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ABSTRACT

Many are aware that factors other than academic talent help to determine a student's success or failure in school A 4-year longitudinal study including 87 men and 34 women at North Carolina State University examines gender differences in students' academic performance, persistence in chemical engineering, and attitudes toward their education and themselves. Although the pre-engineering academic credentials of women entering college often exceeded those of men, these women did not score any higher in technical classes than men. Women students also attributed poor performance to their lack of ability, while men usually attributed it to lack of hard work or being treated unfairly. The critical question of why these women earned lower grades in chemical engineering courses and exhibit lower confidence levels of themselves could not be answered with any real degree of certainty; however, the following measures were suggested to help circumvent the disadvantage of women relative to men entering engineering school: (1) provide engineering students with female role models/mentors; (2) strengthen organizations that can provide career guidance and emotional support to women students; (3) use cooperative learning in engineering courses; and (4) educate professors and academic advisors to the problems and needs of women students. (ZWH)

A Longitudinal Study of Engineering Student Performance and Retention

GENDER DIFFERENCES IN STUDENT PERFORMANCE AND ATTITUDES†

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GENDER DIFFERENCES IN STUDENT PERFORMANCE AND ATTITUDES

EXECUTIVE SUMMARY

A longitudinal study of chemical engineering students has been under way at North Carolina State University since the Fall of 1990. One of us (RMF) taught a sequence of chemical engineering courses in five consecutive semesters, using extensive cooperative (team-based) learning, assignment of open-ended problems and problem formulation exercises, and other techniques designed to address the spectrum of learning styles found in all engineering classes. Data were collected for 87 men and 34 women in the experimental cohort. The first of two previous reports on the study[1] described the performance of the experimental cohort in the introductory chemical engineering course and summarized correlates of success and failure in that course. The second report[2] compared outcomes for students from rural and small-town backgrounds with outcomes for students from urban and suburban backgrounds. This report examines gender differences in the students' academic performance, persistence in chemical engineering, and attitudes toward their education and themselves.

The backgrounds and pre-engineering academic credentials of the women in the study marked them as more likely to succeed than the men. Their parents were on average more highly educated—84% of the women's fathers and 64% of their mothers had college degrees, as compared with 57% of the men's fathers and 48% of their mothers—and had received more training in science and mathematics. The women scored equally well or better than the men on precollege admission tests. *Learning and Study Strategies Inventory* (LASSI) results indicated that the women were more highly motivated to study and made better use of study aids.

Nevertheless, the women did no better than the men throughout college except in nontechnical courses. Men and women did equally well in overall GPA and pre-engineering mathematics and science courses, and the men generally outperformed the women in chemical engineering courses, both in average grade and in the percentages receiving A's. The percentage of men earning A's in two of the experimental courses was more than twice the percentage of women doing so.

[1]Felder, R.M., K.D. Forrest, L. Baker-Ward, E.J. Dietz, and P.H. Mohr, "A Longitudinal Study of Engineering Student Performance and Retention. I. Success and Failure in the Introductory Course," *J. Engr. Education*, *82*(1), 15-21 (1993).

[2]Felder, R.M., P.H. Mohr, E.J. Dietz, and L. Baker-Ward, "A Longitudinal Study of Engineering Student Performance and Retention. II. Differences Between Students from Rural and Urban Backgrounds, *J. Engr. Education*, in press.

Of the students who had intended to major in chemical engineering when they began the first course, the percentage of women who dropped out for any reason after the sophomore year was twice the percentage of men dropping out (16% of the women vs. 8% of the men). The percentages dropping out by the end of the senior year were closer (23% of the women and 19% of the men), with relatively more women transferring into other curricula and more men dropping out of school or being suspended. Throughout the period of the study, men who failed a chemical engineering course were more likely than women to repeat the course and remain in the curriculum, while women who failed a course were more likely to switch out of chemical engineering. Of those who persisted in the curriculum, men were significantly more inclined than women to express an intention of going to graduate school.

The women in the study entered the engineering curriculum with greater anxiety and lower confidence in their preparation than did the men. They began the first course with higher expectations of themselves, but by the midpoint of the first chemical engineering course their expectations were lower and the disparity persisted throughout the curriculum. The women were more likely than the men to attribute poor performance to their own lack of ability and the men were more likely to attribute it to a lack of hard work or being treated unfairly. Conversely, the men were more likely than the women to attribute success to their ability and the women more likely to attribute it to outside help.

The men consistently expressed higher self-assessments of their abilities to solve basic engineering problems, problems that required creativity, and computer problems. The gender difference in self-assessed ability to solve problems creatively became more pronounced as the students approached graduation. When considering their prospective jobs, the women were much more concerned than the men about maintaining good relationships with coworkers and employers and the men were more concerned about having challenging problems and doing creative work.

Cooperative (team-based) learning was a major component of the experimental course sequence and was viewed positively by both men and women but more so by the women; however, the women were also significantly more likely to feel that their contributions were undervalued by other group members. When asked what they perceived to be the greatest benefit of group work, the men were much more likely to say they benefitted from explaining the material to others while the women were more likely to cite having the material explained to them.

The critical question is, *why* did the women in the study—whose qualifications were arguably better than those of the men when they entered the chemical engineering curriculum—earn lower grades in chemical engineering courses and exhibit lower confidence levels and expectations of themselves as they progressed through the curriculum? Observations in the literature and results from this study suggest several possible explanations: (1) Uncertainties in the students' minds about the suitability of women to be engineers; (2) mismatches between characteristic instructional styles of engineering professors, which stress theory over applications, individual work, and competition for grades, and characteristic learning styles of women students; (3) anti-female bias on the part of faculty instructors and advisors; (4) discounting by male classmates, including (and perhaps especially) in cooperative learning groups; (5) a tendency of women to be passive in cooperative learning groups; (6) lack of female role models in engineering school. In addition, men and women might attach different relative priorities to schoolwork and personal relationships when both compete for their limited time.

Whatever the reasons for the observed gender disparities, the weight of evidence suggests that women in engineering school are operating at a disadvantage relative to men, and that American industry and academia are losing valuable talent as a consequence. We believe that the following measures could improve their situation.

1. *Provide engineering students with female role models and mentors.* Bringing many more women onto engineering faculties is a desirable goal, but one that can only be achieved after many years, given the relatively small number of women currently in the pipeline. Peer mentoring, wherein female graduate students and upperclass undergraduates provide guidance and support to first- and second-year undergraduate women, is another possible mechanism that could be equally effective and can be achieved quickly.

2. *Strengthen organizations that can provide career guidance and emotional support to women students, such as student chapters of the Society of Women Engineers, and encourage participation in these organizations.*

3. *Use cooperative learning in engineering courses, structured to provide equal benefits to men and women.* Women respond positively to a classroom environment based on cooperation rather than competition; however, the tendency of some women to take less active roles than men in groups and that of some men to discount women's contributions can work against the women. When mixed groups are formed, the need to elicit and seriously consider contributions from *every* group member should be stressed, and the groups should regularly be required to assess their success in this regard. It might also be worthwhile to experiment with cooperative study groups containing only women.

4. *Educate professors and academic advisors to the problems and needs of women students.* All faculty members should be made aware of the difficulties faced by women engineering students and of the resources on campus—support groups, mentorship programs, and trained counselors, etc.—available to help the women cope with and overcome these difficulties.

A Longitudinal Study of Engineering Student Performance and Retention

GENDER DIFFERENCES IN STUDENT PERFORMANCE AND ATTITUDES

A longitudinal study of chemical engineering students has been under way at North Carolina State University since the Fall of 1990. One of us (RMF) taught a sequence of chemical engineering courses in five consecutive semesters, using extensive cooperative (team-based) learning, assignment of open-ended problems and problem formulation exercises, and other techniques designed to address the spectrum of learning styles found in all engineering classes. The hypothesis is that the students participating in this program will persist in chemical engineering through graduation to a greater extent, earn higher grade point averages in engineering, and develop more positive attitudes about engineering and about their own capabilities than do students who go through the traditionally-taught curriculum.

In the first semester of the study, data were collected on the students including (a) population demographics, (b) SAT scores (mathematics and verbal examinations), (c) admissions index (a predicted grade point average calculated for entering freshmen based on SAT scores and high school performance records), (d) freshman year grade point average and grades in selected freshman courses, (e) profiles on Self-scorable Form G of the *Myers-Briggs Type Indicator*, a widely-used instrument that assesses positions on four scales derived from Carl Jung's theory of psychological types, (f) profiles on the *Learning and Study Strategies Inventory*, an instrument that assesses students' test-taking skills and strategies, motivation to learn, and anxiety levels, and (g) responses to questionnaires regarding family and educational background and motivations for choosing to major in engineering. In addition, the students in each of the experimental courses were questioned about self-expectations, confidence levels, and a wide variety of attitudes and reactions.

The first of two previous reports on the study [Felder *et al.*, 1993] described the performance of the experimental cohort in the introductory chemical engineering course and summarized correlates of success and failure in that course. The second report [Felder *et al.*, in press] compared outcomes for students from rural and small-town backgrounds with outcomes for students from urban and suburban backgrounds. This report examines gender differences in the students' academic performance, persistence in chemical engineering, and attitudes toward their education and themselves.

WOMEN IN ENGINEERING: FALLING INTO THE GENDER GAP

The percentage of women enrolled in engineering curricula was almost negligible for the first six decades of this century, began to rise in the early 1970's and early 1980's, and then leveled off, with the actual number enrolled declining after 1986 [Brush, 1990].

In 1992, women accounted for 15.0% of B.S. degrees, 14.8% of M.S. degrees, and 9.7% of Ph.D. degrees in engineering. The gender gap in the engineering profession is even more dramatic: women make up roughly 50% of the general population and 44% of the United States work force, but as of 1988 they represented only 4% of practicing engineers [Morgan, 1992].

Since the number of white males of college age is expected to drop significantly in the future, steps must be taken to attract and retain more women in engineering curricula [Widnall, 1988]. The obstacles to doing so are formidable, however. From an early age, women are told—subtly or overtly—that science and mathematics are not for them. Some get this message at home, most get it at school from classmates and occasionally from teachers, and many accept it. Boys, for example, are likely to ascribe problems with mathematics to the difficulty of the subject while girls are more likely to attribute failure to their lack of ability [Leder, 1990; AAUW, 1990].

Books and articles published in the 1970's and early 1980's suggested that males are innately superior in certain mathematical reasoning and visual-spatial abilities [Benbow and Stanley, 1980,1983; Maccoby and Jacklin, 1974]. These writings, which continue to receive widespread publicity, may have discouraged many females from even thinking about entering scientific fields [Brush, 1991]. More recent studies have shown that some of the cited ability differences disappear under more careful analysis, others are attributable to gender bias in standard aptitude and achievement tests, and still others result from differences in experience and are responsive to training [Brush, 1991; Friedman, 1989; Linn and Hyde, 1989; Marsh, 1989]. More disturbing than these alleged ability differences, however, are commonly observed differences in self-confidence. In elementary school, for example, boys and girls report equal confidence in mathematical abilities but by high school boys are far more confident [Dossey *et al.*, 1988; Eccles, 1984]. Similar patterns are found in science [Linn, 1986].

The negative impression that many women have of their aptitude for technical subjects is augmented by the traditional instructional mode in college science and engineering courses, which stresses individual work and competitive grading. In a 1983 survey at the University of Michigan, more women than men (in fact, most women respondents) reported themselves to be "uncomfortable working in the intensely competitive environment" of their introductory science classes. This discomfort may be responsible in part for the relatively high attrition rate of women who begin science majors. Tobias [1990] suggests that "what may act as a spur to individual achievement among men is a significant deterrent for women." Moreover, even women who persist in technical curricula through graduation show marked declines in self-confidence and career aspirations [Arnold, 1987; Holland and Eisenhart, 1990].

Suggestions have been made that the difficulties encountered by women in technical curricula might be lessened by creating an academic environment that encourages and rewards the "cooperative behavior that is often necessary in scientific investigation" [Linn and Hyde, 1989]. The experimental sequence of chemical engineering courses in the present study was designed with this objective (among others) in mind. A goal of this report is to examine the extent to which the women in the experimental cohort exhibited (or failed to exhibit) the erosion of performance and confidence observed in the studies cited above. Future work will extend the analysis to a comparison group of students who go through the chemical engineering curriculum as traditionally taught, examining the impact of the experimental instructional methods on students' performance and confidence levels.

DATA TABLES AND STATISTICAL ANALYSIS

Tables 1-28 report data for 87 men and 34 women enrolled for CHE 205 in the Fall 1990 semester. The responses shown for each item almost always fall short of these totals, either because students failed to respond to particular questionnaire items or because they dropped out of the experimental course sequence at some point.

The levels of significance reported in the tables are derived from two-tail Fisher's exact tests unless otherwise noted. "Statistically significant" signifies $p \leq .1$; statistically significant p values are marked by asterisks in the tables. Additional details about the statistical methodology used in the study are given by Felder *et al.* [1993].

PRE-ENGINEERING DATA

Ethnicity and Family Background (Table 1)

Table 1 summarizes data on ethnicity, home communities, and parental education of the 121 students in the experimental cohort.

The ethnic backgrounds of the men and women were fairly similar, with the most notable difference being a higher percentage of women coming from Asian-American backgrounds. The men were more likely than the women to have attended high school in rural and small-town communities.

The parents of the women were more highly educated. Eighty-four percent of the women's fathers and 64% of their mothers had college degrees, as compared with 57% of the men's fathers and 48% of their mothers. Over twice as many of the women's mothers held advanced degrees. More than four times as many men as women had fathers who never attended college, and nearly twice as many men had mothers who never attended college. Roughly equal percentages of women and men had fathers with training in science or technology (W–66%, M–64%), but noticeably more women had mothers with such training (W–40%, M–25%). A much higher percentage of the women students had mothers who worked outside the home while the students were growing up (W–73%, M–46%).

A previous article showed that students in this study with urban and suburban backgrounds consistently outperformed students with rural and small-town backgrounds [Felder *et al.*, in press], and parental educational levels have been shown to correlate with academic success [Astin, 1993]. Since relatively more men than women in the study came from rural/small-town homes and the women's parents were more highly educated, a reasonable (but incorrect) prediction based on the results in this section would be that the women should be more successful in chemical engineering.

Myers-Briggs Type Indicator Profiles (Table 2)

Table 2 shows profiles on Self-Scorable Form G of the *Myers-Briggs Type Indicator* (MBTI), a personality inventory based on Jung's theory of psychological types. Also shown are MBTI data reported by McCaulley *et. al.* (1985) for a population of engineering students at ten different schools.

The NCSU students are roughly equally divided between extraverts (active, experimental, learn by doing) and introverts (reflective, solitary, learn by introspection). They include more sensors (practical, methodical, comfortable with concrete information) than intuitors (imaginative, insightful, comfortable with theory and models), substantially more thinkers (objective, tend to make decisions based on logic and rules) than feelers (nurturing,tend to make decisions based on consideration of impact on others), and more judgers (set and follow agendas, anxious to reach closure on decisions) than perceivers (flexible, spontaneous, tend to defer decisions to gather more data). The NCSU data are generally consistent with the data from the much larger engineering consortium study, especially considering the variations in profiles between consortium schools (see "Range" column).

The nearly equal division between extraverts and introverts in the NCSU group was observed for both men and women, although the larger study predicts a higher percentage of extraverts among the women. The predominance of sensors over intuitors was more pronounced among the women than among the men, although the difference is not statistically significant. This predominance suggests that the men might enjoy a slight advantage in engineering courses that are particularly theoretical and/or mathematical by nature. The predominance of thinkers over feelers was significantly greater among the men, probably reflecting the considerable imbalance in this direction in the general population, and that of judgers over perceivers was significantly greater among the women, perhaps suggesting a greater level of single-minded determination required for women to select engineering as a major field of study. The last two patterns agree with those observed in the national study.

Learning and Study Strategies Inventory (Table 3)

Table 3 shows profiles on the *Learning and Study Strategies Inventory* (LASSI), an instrument that assesses students' test-taking skills and strategies, motivation to learn, and anxiety levels. The lower the score on any of the 10 inventory scales, the more likely the student is to have academic problems related to the characteristic measured by that scale.

The women scored higher than or roughly the same as the men on all but the anxiety scale, on which they were significantly lower. They scored significantly higher on items relating to general attitudes toward learning (importance of school, clarity of educational goals), motivation to study (keeping up-to-date in assignments, maintaining interest in classes), and use of study aids (highlighting main points in texts, doing practice exercises). The lower score obtained by the women on the anxiety scale indicates a higher level of anxiety, which could work to their advantage or detriment in terms of academic performance. One might again infer that on average the women entered the chemical engineering curriculum better equipped than the men to meet its academic challenges.

Precollege and First College Year Performance (Tables 4 and 5)

Table 4 shows selected precollege academic credentials of the students. There were no significant gender differences in SAT scores (although it is noteworthy that the women had a slightly higher average SAT mathematics score) or in advanced placement credit for required freshman calculus, chemistry, or physics courses. The one significant difference was in the "Admissions Index" (AI), a predicted grade-point average calculated as a weighted combination of variables including SAT scores, high school grade point average, and rank in high school graduating class. The women had a significantly higher AI, probably due in large part to the inclusion in the AI formula of extra points for being female.

Table 5 shows first-year grade-point averages (AP credit not included) and average grades in selected first-year courses (A=4.0, AP credit=5.0). The women had a slightly higher overall grade point average than the men and significantly outperformed the men in the English course. There were no statistically significant performance differences in the mathematics and science courses.

Motivation for Choosing Engineering as a Major (Table 6)

Shortly after beginning the first chemical engineering course, the students were asked to select from a list the three most important influences on their decision to major in engineering. Table 6 summarizes the results. More women than men selected "My ability or aptitude in science and math" (W–71%, M–56%), "Desire to work on socially important problems" (W–38%, M–28%), and "Family member's influence" (W–26%, M–14%). More men than women selected "Interest in the field" (W–44%, M–65%) and "Opportunity for job mobility/financial rewards" (W–44%, M–49%).

Implications of Pre-Engineering Data

Considerable social pressure is brought to bear on females from an early age not to pursue technical careers. One might therefore expect that women who overcome these pressures and enroll in engineering would be well equipped with both the motivation and the aptitude to succeed.

This expectation was borne out for the women in this study, whose backgrounds and pre-engineering academic credentials marked them as more likely to succeed than the men. Their parents were on average more highly educated and had received more training in science and mathematics. More of them cited aptitude in science and mathematics as a major influence on their choice of a major. They scored equally well or better than the men on precollege admission tests. According to the LASSI, they were more highly motivated to study, had greater powers of concentration, were better able to extract the main ideas from readings, and made better use of study aids. Also, more of them were classified as judgers on the Myers-Briggs Type Indicator, suggesting that they were more likely to keep up with their coursework on a day-by-day basis.

Nevertheless, the women did not do significantly better than the men in their first year of college except in nontechnical courses, suggesting the existence of factors working against them. We defer discussion of what these factors might be until outcomes from engineering courses have been summarized.

PERFORMANCE IN CHEMICAL ENGINEERING

Grades in Chemical Engineering Courses (Tables 7–9)

The five courses listed below constituted the experimental sequence. Also shown are the number of men and women in the experimental cohort who enrolled in each course.

1. **CHE 205 — Chemical Process Principles. M–87, W–34.** Material and energy balances on chemical processes, taught in the first semester of the sophomore year.
2. **CHE 225 — Chemical Process Systems. M–53, W–18.** Process variable measurement methods, computer simulation of processes, applied statistical analysis.
3. **CHE 311 — Transport Processes I. M–50, W–17.** Fluid dynamics and heat transfer. Probably the most theoretical and mathematics-intensive of the five courses.
4. **CHE 312 — Transport Processes II. M–45, W–16.** Mass transfer and separation processes.
5. **CHE 446 — Chemical Reactor Design and Analysis. M–40, W–15.**

The courses were taught by Dr. Felder in successive semesters, beginning with CHE 205 in the first semester of the students' sophomore year. The percentage of women enrolled remained relatively constant in the 25-28% range.

Table 7 summarizes student performance in each of the five courses. On average the men did better in every course, with statistically significant differences occurring in 225 and 312.

Table 8 shows results for four other chemical engineering courses taught by instructors other than Dr. Felder.[3] Although none of the differences in these courses were statistically significant, noticeably higher percentages of the men earned A's in two of these courses and roughly equal percentages of men and women did so in the other two. The women earned a higher average grade in CHE 425, and the averages were close together in the other three courses.

Table 9 shows overall and chemical engineering GPA's after the third year of the study. The women earned a slightly higher overall GPA and the men had a small but nonsignificant advantage in chemical engineering GPA, mostly due to their higher grades in the experimental courses.

Status of the Students After Years 1 and 3 of the Study (Tables 10 and 11)

Table 10 shows the academic status of the students at the end of the first year of the study (the second year of college), and Table 11 provides similar data for the end of the third year (the fourth year of college). Students were said to be making "satisfactory progress" if they either (1) passed CHE 205 and CHE 225 with a grade of C or higher and were still in the chemical engineering curriculum (Category A), (2) joined the co-op (work-study) program and so did not take CHE 225 in the second semester of the study (Category C), (3) graduated following the Spring 1993 semester (Category H in Table 11), or (4) transferred out of chemical engineering without having failed any of the experimental courses (Category D). Those who failed an experimental course or who were placed on academic probation or dropped out of school (Categories B, E, and F) were classified as having made "unsatisfactory progress." Students still enrolled in chemical engineering and not on academic probation, whether or not they were still in the experimental course sequence, were said to have been "retained."

There were some noteworthy differences in academic status —albeit no statistically significant ones—between the men and women after their sophomore year of college (Table 10). Higher percentages of men fell into the "satisfactory" category and relatively more men were still enrolled in chemical engineering. A slightly higher percentage of men than women failed one of the experimental courses and remained in chemical engineering (Category B), while a substantially higher percentage of women than men transferred out of chemical engineering after failing a course (Category E). A higher percentage of women joined the coop (work-study) program (Category C), although the percentages would later converge.

[3]Chemical engineering courses for which data are not summarized in Table 7 or 8 (specifically, two laboratory courses, an elective project course, and the final senior design course) provided no basis for contrasting male and female performance, as almost all of the students in the study who took them received A's.

Roughly equal percentages of men and women dropped out of school or went on academic suspension (Category F).

After the fourth year of college (Table 11), essentially equal percentages of men and women had graduated in chemical engineering (Category H) or had taken and passed all experimental courses but had not yet graduated (Category A). Men were nearly twice as likely as women to be behind sequence in chemical engineering (Category B). Men and women were equally likely to have transferred out of chemical engineering in good standing (Category D) but women were five times as likely to have transferred out after failing a course (Category E). More than three times as many men as women had dropped out of school or were on academic suspension (Category F). A slightly higher percentage of women were in the "satisfactory" category.

The picture that emerges is as follows. Although the women in the study came into engineering with better predictors of success—higher levels of parental education, higher SAT scores, better study skills and strategies, etc.—the men consistently earned equal or higher grades in chemical engineering courses, and the percentage of men earning A's in two of the experimental courses was more than twice the percentage of women doing so. Of the students who had intended to major in chemical engineering when they began the first course, the percentage of women who dropped out for any reason after the sophomore year was twice the percentage f men dropping out (16% of the women vs. 8% of the men). The percentages dropping out by the end of the senior year were closer (23% of the women and 19% of the men), with relatively more women transferring into other curricula and considerably more men dropping out of school or being suspended. Throughout the period of the study, men who failed a chemical engineering course were more likely than women to repeat the course and remain in the curriculum, while women who failed a course were more likely than the men to switch out of chemical engineering. These results are consistent with patterns described by Dweck and Repucci [1973], who observed that young men are more likely than young women to persist in the face of academic challenges, and by Astin [1993], who noted a greater tendency of women than men to drop out of engineering.

Factors Affecting Decision to Remain in Chemical Engineering (Table 12)

The students who had completed the experimental course sequence were asked as seniors to comment on factors that might have influenced their decision to remain in chemical engineering. The responses are summarized in Table 12.

Both men and women were strongly influenced by the experimental courses, and would choose to go through the sequence again if they had it to do over. The clearest gender difference in the responses had to do with the student chapter of the American Institute of Chemical Engineers, which the women found much more valuable than did the men. This result may tie in with the tendency for women to appreciate group work and to rely on the support of peers and others, and suggests the potential value of support groups for women in engineering. The women also accorded much more importance to the influence of their family, perhaps reflecting the greater percentage of them who had parents with training in science or engineering.

ATTITUDES, REACTIONS, AND SELF-ASSESSMENTS

Confidence levels, self-expectations, and attributions of success and failure (Tables 13-17)

Most of the comparisons shown in the remaining tables are based on responses to questionnaires administered to the students at the beginning of CHE 205, midway through CHE 205, 311, 312, and 446, and when the students had completed the experimental course sequence and were in their eighth semester of college.

As Table 13 shows, the women beginning their first engineering course (CHE 205) reported somewhat higher levels of anxiety than the men about both that course and about schoolwork in general, although the differences were not statistically significant. This result is consistent with that previously reported for the LASSI inventory, which also showed the women with higher anxiety levels. The men were significantly more positive about the quality of the academic preparation they had received for CHE 205. As seniors in their eighth semester of college, the men remaining in the experimental course sequence continued to be more confident about their academic preparation than the women, although the difference was not statistically significant.

In each questionnaire the students were asked to state the lowest final grade that would satisfy them in the course they were taking at the time. Table 14 summarizes the results. At the beginning of CHE 205 the women expressed slightly higher requirements than the men, with a greater percentage saying that they would require creative work beyond that required to earn an A. By the middle of that course (after the first test) both men and women had lowered their criteria for satisfaction, and the men's were now higher. The implication is that even at this early stage of the engineering curriculum the women were starting to have greater difficulty and/or to experience a greater loss of confidence. This trend continued as the men's criteria continued to exceed the women's, with the difference reaching its maximum in the junior year (probably the most demanding year of the curriculum). The decreased difference in the senior year is attributable more to a lowering of male expectations (perhaps a symptom of "senioritis") than to increased female expectations.

In two of the experimental courses, questions were asked that provide a more direct measure of expectations. In the CHE 205 preliminary questionnaire and the CHE 312 midterm questionnaire, students were asked to guess their final course grades (Table 15). In 205 almost all of the students guessed A or B, but the men were more likely to say A. In 312 men were significantly more likely than women to say A or B, and almost half of the women and fewer than 10% of the men said C. As it happens, both men and women overpredicted their grades early in CHE 205, while in CHE 312 the men predicted their grades quite accurately and the women underpredicted theirs, suggesting that at least some of the women's lower expectations resulted from their underestimating their abilities.

In all of the questionnaires, the students were asked to guess what the most likely reason would be if they were to perform below their own expectations in the course (Table 16). The responses varied considerably from course to course, but some trends emerged. "Not working hard enough" was the most common response of both men and women in all courses, but it was by far the predominant male response and it was always given by higher percentages of men except at the beginning of CHE 205. Lack of ability was consistently chosen by a substantially higher percentage of women except at the beginning of CHE 205 (where the difference was slight), and women were more likely to cite personal problems in three of the five courses. Men were more likely to say that their poor performance would be due to unfair tests and/or grading, although there were very few such complaints.

The converse question was also posed, i.e., what the most likely reason would be if the students performed above their expectations (Table 17). Hard work was cited by the highest percentages of both men and women, but men were consistently more likely to report their own ability as the most likely factor while women were more likely to cite help or support from someone else. These attribution patterns match those observed by Fennema and Leder [1990], who found that female mathematics students tend to attribute failure to themselves and success to help from others while male students tend to do the opposite. The data also show that the greater tendency of women than men to downrate their ability was much less pronounced at the beginning of CHE 205 than later in the curriculum, and may have even been slightly reversed at the beginning of CHE 205.

In summary, the women in the study entered the engineering curriculum with greater anxiety and lower confidence in their preparation than did the men. They began the first course with higher expectations of themselves, but by the midpoint of the first chemical engineering course their expectations were lower than those of the men, and the disparity persisted throughout the curriculum. The women were more likely than the men to attribute poor performance to their own lack of ability and men were more likely to attribute it to a lack of hard work or being treated unfairly. Conversely, men were more likely than women to attribute success to their ability and women more likely than men to attribute it to outside help.

Reactions to Features of the Experimental Courses (Table 18)

Table 18 summarizes responses to questionnaire items concerning the students' reactions to various aspects of the experimental courses.

Whenever there was a gender difference in ratings of specific aspects of course instruction, it usually involved higher ratings from the women. Women were more positive about the educational research study in which they were taking part. In both CHE 205 and CHE 311 they expressed themselves more positively about the fairness of the tests and homework grading, with the difference being significant in 205, and they were also more positive about the helpfulness of the lectures, the challenge (extra credit) problems in the experimental courses, and the student chapter of the American Institute of Chemical Engineers.

This pattern of gender differences may reflect the fact that the women (who were more likely than men to be MBTI feelers) were simply more inclined to dispense praise, and it could also stem from their lower self-confidence, which might incline them to view different features of the courses as more helpful to them than they would have if they had more confidence in their own abilities.

Interestingly, the women were even more positive than the men about the availability of computer workstations in CHE 205. This result could reflect a tendency of women—more of whom were MBTI judgers—to plan ahead better than men and seek workstations at times of lower demand, e.g. off-peak hours or any time other than the night before an assignment was due. However, judgers would also have been more bothered than perceivers by workstation unavailability when it arose. It seems more likely that this gender difference is simply one more instance of the tendency of the women to give more positive ratings than the men to everything but their own abilities and levels of confidence.

Only when the students were asked as seniors to rate the instructiveness of the experimental courses did the men respond more positively than the women. Most students of both sexes considered the experimental courses more instructive, but 19% of the women and only 4% of the men rated them equally with the nonexperimental chemical engineering courses. (No students considered them less instructive.) A likely explanation of the weaker positive response of the women involves the students' responses to cooperative learning, a topic discussed in a later section.

Self-assessment of Problem-Solving Abilities (Tables 19-20)

Toward the end of the their junior and senior years, the students were asked to rate their ability to solve basic engineering problems and more challenging problems requiring creativity. In the CHE 446 questionnaire they were also asked to assess their ability to solve routine and challenging problems they might encounter in industry following graduation, and in the senior questionnaire they were asked about their computer problem-solving ability. The men rated their basic problem-solving abilities significantly higher in every instance (Table 19). They also consistently rated their creative and computer problem-solving abilities more highly, significantly so in the senior questionnaire and in the question about working in industry (Table 20).

Reactions to Group Work (Tables 21-25)

All homework in each of the experimental courses was done by teams of three or four students, with one assignment set handed in per group and rotating team leadership. Also, almost every lecture session involved some group work, taking up anywhere from 5 to 40 minutes of the 50-minute period. The homework groups remained together throughout the semester, while the group composition in class varied from one period to another.

Women gave higher ratings than men to both in-class group work (Table 21) and group homework (Table 22) in each individual course and retrospectively for the entire sequence.[4] The female preference for group work was further evidenced by the question posed in 311, 312, and 446 asking whether or not the students would choose to do their homework alone if given the choice (Table 23). In all three classes majorities of both men and women said they would not, but the desire to continue working in groups was much stronger among the women.

In short, group work was viewed extremely positively by both men and women but more so by the women. The difference may reflect a female learning style more oriented towards cooperative learning, or a greater importance attached by women to outside support (recall that women were more likely to list the support of others as a likely reason if they were to succeed), or the tendency of the women to view most aspects of the experimental course instruction more favorably. Group work was a major component of the experimental course sequence and was clearly important to the instructor, so that the latter tendency might have been particularly strong in response to these questions.

A more mixed set of results was obtained when the students were asked to rate how well their homework groups functioned and to assess their own contributions and how they were valued by their team members (Table 24). The women rated their groups more highly in CHE 311 and 446, the ratings were almost identical in CHE 312, and the men gave their groups slightly higher overall ratings in the senior questionnaire. Men were nearly twice as likely as women to feel that they did more than their fair share in their groups. This perception may reflect an unwillingness of some women to acknowledge their own efforts, a tendency of the men to take a more active and hence more visible role in problem solving (see next paragraph), or a genuine imbalance in the work distribution. The women were significantly more likely to feel that their contributions were undervalued by other group members, a perception that plays an important role in subsequent discussions. This feeling is similar to one expressed by female Radcliffe College students, who reported that too often their contributions in small mixed study groups were not valued and so they preferred to study by themselves [Light,1990].

In CHE 311, 312, and 446, the students were asked what they perceived to be the greatest benefit of group work, and the seniors were asked how they thought groups should

[4]The question about in-class group work was not in the 205 questionnaire.

ideally function (Table 25). In 312 and 446, the men were much more likely to say they benefitted from explaining the material to others while the women were more likely to cite having the material explained to them (these options were not given in 311). Roughly equal percentages of men and women said that all the group members should set up the problems individually and then complete them together (a message that had been stressed repeatedly by the course instructor). Of the remaining seniors, however, most men said that team members should work together on all problems and most women said that they should do all of the problems working alone and then compare answers.

These differing attitudes toward group work are logically consistent with other given results. Women give higher ratings to group work than men because group work provides what they believe they need to succeed academically (external help, personal interactions). The men, however, may get more benefits from group work than they realize because they effectively learn the material by explaining it, which might account in part for their better performance in the experimental courses (Table 7) and the higher ratings they gave the instructiveness of those courses (Table 18). Since the women take relatively passive roles in the groups (whether by their own choice or not), the men are more likely to feel that they are doing more than their fair share of the work, a sentiment they express.

It may also be that the tendency of at least some men to discount the ideas of the women in their groups may explain why more women than men would prefer to work individually and then compare answers rather than doing everything together. The former approach would allow the women some time to develop their ideas rather than having them dismissed out of hand as soon as they are conceived. The women's feeling that their contributions were undervalued in group work might have added to their lack of confidence in the experimental courses, thus accounting for the fact that the gender disparity in confidence levels increased as time went by.

POST-GRADUATION PLANS AND PRIORITIES (Tables 26-28)

In their junior and senior years the students were asked about their post-graduation plans (Table 26). The women expressed a significantly greater inclination to enter the workforce as opposed to going to graduate school (immediately or eventually). The difference became more pronounced as the students approached graduation.

The seniors were asked how important different factors would be in determining their level of satisfaction with their first job (Table 27). Both men and women attached considerable importance to enjoying their work and maintaining good relations with coworkers, although marginally more women rated the latter as very important. Factors significantly more important to the women included meeting or exceeding employer expectations and having opportunities to work on a team. Women were also more likely to place great importance on getting good salaries and benefits. Men attached significantly more importance to having assignments that challenge their abilities and on doing creative work.

These results reflect the patterns seen previously of men having more confidence in their problem-solving abilities than women and women tending to place more importance than men on the nature and quality of their interactions with others.

The seniors were also asked to guess the most likely reason if they were to have problems on their first job (Table 28). Lack of ability was not an option on this question. Lack of confidence was, however, and was chosen by 61% of the women and only 21% of the men. The men were more likely to choose conflicts with supervisors or coworkers (no women chose this option), and a higher percentage of men chose poor communication skills. The women thus see having good interactions with coworkers as one of their top requirements for job satisfaction (Table 27), and the men see having poor interactions as their most likely source of problems.

When asked what their highest priority would be in case of a conflict between the demands of work and family, majorities of both men and women chose family but more women than men did so (Table 28).

A relatively low tendency of women engineering graduates to go on to graduate school has been noted elsewhere [e.g. Widnall, 1988]. One contributing factor might be a desire of some of the women graduates to start families shortly after graduation. Another possible factor is suggested by the observed gender differences in self-confidence at the end of four years in college. The women, less confident in their abilities to deal with challenging engineering problems, may be more reluctant to pursue a career track (research or university teaching) that would require advanced knowledge of the field and hence pursuit of a graduate degree. A third possibility is that the women might be less inclined to pursue academic careers due to the lack of female role models in their own university experience [Daniels, 1988].

DISCUSSION

What Accounts for the Observed Gender Differences?

A number of studies have documented negative effects of the college experience on women [Arnold, 1987; Astin, 1993; Holland and Eisenhart, 1990; Widnall, 1988]. Rogers [1993] summarizes these results, noting that "Outside of women's intellectual development, the college experience has a negative effect on women resulting in loss of self-confidence, lowered career aspirations, and failure to develop personal characteristics associated with leadership and success in science and technology, such as independence and self-reliance."

Although the relatively small number of women (15) who completed the experimental course sequence kept many of the observed gender differences from being statistically significant, the internal consistency of the results and their agreement with results from prior studies lend them credence. On average, the women entering the chemical engineering curriculum came from home and family backgrounds more conducive to success and had better academic credentials than did the men. Beginning early in the curriculum, however, they evidenced lower self-confidence, greater anxiety, and lower expectations of themselves in chemical engineering courses, tendencies that either remained stable or increased as the women progressed through the curriculum. Their performance in the experimental chemical engineering courses declined relative to that of the men, especially at the upper end of the grade spectrum (i.e., men consistently earned more A's). Women more than men tended to attribute their failures to a lack of ability and their successes to receiving outside help, whereas men were more likely to attribute failures to insufficient effort or unfair grading and successes to their own ability. Of those in the original group who remained in chemical engineering through their senior year, many more men than women were contemplating enrolling in graduate school. When considering their prospective jobs, women were much more concerned about maintaining good relationships with coworkers and employers, whereas men focused more on having challenging problems and doing creative work.

The critical question is, *why* did the women in the study—whose qualifications were arguably better than those of the men when they entered the chemical engineering curriculum—earn lower grades in chemical engineering courses and exhibit progressively lower confidence levels and expectations of themselves as they advanced through the curriculum? One possible explanation involves inherent gender differences in certain abilities important in the solution of engineering problems; however, as discussed in the introduction, recent studies tend to negate the existence of such differences. The study data and observations in the literature suggest several more likely explanations.

1. *Uncertainties in the students' minds about the suitability of women to be engineers.*

A 1991 survey of 283 students at three universities asked the respondents to state their perceptions of barriers to women entering engineering [Morgan, 1992]. Roughly 20% of the respondents cited beliefs that engineering is too demanding to combine with family responsibilities, men in engineering resent women colleagues, and most parents discourage their daughters from training for engineering. Almost 10% stated that women are afraid they will be considered unfeminine if they enter engineering. No significant gender differences in the responses were found.

Even though these beliefs were not strong enough to deter the women in this study from enrolling in engineering, they could still have contributed to undermining their confidence, especially when compounded with academic setbacks or the other problems listed below. The greater tendency of women than men to drop out of chemical engineering upon failing a course suggests the influence of these self-doubts.

2. *Mismatches between characteristic instructional styles of engineering professors and characteristic learning styles of women students.*

Many engineering courses stress theory (engineering science) over applications (engineering practice). This emphasis invariably places some students at a distinct disadvantage relative to others [Felder and Silverman, 1988], and in particular may work to the detriment of women, more of whom lack the hands-on experience that might clarify the abstract theoretical material [Robinson and Reilly, 1993]. Also, most engineering courses require individual work and grades are assigned on a competitive basis, whereas women tend to be more comfortable in an environment that stresses cooperation [Tobias, 1990], a tendency consistent with the strong enthusiasm for group work expressed by the women in this study.

The instructional approach in the experimental courses—particularly the emphasis on cooperative learning—had been intended to minimize the learning/teaching style mismatches that normally work against women in engineering.[5] However, as will be noted shortly, cooperative learning may be a two-edged sword for women students, creating some problems for them while resolving others.

3. *Discrimination by faculty instructors and advisors.*

Anti-female bias on the part of college faculty members, ranging from holding lower expectations of women than of men to overt harassment—has been documented in several studies (see, for example, Widnall, 1988). Intentional faculty discrimination against the women in this study—if it occurred at all—is not likely to have affected their course grades directly. Examinations in chemical engineering courses consist almost entirely of quantitative problems with unique answers, grading is objective, and letter grades for the courses are based on examination and homework grades and not on subjective evaluations of such things as quality of expression or level of participation in class. Moreover, although the greatest differences between male and female performance were observed in the experimental chemical engineering courses, the anonymous student evaluations of the course instructor by both men and women were uniformly and consistently high, and although the women in the study had many opportunities in interviews and anonymous questionnaires to voice complaints about unfair treatment by the course instructor, no such complaints were ever received.

However, while the women in this study never registered complaints about discrimination by any of their chemical engineering course instructors, several reported hearing disparaging statements about women students from other engineering professors, which could certainly have contributed to a lowering of their self-confidence.

4. *Discounting by male classmates, including (and perhaps especially) in cooperative learning groups.*

Widnall [1988] cites studies showing that women in mixed groups are disadvantaged in several ways: they are interrupted more frequently, their contributions are often ignored or discounted, and they are more uncomfortable with the argumentative style that many men characteristically adopt when points of contention arise. The data from this study

[5]The degree to which it did so will not be known until data for the comparison group have been analyzed.

are consistent with these observations. Women were far more likely than men to complain that their contributions in group work were undervalued, and many more men than women felt that their contributions were highly valued (see Table 24). These feelings, which undoubtedly had some basis in reality, were bound to diminish the women's self-confidence.

5. *A tendency of women to be passive in cooperative learning groups.*

Perhaps due to the devaluation of their contributions in groups or to a learned tendency to defer to men in intellectual matters, the women played less active roles than the men in their groups. (This assertion is based on the women's own estimation and is supported by observation of videotaped group sessions.) Also, many more men than women felt that group work benefitted them most by giving them opportunities to explain material to others, while more women felt that having material explained to them was the greatest benefit of group work (Table 25). All developmental learning theories agree that active involvement in learning is far more effective at promoting understanding than passive reception of information. The implication is that by taking more active roles in group sessions, the men were deriving greater benefits from cooperative learning.

6. *Lack of female role models in engineering school.*

Research has established the vital importance of role models for women in engineering [Daniels, 1988]. The female students in this study would undoubtedly have benefitted by being taught by women engineering professors but they only encountered one in a single course, and her effectiveness as a role model was diminished by her being in her first semester of teaching and coteaching the course with a more experienced male colleague.

7. *Different relative priorities attached by men and women to personal relationships and schoolwork.*

As they progress through the curriculum, both men and women become involved in personal relationships that impose increasing time demands. It may be that the women tended to place a higher priority than the men on the relationships, making them less inclined to expend the time and energy required to earn top grades in their courses. This pattern would be consistent with the observed tendency of the women to be satisfied with lower grades (Table 14) and with the greater priority they expect to attach to family demands over professional demands in their first job (Table 28).

What Support Should Be Provided for Women Engineering Students?

Whatever the reasons for the observed gender disparities, it is clear that women in engineering school are operating at a disadvantage relative to men and that American industry and academia are losing valuable talent as a consequence. The observations summarized in this paper suggest that the following measures could help to improve their situation.

1. *Provide engineering students with female role models and mentors.*

The need for female role models for women students in science and engineering has been widely noted [Daniels, 1988; Robinson and Reilly, 1993; Widnall, 1988], as has the importance of out-of-class student-faculty interactions in promoting academic success and building self-esteem [Astin, 1993; Pascarella and Terenzini, 1991]. Perhaps the most effective way to help women engineering students would therefore be to add more women to engineering faculties.

This objective is not easily realized, however, especially in the near term. The relatively small number of women currently in the engineering graduate school pipeline is far less than the number needed to mentor the women now enrolled as engineering undergraduates, let alone the number who will be enrolled if current recruitment and retention programs succeed. Moreover, women professors are rightfully expected to meet the same performance standards as their male counterparts. It is unreasonable to expect them to seek and secure research funding, perform the research, publish and present papers, and develop and teach courses to the same extent as the men *and* spend the time that serious mentoring requires. Until the number of women entering the professoriate increases substantially and the university infrastructure comes to view mentorship as a valid and vital professorial function, other mechanisms to support women students will be needed.

One possible mechanism is peer mentoring. Female graduate students and upper-class undergraduates could be effective mentors to first- and second-year women, and could reach many more students in a meaningful way than could possibly be reached by the few available women professors.

2. *Strengthen organizations that can provide career guidance and emotional support to women students, such as student chapters of the Society of Women Engineers, and encourage participation in these organizations.*

Besides serving as valuable support groups, such organizations provide a natural forum for successful women engineers to return to campus and provide a realistic and positive picture of engineering as a career for women.

3. *Use cooperative learning in engineering courses, structured to provide equal benefits to men and women.*

By their own assessment, the women in this study were helped considerably by working in groups, and other studies have also shown that women respond positively to a classroom environment based on cooperation rather than competition; however, the tendency of some women to take less active roles than men in groups and that of some men to discount women's contributions can work against the women. When mixed groups are formed, the need to elicit and seriously consider contributions from *every* group member should be stressed, and the groups should regularly be required to assess their success in this regard.

It might also be worthwhile to experiment with cooperative study groups containing only women. Studies have shown that students at women's colleges do not experience the same loss of self-esteem as women at coeducational institutions [Tidball, 1989], suggesting that female study groups might provide the benefits of cooperative learning to women while avoiding the potential drawbacks of this approach.

4. *Educate professors and academic advisors to the problems and needs of women students.*

Beal and Noel [1980] cite research showing that student retention can be increased through improved academic advising. Unfortunately, most professors receive the same level of training for advising that they do for teaching—that is, none. All faculty members should be made aware of the difficulties faced by women engineering students and of the resources on campus—support groups, mentorship programs, and trained counselors, etc.—available to help the women cope with and overcome these difficulties.

FUTURE WORK

As part of the longitudinal study, data are being accumulated on a cohort of chemical engineering students proceeding through the curriculum as traditionally taught. Data on the performance and attitudes of these students will eventually augment the data on the students in the experimental courses. The results should provide more solid statistical support for some of the patterns reported in this paper, and they should also enable determination of the effects of the instructional methods used in the experimental courses (e.g. cooperative learning) on performance and retention of women engineering students. Efforts are also being made to undertake similar studies at other universities in the NSF-sponsored SUCCEED coalition.

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TABLE 1
ETHNICITY, HOME, AND PARENTS

	Men	Women	p
Ethnic background	(N=86)	(N=34)	
African-American	7%	3%	
Caucasian	85%	76%	.14
Asian-American	2%	12%	
Other	6%	9%	
Home community	(N=86)	(N=34)	
Rural	15%	12%	
Small town	35%	24%	.19
Suburban	37%	35%	
Urban	13%	29%	
Father's highest education level	(N=79)	(N=31)	
Advanced degree	22%	29%	
Bachelor's degree	35%	55%	.04*
Attended college	15%	10%	
Never attended college	28%	6%	
Mother's highest education level	(N=78)	(N=30)	
Advanced degree	13%	27%	
Bachelor's degree	35%	37%	.23
Attended college	21%	20%	
Never attended college	32%	17%	
Parents trained in science	(N=47)	(N=15)	
Both	21%	33%	
Mother	4%	7%	.67
Father	43%	33%	
Neither	32%	27%	
Mother's employment history	(N=48)	(N=15)	
Had an outside job	46%	73%	
Student	4%	0%	.21
Stayed at home	50%	27%	

TABLE 2
MYERS-BRIGGS TYPE INDICATOR PROFILES

	NCSU			Engr. Consortium†		
	Men	Women	p	Men	Women	Range‡
N	82	34		3786	698	
Extraversion(E)	48%	50%	.84	43%	55%	37–58%
Introversion(I)	52%	50%		57%	45%	
Sensing(S)	55%	65%	.41	53%	52%	41–59%
Intuition(N)	45%	35%		47%	48%	
Thinking(T)	74%	56%	.08*	75%	61%	68–83%
Feeling(F)	26%	44%		25%	39%	
Judgment(J)	56%	76%	.06*	58%	66%	45–69%
Perception(P)	44%	24%		42%	34%	

†McCaulley, Macdaid, and Granade [1985].

‡Ranges of values obtained at the different consortium schools.

TABLE 3
LEARNING AND STUDY STRATEGIES INVENTORY (LASSI©) SCORES

LASSI Scale	Men (N=81)	Women (N=34)	p†
General attitudes	31.7	34.2	.01*
Motivation to study	31.2	33.6	.01*
Time management	24.3	25.7	.26
Anxiety	26.2	23.9	.10
Concentration	26.7	28.1	.19
Info. processing	28.3	28.1	.86
Select main ideas	18.9	19.9	.12
Study aids	23.9	27.1	.001*
Self-testing	26.2	25.8	.72
Test strategies	29.9	31.1	.19

†t-test.

TABLE 4
PRECOLLEGE ACADEMIC PERFORMANCE

	Men	Women	p
Admissions criteria	(N=71)	(N=30)	
SATM	625	637	.50†
SATV	523	522	.97†
Admissions Index (PREGPA)	2.79	3.05	.001†*
Percentage receiving AP credits in courses	(N=82)	(N=34)	
MA141	20%	18%	1.00
MA241	5%	0%	.32
CH101	4%	3%	1.00
CH107	4%	3%	1.00
PY205	2%	0%	1.00

†t-test

TABLE 5
FIRST YEAR ACADEMIC PERFORMANCE

	Men (N)	Women (N)	p
First year course grades			
Overall GPA	3.21 (70)	3.31 (30)	.41[b]
MA141[a]	3.31 (72)	3.29 (31)	.95[c]
MA241[a]	3.01 (75)	2.97 (31)	.41[c]
CH101[a]	3.41 (74)	3.58 (31)	.62[c]
CH107[a]	3.31 (74)	3.26 (31)	.45[c]
PY205[a]	2.82 (73)	2.55 (29)	.25[c]
ENG111[a]	3.84 (70)	4.45 (29)	.02[c]*

[a]A=4.0, AP credit=5.0

[b]t-test

[c]Wilcoxon's rank-sum test

TABLE 6
MOTIVATION FOR CHOOSING ENGINEERING†

	Men	Women
	(N=86)	(N=34)
Interest in the field	65%	44%
My ability or aptitude in science and math	56%	71%
Opportunity for job mobility, financial rewards	49%	44%
Desire to work on socially important technical problems	28%	38%
Role model or positive experience	22%	21%
Family member's influence	14%	26%
Open house or career day	8%	9%
High school advisor	9%	3%
Suggestion of friend or classmate	7%	3%
SITE or other summer program	5%	9%
Other	13%	6%

†Students could choose up to three options

TABLE 7
PERFORMANCE IN EXPERIMENTAL COURSES

	205			225			311		
	M	W	p	M	W	p	M	W	p
N	87	34		53	18		50	17	
Letter grade									
A	25%	18%		45%	22%		30%	24%	
B	33%	32%		38%	44%		34%	24%	
C	9%	18%	.71	11%	28%	.20	26%	41%	.77
D	8%	9%		2%	6%		6%	6%	
F/Drop[1]	24%	24%		4%	0%		4%	6%	
Percentage receiving A's	25%	18%	.48	45%	22%	.10*	30%	24%	.76
Percentage passing‡	68%	68%	1.00	94%	94%	1.00	90%	88%	1.00
Average grade (A=4.0)	2.28	2.12	.48†	3.19	2.83	.07†	2.80	2.53	.34†

	312			446		
	M	W	p	M	W	p
N	45	16		40	15	
Letter grade						
A	51%	19%		32%	27%	
B	31%	56%		52%	33%	
C	18%	25%	.08*	15%	40%	.14
D	0%	0%		0%	0%	
F	0%	0%		0%	0%	
Percentage receiving A's	51%	19%	.04*	32%	27%	.75
Percentage passing‡	100%	100%		100%	100%	
Average grade (A=4.0)	3.33	2.94	.06†*	3.18	2.87	.18†

[1]Students who dropped any course after 205 were not counted in the statistics for that course.

‡"Passing" refers to receiving a grade of C or better, which is required to advance in the curriculum.

†Wilcoxon's rank-sum test

TABLE 8
PERFORMANCE IN NONEXPERIMENTAL CHE COURSES

	Men	Women	p
CHE 315	(N=62)	(N=23)	
Average grade	2.94	2.83	.36†
% receiving A's	32%	22%	.43
CHE 316	(N=59)	(N=23)	
Average grade	2.88	2.78	.61†
% receiving A's	32%	17%	.27
CHE 425	(N=46)	(N=17)	
Average grade	3.26	3.53	.50†
% receiving A's	50%	53%	1.00
CHE 450	(N=34)	(N=13)	
Average grade	2.74	2.54	.54†
% receiving A's	18%	15%	1.00

†Wilcoxon's rank-sum test

TABLE 9
OVERALL GRADE POINT AVERAGES
AFTER YEAR 3 OF STUDY

	Men	Women	p†
Final overall GPA	(N=81) 3.02	(N=33) 3.08	.69
Final overall CHE GPA	(N=81) 2.64	(N=32) 2.55	.72
Final GPA in experimental CHE courses	(N=79) 2.39	(N=31) 2.20	.51

†t-test

TABLE 10
STATUS IN THE CHE CURRICULUM AFTER SECOND YEAR OF COLLEGE

	Men	Women	p
Status[a]	(N=87)	(N=34)	
A	57%	50%	
B	21%	18%	
C	3%	9%	
D	1%	0%	.34
E	2%	12%	
F	3%	3%	
G	11%	9%	
Overall progress[b]	(N=77)	(N=31)	
Satisfactory	70%	65%	.65
Unsatisfactory	30%	35%	
Retention[c]	(N=77)	(N=31)	
Retained	92%	84%	.29
Not retained	8%	16%	

[a] A = In sequence (passed 205 and 225)
B = Behind sequence (failed 205 or 225)
C = Joined the coop program
D = Transferred out of CHE in good standing
E = Transferred out of CHE after failing 205
F = Dropped out of school or suspended
G = Never was a CHE major

[b] Satisfactory = Category A, C, or D
Unsatisfactory = Category B, E, or F

[c] Retained = Category A, B, or C
Not retained = Category D, E, or F

TABLE 11
STATUS IN THE CHE CURRICULUM AFTER FOURTH YEAR OF COLLEGE

	Men	Women	p
Status[a]	(N=87)	(N=34)	
A	16%	18%	
B	11%	6%	
C	9%	12%	
D	3%	3%	.43
E	3%	15%	
F	10%	3%	
G	11%	9%	
H	34%	35%	
Overall progress[b]	(N=77)	(N=31)	
Satisfactory	71%	74%	.82
Unsatisfactory	29%	26%	
Retention[c]	(N=77)	(N=31)	
Retained	81%	77%	.79
Not retained	19%	23%	

[a] A = In sequence
B = Behind sequence
C = Joined the coop program
D = Transferred out of CHE in good standing
E = Transferred out of CHE after failing a course
F = Dropped out of school or suspended
G = Never was a CHE major
H = Graduated

[b] Satisfactory = Status of A, C, D, or H
Unsatisfactory = Status of B, E, or F

[c] Retained = Status of A, B, C, or H
Not retained = Status of D, E, or F

TABLE 12
FACTORS AFFECTING SENIORS' DECISION TO REMAIN IN CHEMICAL ENGINEERING

	Men	Women	p
Family	(N=51)	(N=16)	
Very important	20%	38%	.31
Somewhat important	33%	31%	
Not very important/Unimportant	47%	31%	
Experimental courses	(N=50)	(N=16)	
Very important	58%	69%	.63
Somewhat important	32%	19%	
Not very important/Unimportant	10%	12%	
AICHE Student Chapter	(N=49)	(N=16)	
Very important	0%	19%	
Somewhat important	22%	25%	.005*
Not very important	37%	6%	
Unimportant	41%	50%	
If you could start college over	(N=43)	(N=18)	
CHE at NCSU in experimental sequence	84%	67%	
CHE but not in experimental sequence	0%	6%	.08*
Other engineering branch	0%	6%	
Not engineering	16%	22%	

TABLE 13
SELF-ASSESSMENTS OF ANXIETY LEVELS AND ACADEMIC PREPARATION

	Men	Women	p
Anxiety level about CHE 205	(N=85)	(N=34)	
Very anxious	28%	41%	
Somewhat anxious	53%	50%	.43
Slightly anxious	18%	9%	
Not at all anxious	1%	0%	
Anxiety level about schoolwork in general	(N=85)	(N=34)	
Very anxious	25%	41%	
Somewhat anxious	46%	44%	.21
Slightly anxious	26%	15%	
Not at all anxious	4%	0%	
Academic preparation for CHE 205	(N=84)	(N=34)	
Weak/Average	55%	76%	.04*
Strong	45%	24%	
Academic preparation for CHE 451	(N=49)	(N=15)	
Excellent	22%	7%	
Good	57%	67%	
Fair	10%	13%	.68
Poor	2%	0%	
Don't know	8%	13%	

TABLE 14
REQUIREMENTS FOR SATISFACTION WITH GRADES

	Men	Women	p
In 205 – Beginning	(N=85)	(N=34)	
Passing	1%	0%	
C or better	13%	6%	.57
B or better	54%	53%	
A	25%	26%	
Creative work beyond good grades	7%	15%	
In CHE 205 – Midterm	(N=79)	(N=30)	
D or better	3%	0%	
C or better	20%	33%	
B or better	49%	43%	.60
A	24%	23%	
Creative work beyond good grades	4%	0%	
In CHE 311 – Midterm	(N=48)	(N=15)	
B or below	46%	80%	.04*
A or better	54%	20%	
In CHE 312 – Midterm	(N=44)	(N=16)	
B or below	36%	81%	.003*
A or better	64%	19%	
In CHE 446 – Midterm	(N=43)	(N=18)	
C or better	9%	6%	
B or better	30%	61%	.18
A	49%	28%	
Creative work beyond good grades	12%	6%	
In remaining senior CHE courses	(N=51)	(N=16)	
D or better	2%	12%	
C or better	10%	12%	.52
B or better	53%	50%	
A	22%	19%	
Creative work beyond good grades	14%	6%	

TABLE 15
GUESSED FINAL GRADES IN CHEMICAL ENGINEERING COURSES

	Men	Women	p
In CHE 205 (beginning)	(N=84)	(N=34)	
A	45%	35%	
B	48%	59%	.77
C	5%	6%	
D	1%	0%	
F	1%	0%	
Average of guessed grades	3.35	3.29	.43†
Average of actual grades	2.28	2.12	.48†
In CHE 312 (midterm)	(N=44)	(N=16)	
A	41%	19%	
B	50%	38%	.01*
C	9%	44%	
Average of guessed grades	3.32	2.75	.01†*
Average of actual grades	3.33	2.94	.06†*

†Wilcoxon's rank-sum test

TABLE 16
MOST LIKELY REASON IF PERFORMANCE IS BELOW EXPECTATIONS

	Men	Women	p
In CHE 205 (beginning)	(N=85)	(N=34)	
Lack ability	12%	9%	
Don't work hard enough	61%	71%	.87
Course too demanding	16%	12%	
Problems in personal life	11%	9%	
In CHE 311 (midterm)	(N=46)	(N=15)	
Lack ability	4%	13%	
Don't work hard enough	52%	33%	.29
Course too demanding	26%	20%	
Tests/grading unfair	2%	0%	
Problems in personal life	15%	33%	
In CHE 312 (midterm)	(N=43)	(N=16)	
Lack ability	0%	12%	
Don't work hard enough	60%	31%	.02*
Course too demanding	9%	31%	
Tests/grading unfair	9%	0%	
Problems in personal life	21%	25%	
In CHE 446	(N=43)	(N=18)	
Lack ability	2%	11%	
Don't work hard enough	70%	67%	.39
Course too demanding	16%	6%	
Tests/grading unfair	2%	0%	
Problems in personal life	9%	17%	
In remaining senior CHE courses	(N=51)	(N=16)	
Lack ability	4%	12%	
Don't work hard enough	69%	62%	.80
Course too demanding	14%	12%	
Tests/grading unfair	6%	6%	
Problems in personal life	8%	6%	

TABLE 17
MOST LIKELY REASON IF PERFORMANCE EXCEEDS EXPECTATIONS

	Men	Women	p
In CHE 205 (beginning)	(N=83)	(N=34)	
Real ability	31%	26%	
Work hard	63%	62%	.29
Help or support from someone else	5%	3%	
Course easier than expected	1%	6%	
Lucky	0%	3%	
In CHE 311 (midterm)	(N=47)	(N=15)	
Real ability	19%	13%	
Work hard	47%	33%	.36
Help or support from someone else	4%	20%	
Helped by group work	19%	27%	
Lucky	11%	7%	
In CHE 312 (midterm)	(N=44)	(N=16)	
Real ability	18%	6%	
Work hard	50%	38%	.27
Help or support from someone else	5%	19%	
Helped by group work	14%	12%	
Lucky	14%	25%	
In CHE 446	(N=43)	(N=18)	
Real ability	28%	22%	
Work hard	42%	44%	.04*
Help or support from someone else	0%	17%	
Helped by group work	16%	0%	
Lucky	14%	17%	
In remaining senior CHE courses	(N=51)	(N=16)	
Real ability	29%	12%	
Work hard	41%	44%	.14
Help or support from someone else	2%	19%	
Helped by group work	16%	19%	
Lucky	12%	6%	

TABLE 18
ATTITUDES TOWARD EXPERIMENTAL COURSES

	Men	Women	p
Attitude to the research project	(N=43)	(N=16)	
Willing and benefitting	67%	81%	
Willing but not benefitting	16%	19%	.78
Indifferent	9%	0%	
Feel like a guinea pig	5%	0%	
What project?	2%	0%	
Fairness of test grading in CHE 205	(N=79)	(N=31)	
Very fair	14%	39%	.02*
OK	67%	52%	
Unfair	19%	10%	
Fairness of test/homework grading in CHE 311	(N=48)	(N=15)	
Very fair	33%	33%	.71
OK	58%	67%	
Unfair	8%	0%	
Lectures	(N=50)	(N=16)	
Very helpful	36%	62%	.14
Helpful	54%	38%	
Not very helpful	10%	0%	
Challenge problems	(N=50)	(N=16)	
Very helpful	6%	12%	
Helpful	26%	44%	.32
Not very helpful	50%	38%	
Not at all helpful	18%	6%	
Overall attitude to AICHE Student Chapter	(N=44)	(N=16)	
Very helpful/positive	7%	12%	
Somewhat helpful/positive	30%	75%	.003*
Neutral	16%	6%	
Didn't participate	48%	6%	
Availability of workstations in CHE 205	(N=79)	(N=31)	
Always	56%	81%	.05*
Usually	41%	19%	
Often have trouble	4%	0%	
Instructiveness of experimental courses compared to other CHE courses	(N=51)	(N=16)	
More instructive	96%	81%	.08*
About same	4%	19%	

TABLE 19
SELF-RATING OF ABILITY TO SOLVE BASIC PROBLEMS

	Men	Women	p
In CHE 312	(N=44)	(N=16)	
Excellent	30%	6%	
Good	57%	62%	.06*
Average	9%	31%	
Fair	5%	0%	
In CHE 446	(N=44)	(N=18)	
Excellent	39%	17%	
Good	50%	44%	.04*
Average	11%	33%	
Fair	0%	6%	
At end of senior year	(N=51)	(N=16)	
Excellent	35%	19%	.06*
Good	59%	56%	
Average	6%	25%	
In industry	(N=44)	(N=18)	
Excellent	50%	33%	
Good	43%	33%	.04*
Average	5%	28%	
Fair	2%	6%	

TABLE 20
SELF-RATING OF ABILITY TO SOLVE CHALLENGING PROBLEMS AND COMPUTER PROBLEMS

	Men	Women	p
Creative problems – CHE 312	(N=44)	(N=16)	
Excellent	9%	0%	
Good	48%	25%	.19
Average	27%	56%	
Fair	11%	12%	
Poor	5%	6%	
Creative problems – CHE 446	(N=43)	(N=18)	
Excellent	26%	6%	
Good	51%	56%	.24
Average	19%	33%	
Fair	2%	6%	
Poor	2%	0%	
Creative problems – end of senior year	(N=51)	(N=16)	
Excellent	22%	0%	
Good	63%	44%	.005*
Average	14%	50%	
Fair	2%	0%	
Poor	0%	6%	
Challenging problems in industry	(N=44)	(N=18)	
Excellent	30%	0%	
Good	48%	61%	.03*
Average	16%	28%	
Fair	7%	11%	
Computer problems at end of senior year	(N=51)	(N=16)	
Excellent	33%	6%	
Good	51%	56%	.07*
Average	12%	31%	
Fair	2%	6%	
Poor	2%	0%	

TABLE 21
HELPFULNESS OF IN-CLASS GROUP WORK

	Men	Women	p
In CHE 311	(N=48)	(N=15)	
Excellent	6%	20%	
Very good	27%	47%	.09*
Average	40%	20%	
Fair	17%	0%	
Poor	10%	13%	
In CHE 312	(N=44)	(N=16)	
Excellent	16%	31%	
Very good	48%	56%	.48
Average	20%	12%	
Fair	7%	0%	
Poor	9%	0%	
In CHE 446	(N=44)	(N=18)	
Excellent	23%	33%	
Very good	39%	44%	.76
Average	30%	22%	
Fair	2%	0%	
Poor	7%	0%	
In all experimental courses	(N=51)	(N=16)	
Helpful	73%	94%	.10*
Not helpful	27%	6%	

TABLE 22
HELPFULNESS OF GROUP HOMEWORK

	Men	Women	p
In CHE 205	(N=79)	(N=31)	
Excellent	34%	48%	
Very good	32%	29%	
Good	15%	10%	.89
Average	9%	10%	
Less than average	5%	3%	
Poor	3%	0%	
Terrible	3%	0%	
In CHE 311	(N=48)	(N=15)	
Excellent	56%	100%	
Very good	25%	0%	.02*
Average	12%	0%	
Fair	6%	0%	
In CHE 312	(N=44)	(N=16)	
Excellent	41%	69%	
Very good	36%	25%	.23
Average	16%	0%	
Fair	5%	6%	
Poor	2%	0%	
In CHE 446	(N=44)	(N=18)	
Excellent	36%	61%	
Very good	52%	22%	.09*
Average	5%	11%	
Fair	7%	6%	
In all experimental courses	(N=51)	(N=16)	
Very helpful	75%	88%	.61
Helpful	24%	12%	
Not very helpful	2%	0%	

TABLE 23
WOULD YOU CHOOSE TO WORK ALONE FOR REMAINDER OF COURSE?

	Men	Women	p
In CHE 311	(N=48)	(N=15)	
Definitely	2%	0%	
Probably	12%	0%	.09*
Probably not	42%	20%	
Definitely not	44%	80%	
In CHE 312	(N=42)	(N=16)	
Definitely	2%	0%	
Probably	5%	6%	.61
Probably not	33%	19%	
Definitely not	60%	75%	
In CHE 446	(N=44)	(N=18)	
Probably	5%	6%	.02*
Probably not	45%	11%	
Definitely not	50%	83%	

TABLE 24
ASSESSMENT OF TEAMWORK AND INDIVIDUAL CONTRIBUTIONS TO GROUPS

	Men	Women	p
Teamwork of group in CHE 311	(N=48)	(N=15)	
Very good/Excellent	67%	93%	.05*
Average/Fair/Poor	33%	7%	
Teamwork of group in CHE 312	(N=44)	(N=16)	
Excellent	11%	12%	1.00
Very good	34%	38%	
Average/Fair/Poor	55%	50%	
Teamwork of group in CHE 446	(N=44)	(N=18)	
Excellent	9%	11%	
Very good	39%	44%	.85
Average/Fair/Poor	52%	44%	
Teamwork of groups in all experimental courses	(N=51)	(N=16)	
A	29%	31%	.50
B	61%	50%	
C/D/F	10%	19%	
How much you did you do in your groups?	(N=51)	(N=16)	
More than my fair share	24%	12%	.72
Fair share	59%	69%	
Less than my fair share	18%	19%	
How valued were your contributions by others?	(N=51)	(N=16)	
Highly valued	20%	6%	
Valued	71%	56%	.02*
Undervalued	6%	38%	
Discounted or ignored	4%	0%	

TABLE 25
PERCEIVED BENEFITS OF GROUP WORK

	Men	Women	p
Greatest benefit - CHE 311	(N=48)	(N=15)	
Getting homework done	35%	27%	.35
Understanding material	60%	60%	
Preparing for tests	4%	13%	
Greatest benefit - CHE 312	(N=43)	(N=16)	
Getting homework done quickly	21%	25%	
Having the material explained	16%	38%	.42
Explaining the material to others	44%	31%	
Preparing for tests	16%	6%	
No benefit	2%	0%	
Greatest benefit - CHE 446	(N=43)	(N=18)	
Getting homework done quickly	21%	33%	
Having the material explained	23%	50%	.07*
Explaining the material to others	40%	17%	
Preparing for tests	12%	0%	
No benefit	5%	0%	
How should homework groups work?	(N=51)	(N=16)	
Each work on all problems and compare	6%	25%	.07*
Set up problems individually and complete together	55%	56%	
Work together on all problems	39%	19%	

TABLE 26
POST-GRADUATION PLANS

	Men	Women	p
In CHE 312	(N=44)	(N=16)	
CHE graduate school	20%	6%	
Other graduate school	32%	6%	.03*
Work towards career	20%	56%	
Work a few years, then graduate school	20%	31%	
Year off	7%	0%	
In CHE 446	(N=43)	(N=18)	
CHE graduate school	19%	17%	
Other graduate school	16%	0%	.05*
Work towards career	28%	67%	
Work a few years, then graduate school	33%	17%	
Year off	5%	0%	
At end of senior year	(N=51)	(N=16)	
CHE graduate school	20%	12%	
Other graduate school	12%	0%	.10*
Work towards career	41%	81%	
Work a few years, then graduate school	22%	6%	
Year off	6%	0%	

TABLE 27
SENIORS' REQUIREMENTS FOR JOB SATISFACTION

	Men	Women	p
Enjoying work	(N=44)	(N=18)	
Very important	91%	100%	.31
Fairly important	9%	0%	
Good relations with coworkers	(N=44)	(N=18)	
Very important	82%	94%	.26
Fairly important	18%	6%	
Meeting/exceeding employer expectations	(N=44)	(N=18)	
Very important	57%	89%	
Fairly important	39%	11%	.06*
Not very important	2%	0%	
Not at all important	2%	0%	
Opportunities to work on a team	(N=44)	(N=18)	
Very important	36%	72%	.04*
Fairly important	48%	22%	
Not very important	16%	6%	
Good salary and benefits	(N=44)	(N=18)	
Very important	18%	39%	
Fairly important	66%	56%	.35
Not very important	14%	6%	
Not at all important	2%	0%	
Assignments that challenge abilities	(N=44)	(N=18)	
Very important	43%	28%	.08*
Fairly important	57%	61%	
Not very important	0%	11%	
Doing creative/innovative work	(N=44)	(N=18)	
Very important	48%	28%	
Fairly important	48%	56%	.15
Not very important	5%	11%	
Not at all important	0%	6%	

TABLE 28
ANTICIPATED PROBLEMS ON FIRST JOB

	Men	Women	p
Most likely reason for problem on first job	(N=42)	(N=18)	
Inadequate technical preparation	14%	11%	
Lack interpersonal/communication skills	14%	6%	.008*
Lack confidence	21%	61%	
Conflict with supervisors or colleagues	31%	0%	
Bad luck	19%	22%	
Second most likely reason for problem on first job	(N=42)	(N=18)	
Inadequate technical preparation	12%	50%	
Lack interpersonal/communication skills	14%	0%	.02*
Lack confidence	26%	11%	
Conflict with supervisors or colleagues	24%	17%	
Bad luck	24%	22%	
Priority in conflicts between job and family	(N=42)	(N=17)	
Job	36%	12%	.11
Family	64%	88%	