INNOVATIVE EDUCATIONAL OPPORTUNITIES FOR WOMEN IN STEM: RESEARCH INTERNSHIPS IN SCIENCE AND ENGINEERING (RISE)

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Abstract - A commonly known fact is the relatively small percentage of women represented in science, technology, engineering and mathematics (STEM) fields. This well documented but little understood phenomenon is a cause of great concern to STEM educators. Based on the available literature on barriers to women's success in STEM, an innovative educational intervention has been developed at the University of Maryland (UM). In the second year of implementation, Research Internships in Science and Engineering (RISE) is designed to facilitate mentoring and role modeling for women at all levels of higher education: from incoming first year students, undergraduates, and graduate students to female faculty members. RISE is a two tiered program consisting of Level One, The First Year Summer Experience (FYSE) focusing on incoming first year students and Level Two, Summer Research Teams focusing on upper-level undergraduates, graduate students and faculty. Developed to address several major barriers that women face in STEM fields, evidence of program impact based on the first year of implementation will be provided.

Index Terms - Barriers, Research Program, Mentor Hierarchy, Retention Strategy

PROGRAM DESCRIPTION

The lack of women in science, technology, engineering and mathematics (STEM) fields has been well documented: from the low percentage of female first year students who enter these majors, to the subset who persist to graduation, to the few who go on to graduate school, and finally, the infinitesimal number who desire and succeed in becoming engineering, math, or science faculty members [1]. A recent report by the Congressional Commission on Advancement of Women and Minorities in Science, Engineering, and Technology Development [2] indicates that there has been virtually no change in the last fifteen years in the percentage of women earning bachelor’s degrees in engineering. This contrasts strongly with the increased numbers of women entering medicine, business, and law fields, also previously “female scarce”.

Barriers contributing to the paucity of women have been identified as external, or contextually based [3] or internal, or individually based [4]. Examples of external barriers include lack of female role models and a "critical mass" of women, the "shadow job" expectation for female faculty of mentoring students even though they receive little formal recognition or reward, and the "chilly climate" of STEM fields. Example internal or individually based barriers include low self-perceptions of ability and confidence.

At UM, an innovative educational intervention has been developed to help overcome key barriers to the success of women in STEM. Research Internships in Science and Engineering (RISE) is designed to serve women in the higher-educational pipeline: incoming first year students, undergraduates, graduate students, and female faculty members. The purpose of this paper is to describe the RISE program and provide initial data demonstrating its effectiveness after one year of implementation.

There appear to be two key points in the career of undergraduate women where participation in a deliberately designed intervention can significantly impact success. The first is during the transition from high school to college (which tends to be the initial encounter with the predominantly male STEM environment). The second is during the latter half of their undergraduate education, when career options, including whether or not to pursue graduate education, are being considered. Taking into account these opportunity points, the RISE program consists of two tracks: RISE: The First Year Summer Experience (FYSE) for first year students (Level One) and RISE: Summer Research Teams (SRT) for more advanced undergraduates (Level Two).

RISE: The First Year Summer Experience (FYSE) is designed for incoming first year women students intending to major in STEM fields. Planned as a two week summer residential experience, twenty five new STEM majors collaborate with female faculty members in STEM fields, members of the Women in Engineering (WIE) program and BESTEAMS (an engineering faculty group conducting research and training on student project teams) to receive an introduction to engineering and the sciences.
Because previous research has shown that female students often enter STEM fields with fewer technical skills and less computer expertise and confidence than men, the program includes technical skill enhancement activities, taught by female graduate students [5]. RISE participants learn to use campus informational technology resources (e.g., creating web pages, and developing a work portfolio) and have the hands-on experience of taking apart and rebuilding a computer. Faculty mentors provide orientations to their laboratories and research projects. Throughout the course of the FYSE program, students are exposed to five different faculty’s areas of research and expertise. Each day, students participate in existing laboratories demonstrations, workshops, experiments (e.g., “Hands on in the Machine Shop” and Wind Tunnel testing). Students also attend a series of “Lunch and Learn” sessions where faculty mentors, scientists, and engineers working in industry discuss their personal experiences in science and engineering. Students receive a stipend of $500 for their participation. In the first year of implementation, 24 female students earned stipends for completing the FYSE program.

RISE: Summer Research Teams (SRT or Level Two) involves a guided team-based research experience for junior and senior women majoring in engineering or the sciences. Driven by the demands of industry for employees who are team savvy, as well as accreditation standards [6], student project teams are becoming commonplace learning environments in engineering and science fields. While positive team experiences have been shown to motivate students and encourage higher levels of academic achievement leading to increased retention and graduation, a common experience for undergraduate women on project teams involved being in the minority [7] From this perspective, the team may become yet another challenge in dealing with isolation in the STEM environment, rather than a potential source of peer support and learning.

The SRT program strives to offer an alternative team experience by bringing women together to conduct research. During the first year of RISE implementation, five research teams were created according to the following structure. Four undergraduate women (Scholars) are teamed with an advanced peer (Undergraduate Fellow) already familiar with the research project, and a female graduate student (Graduate Fellow), committed to the field by virtue of seeking an advanced degree. Heading up the group is a female faculty member (Faculty Mentor). The ten week program occurs during the summer. Scholars are paid $3,000 for their participation. Faculty mentors are paid one month of summer salary for their efforts (up to $8,000 per summer for full participation). Graduate Fellows are paid a $2,000 scholarship to supplement their existing graduate assistantship funding. Undergraduate Fellows are paid $4,500 for their participation in RISE. Paying the faculty and graduate student participants in RISE acknowledges the real work that mentoring undergraduates requires. While many individuals volunteer to take on such tasks (sometimes called "shadow jobs") because they realize the importance to the next generation of scientists and engineers, the lack of reward and recognition can cause burnout, and at worst, resentment.

Research on role modeling suggests that the greater the perceived similarity, the greater the impact of the role model [9] [8]. The RISE project takes advantage of this potent social psychological influence by providing three potential role models for participants: the Undergraduate Fellow who is a peer, the Graduate Fellow and the Faculty Mentor, who serves both as a role model and mentor. Different than role models, mentors actively engage in their protégés’ lives, work for their occupational success, and advise them on various areas of personal and professional concern [10]. Thus students who participate in SRT experience a "role model hierarchy" beginning with models very similar to themselves and ending with the faculty member. The deliberate creation of these hierarchies of multiple role models sets RISE apart from other more typical mentor-mentee pairings.

Because the “publish or perish” mantra is still the key to success in academia, financial support for faculty involvement is not sufficient to overcome the negative impact of shadow jobs, the RISE project uses the faculty member’s own research program as the setting for the student teamwork and mentoring to occur. The intention is that faculty should make direct progress on their own research agendas while they act as mentors. In the first year of the RISE::SRT program, the following research projects were conducted by RISE teams:

- **Beam Halo Monitors & Detector Development for the JLab G0 Program** (led by Dr. Elizabeth Beise, Physics) This project was located at the Thomas Jefferson National Accelerator Facility (JLab) in Newport News, Virginia (students were housed in Newport News and traveled back to UM for training and other events). Students collaborated on the “G0” experiment, a major component of the experimental nuclear physics program at JLab.
- **Coupling of Fast & Slow Chaotic Systems for El Niño Climate Forecast Applications** (led by Dr. Eugenia Kalnay, Meteorology) This project required students to perform mathematical modeling using large data sets to simulate nonlinear chaotic dynamics with multiple time scales from El Niño meteorological data.
- **Spatial Scales of Particle Organization and its Influence on Stream Bed Roughness** (led by Dr. Karen Prestegaard, Geology) Students conducted field research on the relationships among particle size distributions, roughness heights, and flow resistance in stream beds to develop guidelines for application to stream restoration projects and flood mitigation.
- **Measuring & Simulating Volume Change in Conjugated Polymer Actuators** (led by Dr. Elisabeth Smela, Mechanical Engineering) The main objective was to...
devise a system to measure the mechanical properties of a conjugated polymer called a polypyrrole.

- Role of Remote Sensing in Studies of Snow, Water Resources & Climate Change (led by Dr. Kaye Brubaker, Civil and Environmental Engineering and Dr. Rachel Pinker, Meteorology) This was an interdisciplinary Earth Systems science study built on shared research interests of snow, radiation, and remote sensing. The work introduced Scholars to cutting-edge topics in the fields of hydrology and climate, and provided training in advanced computations, data visualization, and applications of satellite data.

The SRT program also addresses another common obstacle to the success of women in STEM fields: the lack of training and support in mentorship and teamwork. Rather than leaving these important role modeling and mentoring functions for each female faculty member to figure out on her own, the entire research team takes part in training on mentorship, effective team functioning, and psychological constructs (e.g., self-efficacy) that are key to enhancing the successful learning of female students. The teamwork training is based on the BESTEAMS’ model (a curriculum model developed for student project teams supported by NSF’s Course, Curriculum and Laboratory grant DUE008079) which focuses on three elements key to successful student project team functioning: personal awareness, interpersonal skills, and project management proficiency. Faculty mentors and Graduate Fellows are also introduced to the basic tenets of social cognitive career theory's central concept of "self-efficacy" [4] and the implications of the research for supporting female education in STEM environments.

In sum, SRT employs an enhanced team experience as a means of overcoming significant barriers to success for women in STEM majors. The enhanced team experience consists of participation in a "role model hierarchy". The Undergraduate Fellow, the Graduate Fellow, and the faculty mentor form the backbone of the hierarchy. In addition, the Scholars themselves act as role models to the FYSE students. Scholars interact with these first year students both formally and informally. Formally, FYSE students are invited to visit each of the RISE research labs and are given an overview of the research in progress. Informally, joint social activities, such as a pool party, allow the older students to mingle with the new first year students. In these ways, the Scholars become part of the role model hierarchy and have an early experience guiding students just starting out in STEM majors.

RISE PARTICIPANTS

RISE: FYSE Participant Selection: The program is open to incoming first year engineering, mathematics, computer and physical science majors. Because the lack of diversity is a significant factor and issue of concern in STEM fields, every attempt is made to recruit students from a variety of racial and socio-economic backgrounds. Recruiting efforts include using the Women in Engineering Programs and Advocates Network (WEPAN) electronic listserv and direct mailings to academic departments recommended by faculty mentors, women's colleges, local community colleges and local historically black institutions. Potential participants for the FYSE program are asked to submit an application, high school transcript, and an essay identifying their career goals and support for women in technical fields, as well as the reasons they would like to participate in the program. Application packages are reviewed by the RISE program staff to identify those students who best match the spirit of the program. In the first year of the program, we had 36 applications for 25 positions. Of those selected, 17 intended to enroll in majors in the college of engineering, while eight planned to enroll in college computer, mathematical and physical sciences at UM.

RISE: SRT Participant Selection: The SRT program follows a similar application process: transcripts of current college coursework, a statement of interest and career goals, and letters of recommendation are expected. Faculty mentors and their research projects have been identified and students can rank their degree of interest in each specific project. Undergraduates who have previously participated in the FYSE program will be particularly encouraged to apply to RISE: SRT in subsequent years of the program.

In the first year of RISE, 60 applications were received. After the initial applications were screened for completeness, faculty ranked their preferences for team member based on the student's experience and skill sets. A matching session was held where faculty and staff established the best congruence between the student and faculty preferences for their research teams.

Eighteen undergraduates from the University of Maryland (N=6) and around the nation (N=12) were selected to participate as Scholars. Table 1 specifies the student's home institutions.

<table>
<thead>
<tr>
<th>College</th>
<th># Scholars</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bryn Mawr College</td>
<td>1</td>
</tr>
<tr>
<td>College of William and Mary</td>
<td>1</td>
</tr>
<tr>
<td>Cornell University</td>
<td>2</td>
</tr>
<tr>
<td>Duke University</td>
<td>1</td>
</tr>
<tr>
<td>Pennsylvania State University</td>
<td>1</td>
</tr>
<tr>
<td>Purdue University</td>
<td>2</td>
</tr>
<tr>
<td>Texas A&amp;M University</td>
<td>1</td>
</tr>
<tr>
<td>University of Arizona</td>
<td>1</td>
</tr>
<tr>
<td>University of Colorado</td>
<td>1</td>
</tr>
<tr>
<td>University of Kentucky</td>
<td>1</td>
</tr>
<tr>
<td>University of Maryland</td>
<td>6</td>
</tr>
</tbody>
</table>

Participants included African American/Blacks (11%), Asian American/Pacific Islander/Asians (28%),...
BESTEAMS team materials were adapted to the experiences of UM (~24,000 undergraduates). We planned multiple workshops on improving teamwork skills. Spread across the summer in three half-day workshops on campus, particularly in a university the size of Virginia and ensuring that students had transportation back to UM for training and other group activities.

**Student Training and Support**

It is extremely important to actively engage students from their first day on campus, particularly in a university the size of UM (~24,000 undergraduates). We planned multiple programs and training sessions to facilitate social and developmental interaction among the undergraduate Scholars.

While the core experience for SRT participants is involvement in the research experience itself with the benefit of several role models, students also attended periodic workshops on improving teamwork skills. Spread across the summer in three half-day workshops, the team training was conducted by BESTEAMS faculty and RISE staff. The BESTEAMS team materials were adapted to the experiences of women in STEM environments and included increasing awareness of subtle forms of discrimination in STEM environments and how to address these issues. Students also participated in sessions focused on applying to graduate school and creating a research portfolio.

Finally, students in both the FYSE and SRT programs were involved in a number of planned and informal social activities including a pool party, trips to Washington, D.C., and Baltimore. One faculty member invited her team to dinner so her team could experience the Maryland tradition of “cracking crabs.” Another faculty member took responsibility for her students’ housing in Virginia and ensuring that students had transportation back to UM for training and other group activities.

**Program Assessment**

The RISE assessment plan includes both qualitative and quantitative methodologies. In year one of the study, undergraduate students completed written surveys, participated in focus groups, and individual interviews. The faculty members, graduate students, and advanced undergraduates were evaluated using semi-structured interviews. Assessment is based on an iterative plan where feedback from the first year influences the program in subsequent years. Among our questions is the degree to which the predominately-female experience acts as a buffer, socializing agent, or source of support and learning, for female students in male dominated fields. The RISE SRT students’ team experience is being evaluated in terms of increasing satisfaction with, and sense of confidence in, their major and career choice, outcome expectations, and perceived barriers and supports using self-efficacy instruments designed by Dr. Robert Lent. In addition to self-efficacy measures, we are tracking student outcomes such as commitment to STEM fields (by following academic performance and persistence in STEM majors, graduation and increased confidence in an engineering career and/or desire to attend graduate school), and perceptions about women in science and engineering fields (e.g., observations concerning chilly climate issues, critical mass, strategies for effective role modeling) via post program interviews.

**RISE First Year Impact**

**RISE FYSE:** One of the instruments used in assessing the experience of the FYSE students was a post program satisfaction survey. All key activities were evaluated in terms of their value to the participants. The items rated 4 or above on a 5 point scale (5=High Value) included: “Activities designed to help you learn about the campus and its resources,” (M=4.7) “Activities to build team skills,” (M=4.1). “Networking activities,” (M=4.7), “Doing a community service learning project,” (M=4.1), and “Self defense training,” (M=4.7). RISE activities that received the
lowest rating included participating in the SRT Research Symposium (M=2.4); a personal identity clarification workshop (M=2.4) and an off campus industry tour (M=2.3). FYSE students appeared to be most positive about the program when it functioned as a bridge to a successful college experience. Issues related to the success of women in science and engineering appeared to be lower priorities as these young women transition to higher education.

Preliminary evidence of the impact of the program in terms of student success in college can be judged from the number continuing in their STEM majors and comparison of their grades with non-RISE participants. Table 2 refers to the academic achievement and persistence in STEM after one semester. Additional follow-ups are planned.

### TABLE 2

<table>
<thead>
<tr>
<th>First Semester Performance</th>
<th>RISE Eng</th>
<th>Non-RISE Eng</th>
<th>RISE CMPS</th>
<th>Non-RISE CMPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>average GPA</td>
<td>3.377</td>
<td>3.236</td>
<td>3.606</td>
<td>2.867</td>
</tr>
<tr>
<td>semester academic honors</td>
<td>35.3%</td>
<td>38.7%</td>
<td>71%</td>
<td>25.6%</td>
</tr>
<tr>
<td>% academic probation</td>
<td>0%</td>
<td>5.3%</td>
<td>0%</td>
<td>14%</td>
</tr>
<tr>
<td>% left engineering/comps</td>
<td>0%</td>
<td>5.3%</td>
<td>25.0%</td>
<td>25.0%</td>
</tr>
<tr>
<td>% changed into engr major from cmps</td>
<td>na</td>
<td>na</td>
<td>12.5%</td>
<td>12.5%</td>
</tr>
<tr>
<td>% left university</td>
<td>0%</td>
<td>1.3%</td>
<td>0%</td>
<td>unknown</td>
</tr>
<tr>
<td>% changed into engr major from undecided</td>
<td>11.8%</td>
<td>6.7%</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>% remained undecided engineering</td>
<td>35.3%</td>
<td>21.3%</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>% changed major into cmps</td>
<td>na</td>
<td>na</td>
<td>na</td>
<td>7%</td>
</tr>
<tr>
<td>% changed from major to undecided</td>
<td>0%</td>
<td>1.3%</td>
<td>na</td>
<td>unknown</td>
</tr>
</tbody>
</table>

As seen above, the RISE participants did well in their initial semester in college. In addition, a significant percentage (58%) continue to participate in ongoing RISE activities such working with the Women in Engineering Program to organize activities for an Inventions patch for local Girl Scout troops, as well as attendance at occasional seminars and social activities.

**RISE: SRT:** The assessment of SRT students was conducted in a focus group format based on their research teams (N=5 focus groups). As a result of these group interviews the following was learned: students viewed the strengths of their experience as meeting peers interested in STEM, working in a predominantly female environment, conducting “real research” and working with the faculty mentors and graduate students. One student noted in her interview that this was the first occasion she had ever worked with a woman faculty member in any context.

Articulated weaknesses of their experience included the length of time of the program (need more time to complete their experiments), less than desirable living arrangements, less than expected interaction with students from other research teams, lack of attention to training specifically in issues related to conducting experimental research, and the need for more direction and structure from their faculty mentors. These concerns are being addressed in the second year of the RISE program.

In terms of long term impact, a six month follow-up of these students is currently underway. Preliminary evidence based on the interviews completed thus far suggests that one of the largest impacts is in the area of commitment to STEM and the desire to attend graduate school. One student had been considering law school after completing a baccalaureate in engineering; now she is applying to a master’s degree in her field. Another had been dreading graduation, facing an entry level job as a “computer programming monkey.” After her experience with RISE, she sought out the additional experience of a mentor (using MentorNet) and now feels excited about the possibilities of having a job and the desire to pursue graduate education. A third student described her experiences for the University of Maryland Alumni magazine [12]. In her article, the student stated: “As I listened to the speakers at our orientation, I began to realize that RISE would be the support system I had been searching for.” (p 10). She ended her piece by saying the following (p.11): “When I signed up for RISE, I was originally hoping that it would be an extracurricular program that would look good on my resume. It turned out to be a life-changing experience and something that I wouldn’t trade for the world...The whole experience has pushed me to pursue a master’s degree, and possibly even a doctorate. Most important, I hope that I can be a mentor to others, just like those who have been so helpful to me.”

Finally, as a result of the SRT experience, several joint publications have been written by the research teams and their mentors (Kalnay, Prestegaard); one student continued her summer research experience into the academic school year with their faculty mentor, and one grant has been funded to extend work begun under the auspices of the RISE program (Brubaker and Pinker).

**CONCLUSION**

In terms of impact, we believe that the RISE model has the potential to bring some of the advantages of a predominately-female learning environment, epitomized by women’s colleges, into more mainstream higher education. Role model hierarchies, mentor training, and predominately-female research teams, are replicable features that can be adopted by a variety of institutions seeking to maximize the participation and success of female students in STEM fields. These features help address barriers to success in STEM:
lack of critical mass including few appropriate role models, the “chilly” climate for women, and the individual’s own internal barriers related to low self-efficacy and confidence. The one semester post program data presented here are largely positive. A longitudinal follow-up is planned.

Finally, the strategy of tailoring an intervention to the needs of the incoming first-year students by offering a supportive introduction to university life and a “jump start” relating to technical skills (FYSE) as well as providing an extended research experience in the later years of the undergraduate experience that involves close contact with successful woman scientists and engineers (SRT), is a programmatic approach that others may adapt to suit their own institutional contingencies and priorities.

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REFERENCES