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Retaining first-year women in science and engineering through research internships

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ABSTRACT: The programme called Women in Science and Engineering Research (WISER) is a research internship programme for first-year women in engineering and science at the Pennsylvania State University (PSU), University Park, USA. The programme places each participating first-year student in a laboratory setting, which is typically headed by a female faculty mentor. This article describes a novel assessment of the impact of the WISER programme on the retention of women in traditionally underrepresented science and engineering majors. For each WISER intern, two *virtual twins* were selected from the university student database, one male and one female. The virtual twins were selected to be similar to the WISER intern based on key characteristics. The assessment involved a statistical evaluation of the progress of this cohort through their undergraduate careers. The results have shown that WISER interns were more than twice as likely to remain in a science or engineering major than their virtual twins. It is acknowledged that WISER interns are self-selected participants in the programme and may differ in some characteristics from their comparison groups. However, the results also reflect the positive impact of the WISER programme.

INTRODUCTION

The Women in Science and Engineering Research (WISER) programme was designed to improve the retention of female undergraduate students in science and engineering majors at the Pennsylvania State University (PSU), University Park, USA.

After the WISER programme had been underway for four years, an assessment was undertaken in order to evaluate whether or not the programme had an impact on retention. In this context, *retention* is defined as the persistence of a student within a science and engineering major during the period of observation of this study. In this article, the authors present and interpret the results of this assessment.

Rationale for Increased Retention in Science and Engineering Majors through the WISER Programme

The WISER programme was shaped by results from research on the problems in recruiting and retaining women in science and engineering majors. The early literature that focused on these problems identified the obstacles that women face and revealed the different needs of female students in science and engineering majors, as compared to their male student counterparts [1-9].

Seymour and Hewitt interviewed male and female undergraduate students with interests in science and engineering [7]. Their ethnographic evaluation of these interviews led them to conclude that female students, more than their male counterparts, wanted to have social relationships to connect them to their major, and that they were more concerned about the lack of encouragement to persist in their majors. Women were also found to prefer collaborative environments and to be more likely than men to have altruistic career goals.

Efforts to raise the participation of women in the engineering, mathematics and science fields have been underway for about two decades. The Programme for Gender Equity, developed by the National Science Foundation (NSF), identified core strategies in order to increase the low numbers of girls and women in science and engineering majors [10]. These include:

- Mentor/role modelling;
- Extracurricular activities;
- Summer camps;
- Professional development for educators;
- Activities for parents.

Campbell et al recommended intervention programmes. They specifically identified undergraduate research and internship programmes as a key strategy to retain women in engineering and science [1].

Undergraduate research, which provides a group setting with other undergraduate and graduate students and faculty mentors, meets the social relationship requirement. The same research environment is funded in order to meet societal needs, and the students can also gain a measure of ownership of the knowledge generated in that environment by working there. It also makes some of their coursework meaningful as they can see what they need to learn in order to contribute more to the research agenda.

Intervention in the first year appears to be critical because this is the year with the highest dropout rate for science and engineering majors [9].

Description of the WISER Programme

WISER was initiated by the Pennsylvania Space Grant Consortium [15]. This programme fulfilled part of the mandate

from the National Aeronautics and Space Administration (NASA) to attract and retain students from underrepresented groups in engineering and science majors. Karen Wynn developed the WISER programme while she was Assistant Director of the Space Grant Consortium. WISER provides first year students access to cooperative research work in the laboratory and informal mentoring from faculty and graduate students, most of whom are women.

The WISER programme was modelled after a successful programme at Dartmouth [11]. Within the first semester of their arrival at the University, all female undergraduate students with intended majors in science or engineering receive a letter inviting them to apply to the WISER programme. Students are selected after a series of interviews, including interviews with potential faculty mentors. Faculty mentors have research programmes in the science and engineering disciplines and are selected on the basis of their interest and support of the WISER programme goals. The WISER programme supports the student's participation with a faculty mentor for two semesters, beginning with the second semester of the student's first year. The student's participation is supported with a combination of academic credit and direct wage payment.

In the first five years of the programme (1994-1999) at the PSU, about 250 first year female students were placed in research laboratories in the science and engineering fields. The programme is still ongoing in 2003 and places 30-40 first-year women undergraduates in research laboratories each year.

Regular evaluation and consultation with WISER interns and their faculty mentors have indicated that the programme has effectively provided a good learning and coping environment for women students in science and engineering courses and that interns were very satisfied with their experiences. One indication of this level of satisfaction involves cases where WISER students continued to participate in their mentors' laboratories for additional semesters.

THE IMPACT OF THE WISER PROGRAMME ON RETENTION: THE METHOD OF ASSESSMENT

The authors assessed the impact of the WISER programme on retention in science and engineering majors during its first four years of operation (1994-1997). The purpose was to determine whether or not the WISER students had increased retention in science and engineering majors in comparison to a similar group that had not participated in the WISER programme.

In this study, the authors defined *retention* to be the persistence of a student in a science and engineering major. If a student stayed in the same science and engineering major, or if he/she changed majors but remained within an science and engineering major, then that student was classified as *retained within a science and engineering major*. If a student changed from an science and engineering major to a non-science and engineering major, then that student was classified as *shifted out of science and engineering major*.

Selection of Groups for Assessment

The WISER group consisted of 96 science or engineering majors who were WISER interns in 1994, 1995 or 1996. For the purposes of comparison, two control groups were selected from the University's electronic data warehouse. One control group was comprised of 96 males and the other control group consisted of 96 females. These students had also indicated an science and engineering major upon their enrolment but did not participate in the WISER programme. They were selected to be similar to the WISER interns in terms of age, year of entry, academic college, ethnicity, college-entrance Scholastic Aptitude Test (SAT) score and certainty of major.

The two control groups are referred to as the *virtual twins* of the WISER interns because each intern was matched with a male and female student from the University data warehouse by virtue of their shared characteristics. For each WISER intern, the female virtual twin was identified by an electronic search of the data warehouse for another student who had the following characteristics:

- Was 17-22 years old;
- Started in the same year and semester as the WISER intern;
- Entered the same college as the WISER intern;
- Was in the same ethnic group;
- Had SAT mathematics and verbal scores within 20 points of the WISER intern's score.

A final criterion, certainty of major, was used in cases where a WISER intern had more than one potential match after employing the first five matching criteria. Data on the certainty of major was taken from the Educational Planning Survey (EPS), a questionnaire that was administered to all incoming PSU freshmen. Students were asked to indicate certainty of major by selecting one of the following fields: *completely certain*, *slightly uncertain*, *50-50*, and *very uncertain*. The same procedure was also used to identify the male virtual twin.

Assessment of the Groups

A retrospective evaluation of the available student records of WISER students and their virtual twins was conducted to cover up to six semesters. Students in these groups entered their science or engineering programmes in autumn 1993 to autumn 1995. Their academic majors were tracked by analysing electronic student records in the data warehouse from the time that the students entered the University up to spring 1997. This end-of-study date, along with other factors such as departure from the University and leaves of absence, resulted in a variable number of semesters of data that were available for each student. All of the 96 subjects in each group were tracked for at least two semesters, slightly less (92-94) for at least four semesters, and less than half (41 or 42) for six semesters or more (see Table 1).

Table 1: Number of semesters of data available for each group in the assessment.

Group	Number of Semesters Available				
	2	3	4	5	6 or more
WISER	96	96	94	70	42
Female Control	96	92	92	60	41
Male Control	96	96	93	59	42
Total	288	284	279	189	125

For the available semesters, data from each subject's academic major and academic college were recorded every semester; any changes in major were also noted. If a change in major resulted in a shift out of the science or engineering curriculum, this was

classified as attrition, or a shift out of a science and engineering major.

From these observations, the following variables were derived:

- The number of students who changed majors each semester;
- The number of students who shifted out of a science and engineering major each semester;
- The number of semesters that a student stayed in his/her major;
- The number of semesters that a student stayed in the science or engineering curriculum.

These items form the basis for this comparison of retention in science and engineering majors between the three groups in the study.

Summary tables and graphs were developed to depict and compare student changes of major within science and engineering and changes to majors outside of science and engineering by group and by semester. Odds ratios were computed in order to compare the relative probabilities of retention among the WISER interns and the two control groups. In order to test the research hypothesis that the WISER programme increased the probability of remaining in a science and engineering major, odds ratios were evaluated statistically with the large-sample approximating normal distribution [12].

The length of time that each group stayed in their majors and in science and engineering majors was compared. The research hypothesis that the WISER group would remain longer in the science and engineering majors was tested with Friedman's test [13]. Each *triplet* formed by a WISER intern and the male and female virtual twins was defined as a block for the analysis with Friedman's test. Within each block, the retention within a major (the number of semesters that the student spent in the major) was ranked, with a rank of 1 assigned to the first student who changed major. Ranks were averaged in case of ties. A similar set of rankings was generated for retention in science and engineering majors. Significant P-values ($P < 0.05$) from the Friedman's test were followed up with comparisons between the WISER group and each of the two control groups using Dunn's method [13].

RESULTS: THE IMPACT OF THE WISER PROGRAMME ON RETENTION

The WISER students in this assessment appeared to be fairly typical of all engineering and science majors in terms of SAT scores, with an average of 629 in mathematics and 563 in verbal, for the first five years of the programme.

Based on their responses to a questionnaire administered to all incoming PSU freshmen, about 20% of the WISER students in the study were completely certain of their major, 35% were slightly uncertain, 34% were *50-50*, while 12% were very uncertain.

Changes in Major: Both within Science and Engineering and to Majors Outside Science and Engineering

Of the 96 students in each group, 30 (31.2%) former WISER interns, 38 (39.6%) female controls, and 37 (38.5%) male controls changed their academic majors during the study period. These raw percentages cannot be interpreted directly as a rate of change because of the variable number of semesters recorded for each student (from two to eight semesters). For this reason, the groups for each semester are reported and compared separately in Table 2.

For the two control groups, the highest rate of change occurred during their third semester (15.6% for the male control group and 18.5% for the female control group; Table 2). The percentage that changed majors in the other semesters, including semester six and beyond, ranged from 5-10%. Among WISER interns, however, rates were highest during semesters four (12.8%) and five (10%). After this, only one out of 42 WISER interns (2.4%) still changed her major.

Table 2: Rate of change in major (either within science and engineering or to a major outside science and engineering), by semester.

Change in Major by Semester						
Group	2	3	4	6	6 or later	Total
WISER	3	7	12	7	1	30
	3.1%	7.3%	12.8%	10.0%	2.4%	
Female	6	17	9	3	3	38
Control	6.2%	18.5%	9.8%	5.0%	7.3%	
Male	7	15	7	4	4	37
Control	7.3%	15.6%	7.5%	6.8%	9.5%	

Note: Percentages are based on the number of students that were tracked for a given semester (see Table 1).

Figure 1 shows the cumulative percentage change across semesters. From this data, the proportion of students in each group with a change in major after six semesters was estimated, if data for the full six semesters had been available for all students in the study. It was estimated that 35.6% of WISER interns would have a change in major after six semesters, compared to 46.8% of their female virtual twins, and 46.7% of their male virtual twins.

Utilising the estimated percentages shown in Figure 1, the odds that a WISER intern would stay in her major rather than switch was estimated as being 1.81:1. This means that a WISER intern was 1.81 times more likely to stay in her major than to switch. In contrast, her female virtual twin was estimated to have odds of 1.14:1 between staying versus switching. This value is close to the even odds value of 1.0, which corresponds to equal probability between staying and switching.

The male virtual twins have the same odds (1.14) as the female virtual twins (the non-WISER control group). The ratio of 1.81 to 1.14 is 1.59, which is defined as the odds ratio. This odds ratio has a P-value of 0.058, which is considered *borderline* level of statistical significance. From this assessment, it can be concluded that there is a possible trend in the evidence that suggests a WISER intern is more likely to stay in her major than either of her virtual twins.

An important difference, as shown in Table 2, was found in the semester in which students from each group changed their academic majors. The two control groups did so earlier, and continued even after the fifth semester. When the WISER interns changed majors, they did so on the fourth or fifth semesters, and there was almost no shifting observed after the fifth semester.

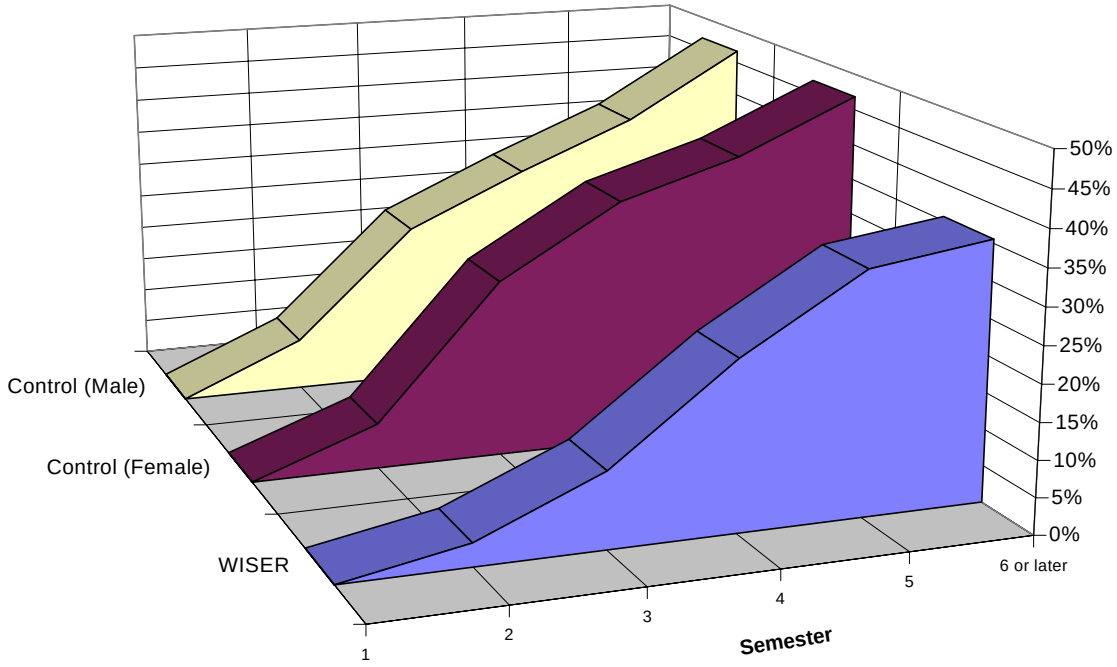

Figure 1: Cumulative percentage changes in major, both within and outside science and engineering, for each group in the study. Percentages are adjusted to allow for a variable number of semesters observed for each student.

Retention in Science and Engineering Majors (Either Remaining in the Same Major or Shifting Majors within Science and Engineering)

Some of the changes in study major, shown in Table 2, were shifts within science and engineering majors. Figure 2 shows the subsets of students who changed majors while staying in science and engineering majors. It appears that this type of shifting occurred at similar rates across the three groups, with highest rates observed in semesters 3 and 4. However, Table 2 shows that in the third semester, WISER interns changed majors at less than half the rate among the control groups (7.3% for WISERs, 18.5% for the female control group, 15.6% for the male control group). Since the three groups shifted majors within science and engineering at about the same rate, this means that the increased rates among the control groups were more likely to represent shifts out of science and engineering majors.

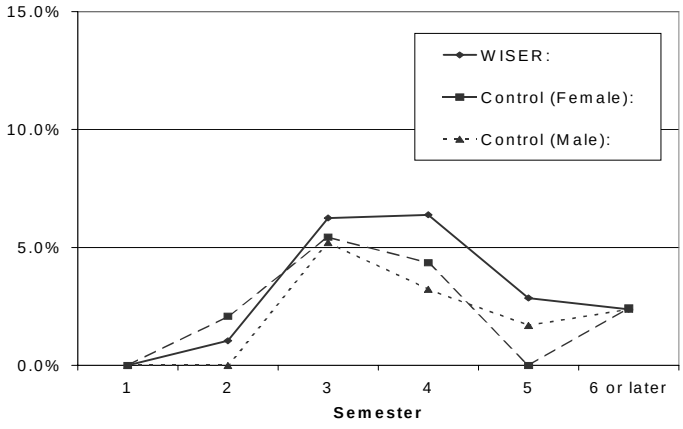

Figure 2: Percentage changing majors within science and engineering by semester.

Changes in major that were not shifts within science and engineering therefore resulted in attrition from science and engineering majors. Of the 96 students in each group, 14 (14.6.2%) former WISER interns, 26 (27.1%) female controls and 27 (28.1%) male controls shifted out of science and engineering majors during the study period. Table 3 gives the semester summary of attrition rates; these are plotted in Figure 3.

Table 3: Rate of shift from science and engineering major by semester.

Semester When Shift from Science and Engineering Major was Made						
Group	2	3	4	5	6 or later	Total
WISER	2	1	6	5	0	14
	2.1%	1.0%	6.4%	7.1%	0.0%	
Female	4	12	5	3	2	26
Control	4.2%	13.0%	5.4%	5.0%	4.9%	
Male	7	10	4	3	3	27
Control	7.3%	10.4%	4.3%	5.1%	7.1%	

Note: Percentages are based on the number of students that were tracked for a given semester (see Table 1).

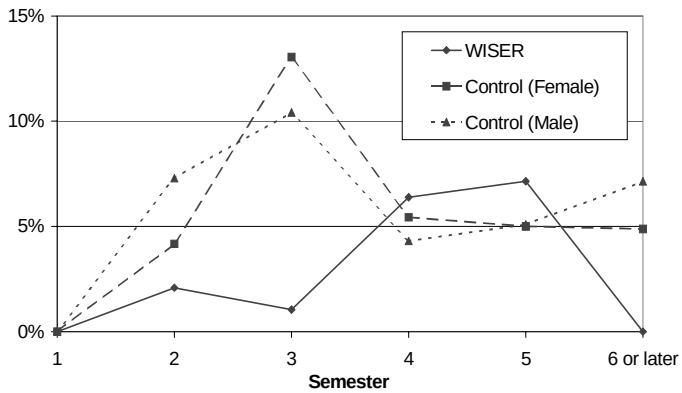

Figure 3: Percentage shifting out of science and engineering majors by semester.

For the two control groups, shifting from science and engineering majors peaked in the third semester. WISER

interns were participating in their internship during semesters two and three, and only three interns made such a move. Only later, during semesters four and five (after the WISER programme ended), did WISER interns shift out of science and engineering majors at significant rates. Beyond the fifth semester, none of the 42 WISER students studied shifted out of science and engineering majors, while some of their male (7.1%) and female (4.9%) virtual twins continued to do so. It appears that the programme supported WISER interns at a time when students were more likely to contemplate shifting out of their science and engineering major.

In terms of cumulative percentage shift from science and engineering majors (Figure 4), both male and female control groups appeared to shift out earlier (second year) and at higher rates than the WISER group, and continued to do so even during their third year. In contrast, WISER interns who dropped out of science and engineering majors did so mostly at the end of their third year and beginning of the fourth year. After this, no additional attrition was observed among the remaining WISER interns.

By accumulating the attrition rate for each semester, it is estimated that 16.6% of former WISER interns would have left science and engineering majors, compared to 32.5% and 34.2% of their female and male virtual twins, respectively. Based on these rates, the estimated odds of staying in a science and engineering major versus switching is 5.02 among WISER students, 2.08 among the female control group, and 1.92 among male control group. This means that a WISER intern was about five times more likely to stay in a science and engineering major than to switch.

In comparison, the matching groups of female and male control groups were about two times more likely to stay in a science and engineering major than to switch. The odds ratio for the WISER group versus the female control group is 2.41 (Z=2.51, P=0.006); compared with the male control group, the odds ratio is 2.61 (Z=2.75, P=0.003). Both odds ratios are highly significant, indicating strong evidence that WISER interns were more likely to stay in a science and engineering major than either of the control groups.

WISER interns had significantly greater retention in science and engineering majors than the male and female control groups. The increased retention is statistically significant both for retention within the originally selected science and engineering major and for switches between science and engineering majors ($P < 0.05$; see Tables 4 and 5). The male and female control groups were not significantly different from each other in these measures of retention ($P > 0.05$; see Tables 4 and 5). Figures 1 and 3 indicate that the male and female control groups shifted majors and left science and engineering majors earlier and at higher rates than the WISER group.

Table 4: Results of the Friedman test and multiple comparison procedures applied to number of semesters in the same major.

Group	Estimated Median	Average Rank	Test Statistic
WISER	4.67	2.28	M = 14.50 (adjusted for ties) df=2, p=0.001
Female Control	4.33	1.88*	
Male Control	4.00	1.83*	

* Significantly different from WISER mean rank at p=0.05.

DISCUSSION

The results show that the WISER programme had the effect of consistently reducing the attrition of women from science and engineering majors. It did not appear to affect the amount of switching *within* science and engineering, where switching may be understood to be a refinement of choice by these young students, rather than a repudiation of their original goals.

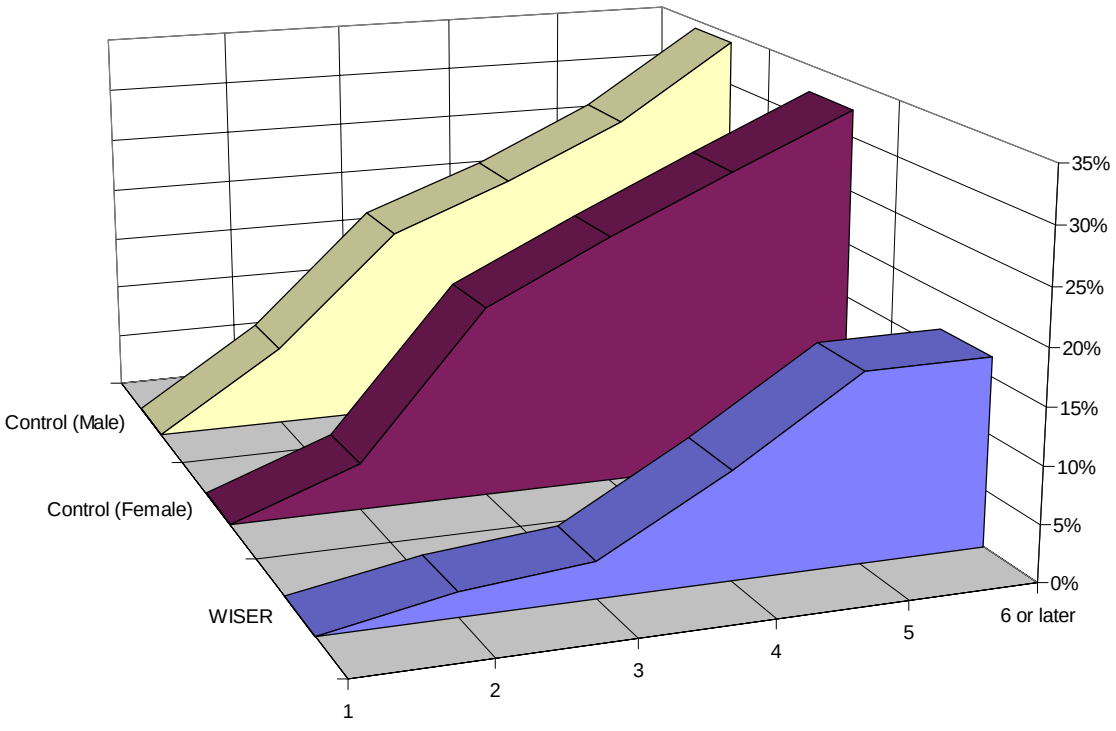

Figure 4: Cumulative percentage shift out of science and engineering majors by group.

Table 5: Results of the Friedman test and multiple comparison procedures applied to number of semesters in science and engineering majors.

Group	Estimated Median	Average Rank	Test Statistic
WISER	5.00	2.31	M = 19.02 (adjusted for ties) df=2, p<0.001
Female Control	4.67	1.91*	
Male Control	4.33	1.78*	

* Significantly different from WISER mean rank, p<0.05.

The WISER programme, offered in the second and third semesters, appears to be very well timed. Non-WISER students began to switch out of science and engineering in the second semester and the attrition rate was highest during the third semester (10.4% and 13% among male and female students, respectively). In contrast, only one WISER (1%) switched out of her science and engineering major in the third semester, and subsequent switching after the internship was similar to, or lower than, non-interns. Thus, the programme appears to have provided a supportive environment at a time when science and engineering students would typically be contemplating moving out of the science and engineering major.

The findings reported in this study are consistent with results from the study by the National Centre for Education Statistics on entry and the persistence of women and minorities in college science and engineering education [14]. In this study, completion of a science and engineering major was significantly and positively associated with, among other factors, intellectual self-confidence and financial aid. The WISER programme did provide some financial aid and it would be reasonable to deduce that the interns' interactions with women faculty staff and graduate students could have contributed to boosting self-confidence in their intellectual ability to pursue science and engineering.

The increased retention among WISER students, in comparison with their virtual twins, may be partly explained by motivational or other factors that led them to apply to, and participate in, the programme. However, it is not believed that students consciously entered WISER to help their retention prospects. Instead, the authors believe that these students were interested in research and probably the social aspects that go with it. Without the WISER programme, they would still also be without the social bonding and mentoring that research in this field indicates would be helpful in retention. Furthermore, the impact was broadly based, with a focus on retention in science and engineering fields overall, rather than retention in the first major that a student identified.

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