Retaining Undergraduate Women in Science, Mathematics, and Engineering.

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The issue of women's underrepresentation in science, mathematics, and engineering (SM&E) fields in the United States, in both education and the workforce (Moore 2001; NSB 2002; NSF 2000, 2003, 2004a, 2004b), continues to be a theme in current research. In spite of substantial gains, gaps still exist between women and men in terms of their college-level enrollment in the SM&E majors. Women are still less likely than men to choose a career that involves SM&E, and are more likely than men to earn bachelor's degrees in nonscience and nonengineering fields. Among those who do choose a major in SM&E, the majority is still concentrated in certain fields such as biology, psychology, and the social sciences (NSF 2000, 2004a, 2004b).

Among the reform efforts in the United States, national initiatives often target K-12 education to encourage all students, but especially girls (and other disadvantaged groups), to participate more actively in science education (NRC 1996, 2000; NSF 2003). Although the rationale underlying these efforts has been to enhance students' interest in the sciences, these efforts are not as visible at the college level. According to Matyas (1992), few programs in the United States directly target female undergraduate students.

There is a small amount of research into the effects of undergraduate research and mentoring programs (Campbell and Skoog 2004), and course-based efforts (Atkin, Green, and McLaughlin 2002), suggesting that such programs are successful in increasing the representation of women in science. However, the bulk of these studies are descriptive in nature, and there is scant comparative information about the relative impact of these programs. For instance, Malcom's (1984) evaluation focuses on programs for enhancing K-12 females' access to and achievement in mathematics and science, and includes identifying criteria to assess the exemplariness of those programs. By contrast, in this research our focus is on comparing the retention of undergraduate women participating in an SM&E support and mentoring program with other, closely matched undergraduate students who are not in the support and mentoring program (nonprogram students). By comparing program and nonprogram students, our purpose is to examine the success and effectiveness these programs have.

The Program for Women in Science, Engineering, and Mathematics

Our research investigated the influence of a living-learning community established to encourage female college students to participate in the SM&E majors. The Program for Women in Science, Engineering, and Mathematics (PWISEM), founded in 2001 at a research university in the American southeast, targets undergraduates (particularly first-year students) to foster the participation of women in these fields, and enhance their retention.

Students enter the program in their first year and live together in an on-campus residence hall. While all first-year program students are required to reside in the hall, after their first year, women can remain in the program but reside elsewhere. In addition to a shared residence, which provides students with built-in study partners, program students have the opportunity to participate in a variety of PWISEM activities. The central formal activity of the program is a one-credit course entitled Women in Science Colloquium, in which women scientists from around the university come to the hall and describe their research. The
program also encourages SM&E success and retention through lectures, panel discussions, mentoring, advising assistance, research internships, tutoring, and field trips. Thus, the program places a premium on student interactions with faculty and with other students.

Research design

In this research, we employed the "static-group pretest-posttest design" (Fraenkel and Wallen 2003, p. 273), in which two already existing groups are used. We compared the PWISEM students with the Honors General Chemistry (HGC) students over the period of one academic year. HGC students were selected as a comparison group due to their similarities with PWISEM students; both groups were different from the general university first-year student population in that they were high-achieving students (as determined by their SAT scores and high school GPAs), and both groups intended to pursue SM&E majors. Their central differences included that the HGC group consisted of both males and females and that PWISEM students participated in activities.

Participants

There were 35 first-year PWISEM students involved in this research. Their ages ranged from 18 to 19, typical for first-year students. There were 63 HGC female and male students who participated in the study, and they had an age range of 17 through 21. In Table 1, we summarize students' intended majors as self-reported in the beginning of their freshman year.

TABLE 1

Number of PWISEM and HGC students in their intended SM&E majors.

<table>
<thead>
<tr>
<th>Intended majors</th>
<th>PWISEM</th>
<th>HGC men</th>
<th>HGC women</th>
</tr>
</thead>
<tbody>
<tr>
<td>Athletic training/sports medicine</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Biochemistry</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Biology</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
10
8
11

Biomedical engineering
1
0
0
0

Chemical engineering
1
1
2

Chemistry
1
2
1

Civil engineering
0
1
0

Computer engineering
0
1
0

Computer science
1
Electrical engineering

Engineering (undecided)

Environmental engineering

Exercise science

Mechanical engineering

Meteorology
<table>
<thead>
<tr>
<th>Field</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nursing</td>
<td>4</td>
</tr>
<tr>
<td>Physics</td>
<td>2</td>
</tr>
<tr>
<td>Science (undecided)</td>
<td>1</td>
</tr>
<tr>
<td>Undecided</td>
<td>0</td>
</tr>
<tr>
<td>Other</td>
<td>0</td>
</tr>
<tr>
<td>TOTAL</td>
<td>35</td>
</tr>
</tbody>
</table>

Note: The document includes a table with the distribution of fields across different categories.
Data collection and analysis

In this research we compared program and nonprogram students in terms of their interest, confidence, determination in pursuing one of the SM&E majors (CIRP 2000), views on science and scientists (NORC 2004), interest in, and understanding of science and technology (NORC 2004), GPAs, and intended/declared majors.

Because the HGC student group involved male students, it was possible for us to make cross-comparisons among the groups with respect to gender.

In order to measure these constructs, we developed a questionnaire with insight from two different instruments (CIRP 2000; NORC 2004). Each of these two instruments have established validity and reliability measures, which refer to the ability of "drawing correct conclusions based on the data obtained from an assessment" (Fraenkel and Wallen 2003, p. 158), and "the consistency of the scores obtained" (p. 165). The questionnaire included 23 items, which reflected the constructs described above, to be rated on Likert scales. In addition, we collected student demographic data in order to ensure that the same students took the pre- and posttests. Among these data were students' intended or declared majors. Data for which we did not have a pre/post pairing were discarded. We administered a pretest at the outset of the fall semester to both groups and the posttest was administered at the end of the academic year.

In our analysis, we recognized that there were three distinct groups within PWISEM and HGC: (1) the PWISEM students, (2) the HGC women students, and (3) the HGC men students. To compare the similarities or differences across the three groups, we performed one-way ANOVA (analysis of variance) for mean differences across the groups in the pretest, and then performed it again for the posttest. Here we used inferential statistics "to make judgments of the probability that an observed difference between groups is a dependable one or one that might have happened by chance" (Trochim 2000, p. 381).

Findings

The response rate of PWISEM students for the pretest was 100% (all of the program students completed the survey). HGC students had a response rate of 64%, meaning that 63 out of 99 students completed the survey. For the posttest, the response rate for PWISEM students was 94.3% (33 out of 35 students completed the survey). HGC students had a response rate of 60.3% (38 out of the 63 students who had completed the pretest completed the posttest). To increase the response rate of HGC students, we used an electronic version of the survey for those who did not return the hard-copy version or were absent in class during the distribution.

According to the results of the pre- and posttests, the three groups of undergraduate students-program women, nonprogram women, and nonprogram men-embodied no significant differences in terms of
interest, confidence, and determination to pursue one of the SM&E majors. They had significantly different scores on some of the items about views of science and scientists, as well as on select items that measured their interest in and understanding of science and technology. The most prominent difference among the groups was in their responses to the item asking for intended/declared majors in the posttest.

Similarity in interest, confidence, views of scientists

In terms of their interest and confidence in pursuing one of the SM&E majors, there were no significant differences either in the pretest or the posttest (Tables 2 and 3). Students were asked to rate their "current level of interest" and "current level of confidence" in pursuing a major in science, mathematics, or engineering on a 5-point scale, 1 being "low" and 5 being "high." All students across the three groups expressed almost the same level-4 out of 5-of interest and confidence both in the beginning and the end of the academic year. Although the difference in terms of interest among the groups was not significant, as seen in Table 2, there had been a decline in the interest mean scores of all three groups from the pretest to the posttest. The decline of interest was consistent for all groups and might indicate important implications, which we discuss later.

TABLE 2

Students' interest in SM&E in the beginning and at the end of the year.

<table>
<thead>
<tr>
<th></th>
<th>Pretest</th>
<th>Posttest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standard Deviation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standard Deviation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PWISEM students</td>
<td>4.40</td>
<td>4.36</td>
</tr>
<tr>
<td></td>
<td>0.70</td>
<td>0.96</td>
</tr>
<tr>
<td>HGC women students</td>
<td>4.45</td>
<td>4.17</td>
</tr>
<tr>
<td></td>
<td>1.06</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pretest</td>
<td>Posttest</td>
</tr>
<tr>
<td>----------------------</td>
<td>---------------------</td>
<td>---------------------</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td>3.94</td>
<td>3.94</td>
</tr>
<tr>
<td><strong>Standard Deviation</strong></td>
<td>0.80</td>
<td>0.91</td>
</tr>
</tbody>
</table>

* Confidence interval: 95%.

**TABLE 3**

Students' confidence in SM&E in the beginning and at the end of the year.

Pretest

Posttest

Mean

Standard Deviation

Mean

Standard Deviation

PWISEM students

3.94

0.80

3.94

0.91
We obtained students' cumulative GPA records for the academic year during which this research took place from the Office of Admissions and Records at the university. There was no significant difference in GPA across the three groups. All of the groups had GPA means above 3.30 (on a 4-point scale), an indication of their academic success.

In terms of their views of science and scientists, the three groups of students again were similar. However, there were differences regarding several items. For example, in the beginning of the academic year, PWISEM students were significantly more likely (confidence interval: 95%) to disagree that "scientists are apt to be odd and peculiar people," whereas HGC men students were more likely to agree [F(2, 95) = 5.53, p = 0.005]. Regarding this item on the posttest, students had similar responses, and tended to disagree. Also, PWISEM students were significantly more likely to disagree that "scientists are not likely to be very religious people" than the HGC men students in the beginning [F(2, 95) = 4.05, p = 0.021]; however, there was no difference at the end.

Regarding interest in and understanding of science and technology, in general, all students were alike. The only exception was in their interest in "issues about the use of new inventions and technologies." HGC men students were significantly more likely to be "very interested" in these issues than the HGC women group in the beginning of the academic year [F(2, 95) = 4.55, p = 0.013]. At the end of the academic year, all students expressed similar interest in the use of new inventions and technologies.
Differences in major choice

Although students were similar in terms of their GPA scores and interest in, confidence, and views of science and scientists, they were different in terms of major choice. According to the results of crosstabulation and a Chi-square test performed for students' intended/declared majors in the beginning of their freshman year, there was no statistically significant relationship among the groups (Table 4).

TABLE 4

Crosstabulation of students' major choices in the beginning of the academic year.

SM&E

<table>
<thead>
<tr>
<th></th>
<th>PWISEM students</th>
<th>HGC women students</th>
<th>HGC men students</th>
</tr>
</thead>
<tbody>
<tr>
<td>SM&amp;E students</td>
<td>93.5% (29)</td>
<td>76.9% (20)</td>
<td>86.2% (25)</td>
</tr>
<tr>
<td>NonSM&amp;E students</td>
<td>0% (0)</td>
<td>11.5% (3)</td>
<td>0% (0)</td>
</tr>
<tr>
<td>Undecided</td>
<td>6.5% (2)</td>
<td>11.5% (3)</td>
<td>13.8% (4)</td>
</tr>
<tr>
<td>TOTAL</td>
<td>100.0% (31)</td>
<td>100.0% (26)</td>
<td>100.0% (29)</td>
</tr>
</tbody>
</table>

* Confidence interval: 95%, nonsignificant relationship.
In the beginning of the academic year, the majority of students from all three groups intended to pursue an SM&E major (93.5% of the PWISEM students, 76.9% of the HGC women students, and 86.2% of the HGC men students). Noticeably, at the beginning of the year there were no students from either the PWISEM or the HGC men student groups who wanted a nonSM&E major, while 11.5% of the HGC women students were in this category.

However, at the end of the same academic year, there were more students deciding for a nonSM&E major, and this was particularly true for the nonprogram women group (Table 5). Moreover, according to the results of the crosstabulation and Chi-square test, the relationship among the groups and their declared majors was significant, $\chi^2(4, N = 86) = 9.618, p = 0.047$. At the end of the academic period, a considerable number of HGC women students (30.8%) and HGC men students (13.8%) declared a nonSM&E major.

Also, compared with the beginning of the academic year, there were fewer students in the undecided category from both the HGC women and HGC men groups. Namely, more students from these groups decided on the major they wanted to pursue, but most of these students decided not to have an SM&E major. In other words, after one year, significantly more PWISEM students remained in the SM&E fields than students in either of the HGC groups.

**TABLE 5**

Crosstabulation of students' major choices at the end of the academic year.

<table>
<thead>
<tr>
<th></th>
<th>SM&amp;E</th>
<th>NonSM&amp;E</th>
<th>Undecided</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>PWISEM students</td>
<td>90.3%</td>
<td>3.2%</td>
<td>6.5%</td>
<td>100.0%</td>
</tr>
<tr>
<td></td>
<td>(28)</td>
<td>(1)</td>
<td>(2)</td>
<td>(31)</td>
</tr>
<tr>
<td>HGC women students</td>
<td>69.2%</td>
<td>30.8%</td>
<td>0%</td>
<td>100.0%</td>
</tr>
<tr>
<td></td>
<td>(18)</td>
<td>(8)</td>
<td>(0)</td>
<td>(26)</td>
</tr>
<tr>
<td>HGC men students</td>
<td>69.2%</td>
<td>30.8%</td>
<td>0%</td>
<td>100.0%</td>
</tr>
<tr>
<td></td>
<td>(18)</td>
<td>(8)</td>
<td>(0)</td>
<td>(26)</td>
</tr>
</tbody>
</table>
Conclusions

The women support and retention program at the center of this study (PWISEM) was successful in retaining female students in their intended SM&E majors. When compared with nonprogram students, program students were more likely to choose an SM&E major. This difference is interesting given that there was no significant difference among the groups in terms of their interest, confidence, or academic potential (as measured by SAT and GPAs). In other words, all of the undergraduates involved in this study were interested and confident in pursuing SM&E, they had similar views about science and scientists, and similar interests in and understandings of science and technology, but more program students decided to remain in SM&E after their first year at college. Thus, this research adds to the call for support programs or orientation courses directed toward women.

There is clear indication that factors other than interest or confidence play a major role in students' decisions to be involved in SM&E. As other research has reported, supportive environments, close student-faculty/scientist relationships (Meyer 2002), opportunities for research experiences, mentoring, and academic networking (Atkin, Green, and McLaughlin 2002; Campbell and Skoog 2004; Downing, Crosby, and Blake-Beard 2005), and teacher attitudes (Cutler 2004; Friedman 1999), may be fundamental factors in PWISEM's success. These factors are also among the three success criteria-strong academic emphasis, multiple strategies, and a systems approach-developed by Stage et al. after their evaluation of such programs (Stage et al.'s study, as cited in Fraser and Walberg 1995). Further research in examining and assessing programs designed for undergraduate women may suggest other criteria and strategies for development and improvement.

The profile of students involved in this study suggests that there is need for concern about the retention of both men and women in SM&E majors. The consistent decline in the interest of all students (Table 2) is another aspect that brings into question the SM&E culture itself. As Seymour suggests, "some aspects of the learning environments in which many women feel most comfortable-particularly those which are interactive, cooperative, experiential, and learner-focused-are also congenial to many young men" (1995, p. 470). Seymour also suggests that changing the pedagogy from a teacher-centered to a learner-centered approach promises to reduce the loss of both women and men students from the SM&

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