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Engineering Undergraduate Attrition and Contributing Factors*

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The current work environment requires engineers to be global citizens, as well as aspirational, ethical leaders. To foster this new generation of engineering talent, modern curricula must advance strong analytical skills, creativity, professionalism, and leadership. However, a new curriculum with poor student retention cannot be deemed successful. The key components of a successful curriculum appear to be well-designed academic programs, dedicated faculty and strong support services. At the Ira A. Fulton School of Engineering (FSE), we believe that we possess these key components and yet approximately 65% of enrolled students leave our School. There is widespread speculation about the reasons for leaving, including financial need and lack of academic preparedness. To address these national and local attrition-related phenomena, a survey was designed to obtain clear quantitative information about why students leave FSE. During the fall 2005, students, who over several years transferred from engineering to a different school within ASU, were asked to complete an online survey. The hope was that information gained could be a basis for decision making and assessing proposed improvements for increasing retention. The aim of the study was to discover factors with the greatest bearing upon the decision to leave engineering. This research elicited student attitudes concerning educational experiences in their new major contrasted to their engineering experiences. The key questions investigated in this research are: What factors contribute to the decision to leave FSE? How does the student's experience in their new major compare to their experience in engineering? What factors in our programs promote loss of student talent?

Keywords: Advising, assessment, culture, curriculum, education, engineering, faculty, persistence, and retention

INTRODUCTION

THE FULTON SCHOOL of Engineering is one of many institutions concerned with the problem of attracting and retaining the best and brightest of our young citizens. Nationally, engineering programs are losing top performing students, whereas research has shown that retaining students is less expensive than recruiting new students. Furthermore, Wankat [1], asserted that higher retention rates more than pay for the costs of redesigning courses. ASU administrators have argued that first year persistence and graduation rates are standard measures of academic quality as well as measures of institutional effectiveness. They have called for increased examination of persistence issues and interventions.

Many have written on the subject, diagnosing the impediments and suggesting solutions. Our research added local, but not necessarily unique, information about our specific problem. As in previous research, former FSE students' reasons for leaving can be grouped into four main categories of dissatisfaction: Academic and Career Advising; Engineering Structure, Curriculum, and Culture; Faculty; and High School Preparation. More specifically, our findings indicated that when compared with their new major, most students had greater language difficulties with international faculty and TAs in FSE. Students felt quality of instruction was poorer and faculty members were less approachable regarding academics and advising while engineering was their major. Additionally, a majority of students experienced poorer recitation support, more conceptual difficulties, and problems with class size in engineering. They also reported low morale due to the competitive culture and lack of peer support. Also our findings showed that students were less satisfied with engineering advisors and career counseling and were less likely to agree that the career options and rewards were worth the effort to pursue engineering. (Former engineering data were compared to 'new major' and all findings represent significant differences between the two majors.) Finally, some students felt they lacked 'adequate' high school preparation for the engineering major in terms of science and mathematics education. In total, the responses given by former FSE undergraduate students who remained at the University are completely consistent with the national literature on the subject of retention and why students leave engineering.

We have organized our report in the following manner. We start each section with a summary of national data and the reasons for leaving engineering

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reported by other researchers. Then, we provide the FSE responses and current retention efforts. It is noteworthy that many of the scholarly findings support anecdotal information frequently reported to us from students and faculty regarding attitudes and experiences. At the close of this report, we use national research, best practices, and FSE survey results to suggest a general set of recommendations. Our challenge is to find viable solutions to increase number and diversity of FSE graduates.

ACADEMIC AND CAREER ADVISING

Nationwide, students have identified academic advising and career counseling as critical needs that have not been successfully met. Specifically, students suggested that departmental advisors should provide: a) advice on academic and career alternatives and how best to pursue them and b) accurate information on required courses and appropriate sequencing in order to fulfill particular degree requirements. Inadequate advising was mentioned as a concern by 81% of engineering switchers and inadequate advising was an issue raised by 53% of all non-switchers [2]. (A switcher is a student who 'switches' to a non-engineering major, whereas a non-switcher is a student who persists in engineering.) On seven distinct engineering program campuses, there was a common theme from students. They reported gaps, overlaps and confusion in division of responsibility between departments, central advising services, faculty, as well as advising programs for underrepresented groups.

One of the most difficult problems reported for freshmen was learning quickly enough the campus system of advising, counseling, and tutorial services in order to prevent small problems from becoming large ones. Students believed that advisors provided inaccurate information about course requirements and lacked information about special programs, sources of financial help, and career opportunities. Moreover, advisors were typically too overwhelmed with student load to provide adequate care [3]. Our survey responses are consistent with national findings and highlight lack of satisfaction with engineering and career advising when compared with the new majors.

FSE results: academic advising, career advising, and career opportunities

Students were less satisfied with advising regarding both academics and career counseling. In addition, they were less likely to agree that the career options were worth the effort. See Table 1.

Some argue that the engineering field is relatively invisible in the mass media or poorly depicted [4]. According to the National Academy of Sciences [5], students frequently believe that engineering classes are too time consuming, without realizing that the rewards are worth the effort. Researchers at the University of Washington conducted a longitudinal study of female undergraduate students in engineering and science. They found awareness of career opportunities in science and engineering to be an important persistence factor for freshmen [6]. Some engineering students fail to see the potential benefits of engineering or where it fits into the big picture in society [5]. If engineering could make its societal value explicit, it would help attract and retain future students and significantly increase the persistence of women and minorities [7]. Females value human interaction, yet engineering is not perceived to offer that exchange [4]. Engineering has simply not gotten the message across that it places a high priority on helping society, fosters teamwork, and employs diverse interpersonal skills.

ENGINEERING STRUCTURE, CURRICULUM, AND CULTURE

Issues that factor into student attrition are from a common set of problems experienced by both switchers and non-switchers [2]. Some even argue that problems stem from engineering structure, curriculum, and culture, which have contributed to attrition more than individual inadequacies or appeal of other majors. National studies have compared issues reported by students who switch and those who do not. Both groups reported poor teaching and difficulty in getting help with academic problems as major issues (90% of switchers and 74% of non-switchers). Also about 40% of switchers and non-switchers reported inadequate high school mathematics and science preparation [8]. What distinguished the survivors from those who left was not the nature of their problems, but whether they were able to assess problems accurately and find resources quickly enough to survive. Often faculty intervention played a large role during a crisis point in the student's academic or personal life.

Introductory science courses at the university level are often held in large lecture classrooms in which students may feel isolated and uncomfortable

Table 1. Academic and career advising

Survey Item	FSE	New Major	Std. Deviation	p-value ≤ 0.05
Q3 Quality of Advising	2.75	3.91	1.07	.000
Q22 Satisfaction with career counseling	2.40	3.64	1.09	.000
Q6 Career options worth the effort to get the degree	3.25	4.33	.832	.000

Range, 5 = Strongly Agree to 1 = Strongly Disagree. Career counseling satisfaction range: 5 = High to 1 = Low

Table 2. Engineering structure, curriculum, and culture (FSE curriculum load and financial problems were not significantly different from the new major)

Survey Item	FSE	New Major	Std. Deviation	p-value ≤ 0.05
Q8 I had conceptual difficulties with subjects	3.11	1.95	1.10	.000
Q15 I had problems related to class size	2.72	1.89	1.26	.000
Q14 I had poor recitation support by TAs	3.13	1.76	.987	.000
Q17 I enjoyed my courses	2.81	4.37	1.40	.000
Q12 Experienced low morale due to the competitive culture	2.75	1.72	1.45	.000
Q18 I had peer support in my major	2.66	4.03	1.57	.000

interacting with the instructor. Seymour [3] found that science, math, and engineering switchers and non-switchers indicated that large classes contributed to the poor quality of their learning experiences. In research institutions, some faculty members put greater emphasis on research than teaching and tend to promote a weed-out system. Furthermore, the competitive engineering culture contributed to student decisions to leave [2].

In a longitudinal study of persistence of undergraduate women in engineering and science at the University of Washington, researchers found that both freshmen and sophomore women were most likely to persist if they enjoyed their math and science classes. Freshmen persisters also considered women's programs and faculty to have a positive influence on them, while sophomore persisters had a positive relationship with an advisor and felt accepted in their department [6]. At that time some departments in the University of Washington, College of Engineering instituted policy changes to provide engineering curriculum in the sophomore year rather than the junior year.

FSE results

Survey respondents reported more conceptual difficulties with subjects, more issues relating to class size, and poorer recitation support by TAs in engineering compared to the new major. In addition, former engineering students experienced low morale due to the competitive culture in engineering and indicated that they lacked peer support in engineering. See Table 2.

These patterns of responses are not unique to FSE. A national curricular model, *Invention 2000*, was created by faculty teams who visited 31 universities and studied curriculum in a wide range of institutions [5]. Their call for systemic changes in engineering education included: 'a shift from disciplinary to interdisciplinary approaches; more emphasis on the social, environmental, business, and political context of engineering; and emphasis on engineering practice and design throughout the curriculum' (p. 105).

The NAE recommended that the following approaches should be taught from the earliest stages of the curriculum, including the first year: the iterative process of designing, predicting performance, building, and testing. They indicated that it was critical to engage students in courses that connect engineering design and solutions to real-world problems [5]. Using teaching techniques that engage students and focus upon context would attract and retain more diverse students, who are not learning under the standard lecture-style, large-class, educational system.

FSE is currently addressing these issues by introducing a revamped curriculum that reduces the required credit hours, increases life-sciences studies, and introduces freshman and sophomores to more engineering courses.

FACULTY

National studies reveal that science, math, and engineering students are generally dissatisfied with faculty advising and academic support [2, 3, 5]. Both switchers and non-switchers indicated that advisory systems were poorly organized and often, faculty did not keep their office hours, or discouraged students from attending. In addition, counseling on academic or financial matters was ineffective [9]. Problems often stemmed from students assuming a broader role for faculty advisors than faculty expected.

FSE results: faculty

Survey respondents indicated less satisfaction with the 'quality of instructors' and found faculty

Table 3. Faculty

Survey Item	FSE	New Major	Std. Deviation	p-value ≤ 0.05
Q19 Faculty are approachable	2.59	4.34	1.44	.000
Q2 Quality of instructors*	2.92	4.23	1.35	.000
Q26 Had adequate advising or help with academics (faculty)	2.77	3.43	1.78	.000
Q13 Had language difficulties with international faculty/TAs	3.60	1.71	1.65	.000
Q24 Had research opportunities with faculty[1]	1.93	3.23	1.70	.000

* Quality of instructor scale: High = 5 to Low = 1.
[1] Note that with the new opportunities for undergraduate research supported by the new Fulton Undergraduate Research Initiative, we have already addressed this problem, to a certain degree.

to be less approachable when engineering was their major. Students had greater language difficulties with international faculty and TA's in the engineering major. Also students felt less satisfied with advising or help with academic problems (engineering faculty specifically). Furthermore, students reported a lack of research opportunities with engineering faculty. See Table 3.

Again, FSE findings are consistent with national data. Poor teaching in STEM classes has been the most common complaint, mentioned by 90.2% of those who left engineering [10]. Students believed the source of the problem to be that faculty 'do not value teaching as a professional activity, and thus, lack the incentive to learn to teach effectively' (p. 146). Furthermore, students perceived that instructors were too busy to meet with them. In one study, 12% of men and 20% of women indicated that professors had no time for students [11]. Conversely, many of the professors did not feel this was the case. Faculty complained that very few students came to office hours although this was time intentionally set aside. It is likely that professors were not adequately communicating their interests to students. However, an instructor's willingness to provide help is not the only factor influencing student behavior. There are often other issues present that ultimately deter students from getting the help they need, such as faculty or instructor approachability and language barriers.

OTHER INFLUENCES: LACK OF HIGH SCHOOL PREPARATION

At a national roundtable held November 2005, a number of university presidents noted the below-average school systems and said that turning a blind eye to neighboring troubled schools is deplorable. Michael Crow (ASU's president) stated that ASU certifies 1500 teachers a year, but the degrees mean little if graduates are not equipped to properly educate primary and secondary school students. He further pointed out that the 'problem is completely within the university' [12]. Mark Yudof, Chancellor of the University of Texas System added, 'It's almost immoral to say there's something wrong with K-12 education without doing something about it' and he cited a UT-created charter school that uses research-based methods of teaching. Nationally, students' accounts of under-preparation were broadly of two types: deficiencies of curriculum content and subject depth, and failure to acquire appropriate study skills, habits and attitudes. Some switchers had received little to no high school teaching in calculus, or described the content and depth of their high school science or math as insufficient [10]. Former FSE student data are in alignment with national data.

FSE results

Former FSE students felt that they lacked adequate high school preparation for the engineering major (Table 4). Current ASU programs and projects are underway to partially address this issue and it is evident that university presidents believe that it is a university issue.

The Director of CRESMET (Center for Research on Education in Science, Mathematics, Engineering, and Technology), Dr. Marilyn Carlson, stated that the five-year NSF funded grant, Math, Science Partnership (MSP) with high school teachers 'will be addressing some of the issues revealed in the Fulton survey and that the grant project will be infusing some engineering design principles and information about what engineers do in the MSP interventions'. However, Carlson also indicated that to make a 'real impact on what is reported here, some bigger and united efforts will be needed' (personal interview, 11/14/2005). CRESMET is initiating efforts on this front.

RECOMMENDATIONS BASED ON NATIONAL BEST PRACTICES

Advising:

- Define and communicate roles to improve coordination of diverse advising services.
- Reduce advising load and train advisors to increase information accuracy regarding course requirements, as well as disseminate knowledge and refer students to special programs, financial, academic and career resources.

Engineering curriculum, structure, and culture:

- Expose first-year students to design process, predictive performance, building, and testing.
- Connect engineering design and solutions to real-world problems, reveal social relevance.
- Facilitate shift to interdisciplinary approach; emphasize business, environmental, and political context of engineering.
- Employ strategies which in effect reduce class size [5].
- Improve student climate with summer programs, cohort groups, peer mentors, and special housing; reward students for collaborating with classroom peers.

Faculty:

- Disseminate NAE's, Educating the Engineer of 2020 and Implement Wankat's 'Perfect 10'

Table 4. High school preparation

Survey Item	FSE	New Major	Std. Deviation	p-value ≤ 0.05
Q9 Had adequate high school preparation for the major	3.36	3.99	1.36	.000

elements to increase perception of faculty teaching quality and approachability
- Provide workshops for TAs to develop effective teaching skills, with handouts such as 'Helping Graduate TAs Lead Discussions with Undergraduate Students' [13]. Also, given the rising number of international graduate students, workshops should assist them in communicating in English and understanding our cultural differences (e.g., see UCSB's, International TA Handbook http://www.oic.id.ucsb.edu/TA/) Undergraduate students would benefit from workshops on understanding international instructors (e.g., http://www.indiana.edu/~comu/instruct.html).
- Reward faculty for teaching excellence
- Expand Fulton Undergraduate Research Initiative (FURI) to mentor research of additional students
- Reward departments for hiring female and underrepresented minority faculty

High school preparation:
- Work with successful units on campus to improve math and science preparation (e.g., CRESMET, AISES, WISE, MESA, Math/Science Honors Program, Alpha Partnership, CARSEF, & Sally Ride)

Academic and career advising:
- *Advisors instill student success:* In an ASU presentation titled, *Student Success: Improving Retention and Graduation Rates at Arizona State University,* (See Appendix A), the following was suggested: advisors should treat each student interaction with the diligence, caring and professionalism that they would want for themselves or a family member; and they should be approachable. Advisors should recognize their key role in student success and participate in any retention efforts underway in their area.
- *Show engineering application:* To shed a positive light on engineering, advisors and faculty can show applications of the coursework so the students can connect what they are studying to the 'real world.' The perceived relevance of scientific process and content to everyday life experiences is a factor in science interest and participation at the collegiate level [5, 14].
- Provide Outreach to Primary and Secondary Schools: To confront stereotypes when they form, faculty and undergraduates could participate in workshops and outreach for elementary and secondary school students. This may help change stereotypes at a young age and can also help the college students gain confidence in their abilities by enabling them to serve as role models for younger students.
- *Provide diverse role models:* Many undergraduates cite the importance of their male role models or mentors in assisting them in pursuit of a science career. Although men have been important advocates, role models, and mentors for women scientists, students need more exposure to females who are successful in engineering fields. ASEE national data showed that just 6 percent of full professors, 12 percent of associate professors, and 18 percent of assistant professors are women [4]. Sanoff asserted that because women look to faculty members as role models, the low numbers could 'reinforce the lack of interest women show in engineering' ([4], p 28).
- *Increase female faculty:* Ultimately, the best solution is to hire and retain female faculty who can serve as role models. Women faculty members who have families can also choose to share their stories about balancing work and family. In a study at a State University of New York, Robst, Keil, and Russo [15] found a positive relation between retention of undergraduate female students and percentage of science and math credits taken with female instructors. Also they found that a greater percentage of female students in those classes lead to increased female retention, however the effect of female faculty fell as the percentage of female students rose. They found no significant relationship for male students' retention rates. They concluded their results provided support for gender-based programs for hiring in specific disciplines. Astin has found that the percentage of women on the faculty at coed institutions to be positively correlated with students' satisfaction with faculty [16]. According to the National Resource Council, the presence of women faculty at all ranks would be a sign to female students that they will be respected and treated fairly [17].
- *Provide guest lecturers and media presentations:* Faculty could provide role models to students by bringing guest lecturers to talk about their experiences or to give a lecture in their field of expertise. Also, videos or DVDs of scientists describing their research could be included during class or structured as extra credit. In order to acknowledge women's contributions to science, administrators could invite female scientists, including post-docs and graduate students from other universities, government and industry, to give colloquia as part of a department's regular colloquium series.

Engineering curriculum, structure and culture:
- *Personalize large classes and reduce class size:* The size and demographics of a university class may be different from what students experienced in high school. When females were asked what they disliked about large classes, they stated that such courses were impersonal and that the professor didn't know who they were; consequently, they felt isolated. Research has revealed that females are less willing to ask questions in large lecture settings [18]. In a study by Hewitt and Seymour, 1991, 30% of women surveyed felt that it was 'a problem' if instructors did not care about students. Females described a good

professor as approachable, friendly, and someone who wanted to get to know students. College females perceived that learning was more difficult due to lack of close contact with faculty [9]. Audiences in large classroom settings could be broken into smaller groups for short episodes of peer discussion and to work on problems, scientific inquiry, and other active exercises. Alternatively, cooperative small group learning situations could be provided during recitation sessions with graduate student teaching assistants to compliment lecture instruction, with an otherwise unchanged lecture and lab pedagogy [8, 19, 20]. Online courses may use student groups led by a teaching assistant 'coach' as the main vehicle to gain mastery, and offer mini-lectures on an 'as needed' basis to clarify common areas of difficulty. Another technology-supported alternative is the 'virtual classroom' that offers student-student and student-faculty computer teleconferencing as the delivery system, with computer-generated data and examples [2]. Another option to reduce class size is to offer interdisciplinary one-unit seminars, which provides opportunities for students to get acquainted with speakers in a more intimate setting.

- *Improve Quality of Graduate-Level Teachers:* Graduate students are often asked to lead discussion groups (also called recitation section). However, these students have minimal instructional training; thus, in their preparation, *what* to teach is emphasized over *how* to teach [13]. As a result, students feel that they have poor recitation support by TAs, a finding also evident in this current FSE study. Jensen *et al.* described teaching strategies for TAs such as: helping students prepare for exams; brainstorming to work through essay questions; holding post-exam discussions covering wrong answers in addition to correct answers; and employing group work. Purdue University offers a course titled, 'Educational Methods in Engineering'. In a survey conducted by Wankat those graduates of the course currently active in academia reported 'a very significant impact on their careers' ([21], p. 925).
- *Shift from a competitive to a cooperative educational model:* It is a common belief among first-year students that introductory math and engineering classes are 'weedouts.' The perception of a 'weeding out' atmosphere discourages many interested students from pursuing engineering degrees. Some faculty members think that deficits in ability distinguish those who leave from those who remain. Widespread acceptance of this theory allows schools and departments to regard student attrition as a kind of 'natural selection' process [3]. In fact, studies have shown repeatedly [3, 22–24] that students who leave the sciences are intelligent and strongly motivated, but are discouraged by the competitive atmosphere. One study found that 33% of the students switching out of a science, math, or engineering field indicated that one of their primary reasons for leaving was that their morale was undermined by competitive culture [9]. NAE 2005 asserted that 'accepting attrition as inevitable is both unfair to students and wasteful of resources and faculty time' [5] (p. 53). Educators have realized that they can not afford to discourage engineering students because retention numbers must improve in order to meet the country's projected demand for engineers. Rather than functioning as 'gatekeeper' courses, calculus and physics should be redesigned so that motivated students can master them. Courses should be developed to show connections between subjects to improve relevance.
- *Faculty utilize cooperative and collaborative work:* Faculty who teach introductory science courses should shift the pedagogical focus away from a competitive, 'weeding out' model to a cooperative, stimulating model to retain more talented, diverse students. There are several ways to shift this focus.
- *Provide cooperative opportunities in introductory classes.* Melsa argued that there is sufficient evidence that learning is enhanced through cooperative experiences [25]. Cooperative learning is an approach to learning which uses small groups of students working together to solve problems, complete a task or accomplish a common goal. Small groups provide a forum in which students ask questions, discuss ideas, make mistakes, learn to listen to others' ideas, offer constructive criticism, and summarize their discoveries in writing National Council of Teachers of Mathematics [26]. Besides improved academic achievement, some have noted improvement in critical thinking and reasoning abilities, self-esteem, and social skills [27]. Also bright students can be given the opportunity to assist others' learning through peer mentoring [25].

A meta-analysis by Springer, Stanne, and Donovan [28] indicated that students who learn in small groups demonstrate greater academic performance, express more positive attitudes toward learning, and persist in STEM courses and programs more than their more traditionally taught counterparts. They suggested that the provision of small group alternatives to lecture-based instruction 'may have particularly large effects on the academic achievement of members of underrepresented groups and the learning-related attitudes of women and pre-service teachers' (p. 42). Of particular note is that these researchers reported a 22% difference in attrition rate with small-group learning. This substantial effect upon student retention occurred across multiple postsecondary institutions with vastly different forms of small-group activities. Small group learning is often provided with peer educators.

A review of colleges in the United States found that 76 to 83 percent of all higher education institutions utilize peer educators [29]. Most WISE programs include formal mentoring in which upperclassmen serve as role models for freshmen. These mentors help with homework, give advice, and ease the college transition [30].

Also anecdotal accounts about competitiveness in the classroom indicate that some students foster this climate because they perceive that attrition of students in engineering curricula will improve their chances of getting a preferred job when they graduate. One method to change this attitude would be to reward students with extra credit if they substantially improve the grade of a student with low midterm grades or help another team overcome difficulties with their project. Moving from 'survival of the fittest' to 'cooperative competitiveness' is designed to increase student success in meeting and exceeding course objectives. Giving students leadership roles in enhancing the level of overall class achievement can be important for development of their future professional career and management skills. This concept is widely practiced in robotic competitions such as the F.I.R.S.T. competition founded by the inventor Dean Kamen.

In order to provide more stimulating curricula, design introductory courses that are more discovery-oriented and explore interesting topics while teaching the 'basics.' When projects are problem-based, the students become active learners who are motivated to seek knowledge and skills to solve problems [20, 31].

Currently there is a nationwide emphasis upon developing more conceptual and exploratory-learning curriculum for undergraduates [32]. Resources exist to assist in the implementation of active learning experiences and team-based learning. Felder and Brent described typical undergraduate student reactions and faculty concerns regarding adoption of such activities [33]. Kaufman, Felder, and Fuller provided a method to account for individual effort in cooperative teams [34]. Yuretich described a variety of activities to promote higher-level reasoning and provided data to confirm efficacy of the techniques [32]. Ingram *et al.* created student-centered activities to foster inquiry outside of laboratory settings [35]. Similarly, Reeve, Hammond and Bradshaw initiated research workshops for students to practice formulating research questions and experimental protocols [19]. Vivas and Allada described thematic case-based learning to integrate course content with industry context [36]. Smith *et al.* summarized methods to engage students, particularly with cooperative and problem-based learning, and gave suggestions for redesigning engineering classes and programs to include them [37]. Also Hadgraft discussed adoption of problem-based learning and teamwork at the university department level [38].

Also a number of programs have incorporated engineering design, building, and testing into freshman curriculum. One example is the Engineering Division of Lafayette College's first-year engineering course [39]. Many programs emphasize the social relevance of engineering, such as Smith College's Picker Engineering Program [40] [41]. Others have emphasized an interdisciplinary approach, such as the University of Nevada's program, Entertainment: Engineering & Design, which partners with business [42]. Educators at Northwestern University's School of Engineering and Applied Science emphasized the need for future engineers to develop and use 'sustainable technology, benign manufacturing processes and an expanded array of environmental assessment tools' to maintain both healthy economies and environments [43].

- *Improve student climate with summer programs, cohorts, peer mentors, and housing:* The following programs improve learning climate and social integration for participants during the first crucial year of enrollment. The more integrated a student is in the social activities of a campus environment, the more likely the student is to persist in college [44].

Four types of programs are: summer programs, cohort groups, assigning peer mentors, and designating residence halls. First, a popular community-building experience is the summer program. Increasingly all freshmen, instead of only underrepresented minorities, are invited to attend classes for several weeks as a college orientation. Data support the value of these summer programs in increasing retention. Loftus [7] cited several compelling examples, such as since the inception of Syracuse's retention programs, the four-year graduation rate within the college of engineering and computer science has risen approximately 11 percent overall and 18 percent for females. Also, before the summer program at Virginia Tech was started in 1997, fewer than 30 percent of African American and Hispanic freshman engineering students graduated in engineering. That has increased to 52 percent for the first group and 63 percent for the second group of participants.

Second, some schools build community by creating learning cohorts. Cohort students are enrolled in the same basic classes each semester. In 1993 Texas A&M began their 'Learning Communities' cohort program. Currently Texas A&M has over 15 groups of 100 freshmen who learn together in the same sections of calculus, chemistry, and physics. Institution of cohort learning was believed to be especially valuable for students transitioning from a rural background to a large university setting [7]. Tinto reported that at the University of Oregon and the University of Washington, student cohorts may attend classes with 300 other students, but stay together for small discussion sections of up to 30 students lead by graduate or upper-level students [31]. Tinto stressed that students in learning communities create their own peer groups which support them both academically and socially.

Third, the use of peer educators can improve the learning atmosphere. A review of US colleges found that approximately 80% of all higher education institutions utilize peer educators [29]. Small-group learning is effective in a variety of contexts [28]. Also at Northwestern, implementing a peer-facilitated science workshop resulted in higher retention. Evidence suggested particular benefits for minority students in the program [20]. Most STEM WISE programs include formal mentoring in which upperclassmen serve as role models for freshmen women. The mentors help with homework, give advice, and serve as role models during the freshman year, which can be the most taxing [30].

A fourth method to build community is designating residence halls or floors for engineering students. All-engineering dorm options for men and women are increasing in popularity. Some benefits include less peer pressure to play versus study as well as increased opportunities for teamwork and peer mentoring [7]. In summary, these programs seek to ease the critical transition from high school to the college context. They are increasingly being implemented separately or in conjunction with each other to improve the learning climate for all students.

Faculty improve instruction: 'A Perfect 10'

In a recent *Prism* article, authors recommended ten proven steps to improve quality of instruction and approachability for engineering faculty [45]. These recommendations are condensed below.

1. Provide a list of educational objectives.
2. Teach inductively with simple examples.
3. Divide lecture time with activity intervals.
4. Break class into small groups to practice active learning.
5. Share enthusiasm and explain topic relevance.
6. Learn names of students.
7. Come early and stay late for lectures.
8. Encourage study groups for homework assignments.
9. Reduce time pressure on examinations.
10. Obtain written suggestions from students to improve learning; then initiate several.

It is suggested that implementing the 'Perfect 10' list of recommendations would increase faculty approachability in a number of ways. For example, learning and then using student names during the lecture makes instructors appear more interested in students. Arriving to class early and staying late encourages more questions before and after class, which may result in increased student visits to faculty during office hours.

Initiating the remaining 'Perfect 10' recommendations may affect the quality of teaching and also may enhance student self-confidence. Underrepresented students especially thrive in classes with a variety of project-based activities that require teamwork. Research shows that women have different learning styles from men. Women tend to thrive in project-based learning rather than lecture courses, especially when there's teamwork involved. As a result, schools are introducing design courses as early as the freshman year to give students a taste of what engineering is really like. At the University of Michigan, students in an Engineering 100 section build a greenhouse for nonprofit groups [7]. At Alverno College, an all women's college in Milwaukee, science classes, particularly the introductory ones, have used collaboration, which boosted students' self-confidence [46]. Women are more likely to blame themselves or to cite their own inadequacy when encountering academic problems whereas men tend to place responsibility for difficulties outside themselves [47]. A male student's response to a poor test grade, therefore, may be to blame the examination or to blame the professor for inadequate teaching. Women are more likely to believe they are incompetent when they receive just one bad exam grade and are in general less confident of their performance. Subsequently they make important decisions, such as the decision to change majors, based on either an inaccurate appraisal of their performance or on an insufficient amount of data, such as one poor test grade. Applying Wankat and Oreovicz's [45] suggestion in 'The Perfect 10' to reduce or eliminate time pressure on tests would be a good example of an adaptation to foster self-confidence.

- *Provide research opportunities with Fulton undergraduate research initiatives program:* Summer or academic-year research opportunities often allow students to recognize new aptitudes and get a better sense of the purpose of classroom learning. Hadgraft highlighted the benefits of student motivation and productivity when engaged in a research mission [38]. Also working with a faculty member or other researcher provides students with the opportunity to find role models and mentors and gain insight into what science is all about [48] [49]. By interviewing science mentors at numerous institutions in New York, Gafney found other benefits, as mentors observed, 'The work habits required for success in research can carry over and help students in their class work–things like good time management, careful note taking, and the ability to discern the more substantive issues of a problem' (p. 54). Nagda *et al.* studied how participation in undergraduate student-faculty research partnerships, which included peer advising, affected retention [49]. They found that between 1989 and 1994 participants in the program at University of Michigan's College of Literature, Science and the Arts had an attrition rate of 11.4% compared to a 23.5% rate for non-participants. They concluded from their data that participation effect was strongest for African American students and for sophomores.

These authors emphasized that such research partnerships for undergraduates successfully combine the educational and research missions of a university.

The Ira A. Fulton School of Engineering has initiated the Fulton Undergraduate Research Initiative (FURI) to encourage student research. Students are paid to conduct their own research projects under the guidance of a faculty mentor. All FURI students present their research findings during ASU's Undergraduate Student Research Symposium.

CONCLUSIONS

Members of Arizona State University's Fulton School of Engineering (FSE) Office of Academic Affairs and Strategic Initiatives developed and administered an online survey for non-persisting students. Local findings of complaints matched long-standing national trends. According to our survey results, we have ordered the top ten mean differences in students' responses for engineering versus their new majors:

1. language difficulties with international faculty or TAs
2. faculty approachability
3. enjoyment of courses
4. peer support in major; recitation support by TAs
5. quality of instructors
6. research opportunities with faculty
7. satisfaction with career counseling
8. conceptual difficulties with subjects
9. quality of advising
10. career opportunities worth effort to get degree.

It is notable that in the current survey, the highest level of dissatisfaction with engineering compared to other majors was due to difficulties with international instructors. This is a much greater factor than has been reported in the past. The authors believe this could reflect the national trend of greater percentages of international students enrolled in graduate engineering programs, thus more instruction provided by international TAs. The 2006 National Science Foundation's Science and Engineering Indicator suggested that the number of Science and engineering graduate students on temporary visas more than doubled between 1983–2003, rising from 19% to 27%' [50]. Survey results led to numerous recommendations based upon research data and best practices. Most of the former FSE students' top-ten factors listed above fall under the two categories of 1) Faculty and 2) Structure, Curriculum, and Culture. These would be improved by faculty receiving continuing education and adopting new teaching techniques such as Wankat's, 'A Perfect 10' [45]. Graduate students would benefit from teaching workshops. Also all freshmen should be exposed to discovery-based and small group learning with peers, as well as engineering activities, interdisciplinary contexts, and societal value of engineering. These aspects have been found to both improve learning in diverse student populations as well as inspire students to persist in obtaining an engineering degree.

FSE is committed to the challenge of developing viable solutions to increase overall retention rate as well as diversity of engineering graduates to meet both internal and external pressures for accountability and industry demands.

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APPENDIX

Methods and student demographics- former FSE student survey Fall 2005

Talking about Leaving, (Seymour, 2000) provided the impetus for our local FSE survey development. The intent was to create an instrument based on current, national data to serve the needs of our School and University and to examine alignment with national trends. The assessment process included emailing the online survey web link to 642 former FSE students. After the initial 20% response, follow-up phone calls were made to 450 students (final 40.7% response rate). Attention was paid to URM, females and FSE departments to ensure a representative sample.

Gender	Number of respondents (#)	Percentage of respondents (%)	Fulton dropouts by gender (#)	Fulton dropouts (%)
Female	77	29.5	144	22
Male	184	70.5	498	78
Total	261	100.0	642	100

Ethnicity	Number of respondents (#)	Percentage of respondents (%)	Fulton dropouts by gender (#)	Fulton dropouts (%)
AMERICAN INDIAN	7	2.7	17	3
ASIAN OR PACIFIC ISLANDER	23	8.8	58	9
BLACK	6	2.3	16	2
CAUCASIAN/WHITE	183	70.1	436	68
HISPANIC	30	11.5	76	12
NOT REPORTED	12	4.6	39	6
Total	261	100.0	642	100

Last Engineering Major	Number of respondents (#)	Percentage of respondents (%)	Fulton numbers by department* (#)	Fulton percent by department (%)
Bioengineering	26	10.0	434	13
Chemical Engineering	26	10.0	224	7
Civil Engineering	22	8.4	391	11
Computer Systems Engineering	78	29.9	816	24
Electrical Engineering	30	11.5	513	15
Industrial Engineering	13	5.0	161	5
Mechanical & Aerospace Engineering	66	25.2	869	25
Total	261	100.0	3408	100

**Source: FSE Undergraduate Enrollment Summary, 2004, Office of Institutional Analysis*
The table represents student's last major before he or she decided to drop out of Fulton School

Former FSE student respondents attended Arizona high schools (81%); the top three states supplying non-Arizona students were California, Illinois, and Nevada. While in engineering, 76% worked off campus. As first year students, 54% lived off campus and 46% lived on campus.

FSE switched $\leq$ 24 Hours	% below 2.0 GPA	% above 2.0 GPA	% above 3.0 GPA	Mean
GPA FSE	17%	39%	44%	2.74
GPA New	1%	40%	59%	3.08

GPA (n = 100 students left FSE $\leq$ 24 hours)