/not part.	Male	24	4.08	1.17
	Female	15	4.30	.49
Climate: girl friendly/not girl fr.	Male	17	3.82	1.07
	Female	15	4.20	.70

Note: N¹ Overall N was 25 Males and 15 females, however, numbers of responses differed for some items.

DISCUSSION

This study was undertaken to identify factors in the success of the Center at attracting female students. Prior research that informed the study showed that female students have lower levels of reported self-confidence in engineering than males, that money is a motivator for women in the choice of engineering careers, that women are often influenced by others in their choice of engineering, that male and female students report different perceptions of their engineering experience, and that both male and female student responses on climate survey questions tend to fall in the low - average range of 2.5-3.5. The ERC data is compared to each of these items in this section.

The ERC study demonstrated the participants in the research program reported a high level of satisfaction. Analysis of the survey results indicated a trend towards increasingly positive responses as time spent in the Center increased. This caused a reexamination of the focus group data. As mentioned earlier, research shows female students report a lower level of self-confidence, and it was several of the females in the focus groups who reported more dissatisfaction with the availability of their mentors and a need for more guidance. It was determined that the students

who expressed a desire for more direction were in their first semester of the ERC. Female students who had been with the center for multiple semesters reported a significantly different kind of dissatisfaction. These students focused on obstacles to their increased involvement in the project, (with respect both to time and intellectual level.) Rather than asking for help, they felt that they had more to offer the project.

Self-efficacious students “participated more readily, worked harder, (and) persist[ed] longer” [19, p. 86]. Considering the level of participation, persistence, and commitment with which ERC students engaged in their research, it may be concluded that they enjoy a high sense of self-efficacy. It is probable that self-confidence in the lab increases with time. Therefore, laboratory experiences that last more than one semester could serve as a mechanism to address the lack of confidence reported by female engineering students.

The primary variable affecting the choice of engineering for these students was an interest in the sciences. The response with the highest percentage of responses for males was their enjoyment of the sciences, while for females it was an aptitude for math and science.

This is in contrast to results that found the primary reason for females to choose an engineering career was the “financially rewarding” aspects [14].

While many students were initially attracted to the ERC for monetary reasons, it was apparent that over time they came to develop a high degree of interest in the research experience, which they came to enjoy. Focus group, longer-term students had taken ownership of the projects. At that point the work was done “for its own sake, rather than as a means to an end” [9, p. 315], an indicator of intrinsic motivation. The commitment of these students was evident in the long hours they spent working on their research projects, another indicator of intrinsic motivation [16].

In research on the effects of classroom autonomy on 365 college students, it was found that “perceptions of autonomy had positive effects not only on intrinsic motivation, but also upon task value and self-efficacy” [6, p. 484]. It was apparent that the focus group participants highly valued the autonomy with which they were allowed to carry out their tasks. This may be one of the reasons for their demonstrated intrinsic motivation, value placed on the research project, and their overall satisfaction.

For these participants then, it seemed obvious that their ERC sponsored research experiences helped them develop intrinsic motivation, responsible behavior, and a sense of increased self-efficacy.

Research has shown that female students are influenced by teachers and counselors more than men in their choice of career fields. [14,15]. The female focus groups students reported data consistent with this finding. They mentioned receiving encouragement from teachers, classroom visitors, and academic advisors. The survey results, however, showed essentially similar results for both men and women on responses measuring influence of family members and teachers. The most significant difference on this measure is that 79% of the males reported being influenced by a peer, while only 6% of the females indicated this as a factor.

In stark contrast to the literature that reports that females indicate different perceptions of the engineering climate and experiences than do men, the ERC survey found only one significant difference between male and female students on 10 measures. The only difference was that females related the climate more positive than men did. The focus group participants mentioned that the friendly, accepting climate of the ERC provided the context within which they could grow and appreciate their research experiences. One study of educational resilience and its role in the retention of women engineering undergraduates proposed that it was important to note that the degree of belongingness to the department felt by students had strongly affected their retention [8].

Reference [7] purported that climate in the academic setting, as “the prevailing condition affecting life and activity,” was set by “the expectations and past experiences for students, faculty members, and staff; by the history of the institution, and by the behaviors and goals that

are expected and rewarded.” (p. 2) The ERC faculty and administration have achieved a climate that is supportive of its female students.

A review of the literature on factors in the under representation of women in engineering, reported that for women, vicarious learning (which occurred when “good models” were available to women) was an important source of self-efficacy for women [1]. The Associate Director for Education of the Center is a female; there are currently 2 female faculty members, as well as a graduate student mentor population that has 9 female students. It is possible that the presence of female role models in the Center has provided positive role models to the undergraduate students. But it must also be true that the overall atmosphere created by the male faculty members is also “female friendly.” Climate that supports women in their development—academically, professionally, and personally as “warm” [5]. In a “chilly” climate women are treated differently from men because of their gender. The results of the ERC study is a clear indication that the Center has avoided the chilly climate that female students often experience in engineering education.

Finally, as pointed out in the Climate Survey conducted by WEPAN, the mean responses to the majority of the questions were in the low-average range. The ERC survey averages were all in the 3.82 to 4.85 range, confirming the focus group data that students have a high degree of satisfaction with the program.

To support the data collected through the focus groups and surveys, the retention records of the Undergraduate Researchers were examined. Students may choose to reapply to continue their research after the first semester. The degree to which students elect to do this is yet another measure of the degree of satisfaction those students have with the Center. The percentage of students who apply for additional semesters varies with graduations and students pursuing internships, but is generally 60% or higher. The current group of student includes 75% repeat students. This high rate of reapplication is further evidence of the high degree of satisfaction reported by the sample populations in the survey and focus groups.

SUMMARY

Advocates for making engineering and the sciences more “female friendly” have held that changes in the engineering climate that would make the atmosphere more conducive to female students would in fact enhance learning for all students. The ERC study is direct evidence that this is indeed true. The supportive, positive environment afforded to all undergraduate students has not only resulted in a high degree of participation by women, but has also produced a high degree of satisfaction on the part of male students as well. The Center also exceeds national averages in the participation of minority students. Although the small numbers of students precluded statistical analysis, the

average responses of minority students on all of the questions were higher than the responses of non-minority students, further evidence that “warm” climates are beneficial to all students.

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REFERENCES

- [1] Blaisdell, S., *Factors in the Under Representation of Women in Science and Engineering*, West Lafayette, In: Women In Engineering Program Advocates Network, 1999.
- [2] Brainard, S. G., Staffin-Metz, S., & Gillmore, G. M., *WEPAN Pilot Climate Survey*, www.wepan.org/climate.html, 2001.
- [3] The Congressional Commission on the Advancement of Women and Minorities in Science, Engineering and Technology Development, *Land of Plenty: Diversity as America's Competitive Edge in Science, Engineering and Technology*, 2000.
- [4] Cosgrove, C., Blaisdell, S. and Anderson, M., “A climate survey and needs assessment”, *Proceedings of the Women in Engineering Conference: Effecting the Climate*, June, 1994.
- [5] Fish, M., “Assessing the climate and student needs”, In S. Metz (Ed.) *Increasing Access for Women in Engineering*, Hoboken, NJ: Office of Women's Programs, 1996, pp. 71-108.
- [6] Garcia, T., & Pintich, P., “The effects of autonomy on motivation and performance in the college classroom”, *Contemporary Educational Psychology*, 21, 1996, pp. 477-486.
- [7] Ginorio, A. B, *Warming the Climate for Women in Academic Science*. Washington, DC: Association of American Colleges and Universities 1995.
- [8] Graham, J., & Caso, R, “Retention of women in undergraduate engineering programs: An empirical investigation of the role of educational resilience”, Paper presented at the NAMEPA/WEPAN 2001 Joint National conference, April 21-24, 2001, Alexandria, VA.
- [9] Hidi, S, “An interest researcher's perspective: The effects of extrinsic and intrinsic factors on motivation”, In C. Sansone & J. Harackiewicz (Eds.), *Intrinsic and extrinsic motivation: The Search for Optimal Performance*, San Diego, CA: Academic Press, 2000, pp. 311-333.
- [10] McIlwee, J. S. & Robinson, J. G., *Women in Engineering: Gender, Power and Workplace Culture*. Albany, NY: State University of New York Press, 1992.
- [11] Palmgre, C., Lazarus, B. & Nair, I., “Increasing women's retention and persistence: a report of research in progress”, *Proceedings of the Women in Engineering Conference*, June 1993.
- [12] Pauschke, Joy, National Science Foundation, personal communication, 2000.
- [13] Prus, J. & Johnson, R, “Assessment & testing myths and realities”, *New Directions for Community Colleges*, 88, 1994.
- [14] Rinehart, J. & Watson, K., “A campus climate survey at Texas A&M University”, *Proceedings of the Women in Engineering Conference*, Seattle, Washington, June 14-16, 1998.
- [15] Seymour, E. & Hewitt, N.M., *Talking About Leaving: Why Undergraduates Leave the Sciences*, Boulder, Co: Westview Press, 1997.
- [16] Shah, J., & Kruglanski, A. “The structure and substance of intrinsic motivation”, In C. Sansone & J. Harackiewicz (Eds.), *Intrinsic and Extrinsic motivation: The Search for Optimal Performance*, San Diego, CA: Academic Press, 2000, pp. 105-127.
- [17] Spradley, J, *The Ethnographic Interview*, New York: Holt, Rinehart, and Winston, 1979.
- [18] Zimmerman, B. J., “Self-efficacy: An essential motive to learn”, *Contemporary Educational Psychology*, 25, 2000, pp. 82-91.