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Portraying the Academic Experiences of Students in Engineering: Students’ Perceptions of their Educational Experiences and Career Aspirations in Engineering.

Abstract

Understanding better the experiences of students pursuing an engineering degree is an important issue for the pedagogy of engineering programs. This study sought to identify students’ perceptions of their educational experiences and their motivations for and dreams of a career in engineering. The study also provided a snapshot of the current status of engineering education at this institution from the perspective of engineering students—including students’ decisions behind their choice of engineering as a major, the learning experiences of engineering students, and gender-related perspectives regarding engineering education. The findings suggest opportunities to improve the educational process for students in this engineering program.

Introduction

The quality of learning and attrition are two issues important to post-secondary engineering education. The quality of students’ learning and their decisions to stay or leave a program of study is a complex phenomenon based on interactions among students, faculty, and the environment. Learning and the decision to persist in engineering are largely influenced by the experiences of students during their course of study. Seymour and Hewitt and others recognized the importance of students’ perceptions and a need to understand better these experiences. This study presents the findings of the experiences of engineering students at one institution. The first part of this introduction reviews some of the findings of previous studies related to the quality of student learning experiences. The second part of the introduction focuses on previous studies related to the connection between student experiences and attrition in sciences, math, and engineering programs. The remainder of the paper describes this study and its findings, concluding with recommendations for improving the quality of students’ learning experiences.

Quality of student learning experiences

Alexander Astin addressed the question, "What environmental factors make the biggest difference in college students' academic development, personal development, and satisfaction?" He conducted a longitudinal study of 27,064 students at 309 baccalaureate-granting institutions. This work represented a large-scale attempt to study the impact of different approaches to general education on student development using a large national sample of undergraduate institutions and a wide range of student outcomes. He was primarily interested in the outcomes and in particular, how environments affect them. One-hundred-ninety-two environmental factors were investigated to determine which factors influenced students' academic achievement, personal development, and satisfaction with college.

Astin found that the particular manner in which the general education curriculum is structured makes very little difference for most of the 82 outcomes he identified. Instead, he found that two environmental factors—the frequency and quality of student-student interaction, and the
frequency and quality of student-faculty interaction--make the most difference. Student-student interaction produced significant effects on 18 of the top 22 outcomes and student-faculty interaction produced significant effects on 17 outcomes. Here are the lists of positive and negative factors in decreasing order of correlation:

Factors Positively Associated with Positive Student Outcomes

- Student-student interaction
- Student-faculty interaction
- A faculty that is very student-oriented
- Discussing racial/ethnic issues with other students
- Hours devoted to studying
- Tutoring other students
- Socializing with students of different race/ethnicity
- A student body that has high socioeconomic status
- An institutional emphasis on diversity
- A faculty that is positive about the general education program
- A student body that values altruism and social activism

Factors Negatively Associated with Positive Student Outcomes

- Hours spent watching television
- Institutional size
- Use of teaching assistants
- Full-time employment
- Lack of community among students
- Living at home and commuting
- Participating in inter-collegiate athletics
- Peers oriented toward materialism

In short, Astin\textsuperscript{4,5} said it appeared that how students approach their general education and how the faculty actually deliver the curriculum are far more important that the formal curricular structure. More specifically, the findings strongly support a growing body of research suggesting that one of the crucial factors in the educational development of the undergraduate is the degree to which the student is actively engaged or involved in the undergraduate experience. His research findings suggested that curricular planning efforts will reap much greater payoffs in terms of students’ outcomes if we focus less on formal structure and content and put much more emphasis on process, pedagogy, and other features of the delivery system, as well as on the broader interpersonal and institutional environment and culture in which learning takes place.

Richard Light reached similar conclusions in his intensive interviews with a randomly selected sample of Harvard undergraduates (interviewed during their first and last year).\textsuperscript{6} He wrote in the preface to the *Harvard Assessment Seminars: Second Report*: The biggest challenge for me is to ask what the details all add up to. Do the many suggestions that interviewers get from their long conversations with undergraduates drive toward any broad, overarching principle? Is there any common theme that faculty members can use to help students, and indeed that students can use to help themselves? The answer is a strong yes. All the specific findings point to, and illustrate, one main...
idea. It is that students who get the most out of college, who grow the most academically, and who are the happiest, organize their time to include interpersonal activities with faculty members, or with fellow students, built around substantive, academic work.

A major component of the educational delivery system is teaching, which is also an important venue for faculty-student interaction. K. Patricia Cross\textsuperscript{7} offered five research-based assertions about college teaching in her 1991 ASEE ERM Distinguished Lecture. Selected assertions relevant to this paper are: (1) good teaching makes a difference in student learning; (2) teachers vary markedly in what they are trying to accomplish through their teaching; and (3) there are some characteristics and teaching methods that are associated with good teaching – knowledge of subject matter, enthusiasm, and understanding of the learning process. She reports that student ratings of teaching are consistent (with other measures), unbiased, and useful. Students generally agree on what constitutes good teaching practices and their views are consistent with those of faculty. Four factors in good teaching, based on student ratings, are:

1. **Skill.** Communicates in an exciting way.
2. **Rapport.** Understands and empathizes with students.
3. **Structure.** Provides guidance to course and material.
4. **Load.** Requires moderate work load.

Finally, given all the interest in creativity and innovation in engineering education, Pelz and Andrews argue that creative performance from students requires maintaining a creative tension between challenge and security.\textsuperscript{8,9} Several other large-scale, comprehensive syntheses of higher education research have arrived at similar conclusions concerning what factors make a difference in student learning.\textsuperscript{10,11,12} Overall, this research indicates that curricula and pedagogy structured to encourage student engagement improves the learning experiences of students.

**Quality of Experience and Student Attrition in Science, Math, and Engineering Programs**

Although this study did not address the issue of student attrition in engineering programs directly, several previous studies have tried to find reasons and answers to the causes of attrition as an initial step towards finding ways to increase retention.\textsuperscript{1,2,3,14,15} The discussion about high rates of attrition in engineering studies is important and has been ongoing for a long time.\textsuperscript{1} Even the popular press has joined the discussion and is pushing the belief that attrition in engineering is detrimental to the future of the profession and scientific innovation.\textsuperscript{13} As described below, the discussion often links student attrition to their academic experiences.

In their well-known study, Seymour and Hewitt\textsuperscript{2} found no significant differences between students who left S.M.E. (Science, Math, Engineering) majors and students who stayed in S.M.E. majors. Rather, both groups possessed similar attributes, histories, and experienced similar problems in their programs. The major finding in their study was that although students who left or stayed in S.M.E. majors experienced similar problems, those who left experienced more of those problems. Furthermore, they found that students who stayed often received help (often by chance) at critical decision points contributing to their decisions to stay in the major—students who left often did not receive help when it could have made a difference in their decision to leave.
Seymour and Hewitt reviewed several early studies on S.M.E. students and found two major reasons for attrition among S.M.E. majors: (a) students who left S.M.E. majors found other majors more attractive and (b) students who left found the work too difficult. Additional findings included perceptions that incoming freshman were unprepared for the rigors of S.M.E. studies; that female students cited pedagogical practices that lowered their self-esteem and career ambitions, and that the effects of a male-oriented pedagogy were cited as causes of attrition in women and minority students. Furthermore, Baille & Fitzgerald studied student issues related to attrition in engineering and found students who left (a) had misconceptions of engineering study (it was more theoretical and math oriented than expected), (b) had perceived engineering study as dull and disconnected from the real world, (c) had difficulty knowing how to learn effectively and efficiently, and (d) had become isolated. These studies posit direct relationships between student experiences, along with other factors, and student attrition in engineering programs.

In an overview of their findings, Seymour and Hewitt used the metaphor of an iceberg to describe the prioritization of problems influencing students to switch from engineering. These problems were interrelated within a field of issues experienced, “to some degree, by all S.M.E. students” (p. 31). For example, primary concerns of students cited as a reason for switching were:

- Other majors (non-S.M.E.) became more interesting and/or offered a better experience
- Loss/lack of interest in S.M.E. disciplines
- Rejection of S.M.E. careers and associated lifestyles
- Shift to a more appealing career option (non-S.M.E.)
- Poor teaching by S.M.E. faculty
- S.M.E. career not worth the effort
- Discouraged/lost confidence due to low grades

These were also the primary concerns of non-switchers. The fact that both groups, switchers and non-switchers, experienced the same problems points to the presence or absence of some trigger for causing a student to decide to switch or not. In addition, Seymour and Hewitt pointed out that the problems generally are not grounded in personal inadequacy, as often believed, but in the structural and cultural aspects of S.M.E. education. They also pointed out that the decision not to switch often involved the chance intervention of some person or event. The decision to switch or not seems to rest on the accumulation of negative or positive experiences—not on some inherent characteristics of the students. They also found little difference in the concerns of students (the problem iceberg) across all seven of the institutions they studied.

Levin and Wyckoff tested several variables to develop a model that predicted persistence in engineering study. From their analysis of significant predictors of persistence, they concluded that academic success and interest in engineering must interact. They also stated that high academic ability is not enough and that there is a complex interaction between academic ability and interest requiring further research. They also found that students with a high level of focus on and high intrinsic interest in science, math, and problem solving had the highest persistence. In addition, they found that gender explained approximately 10% of the differences in attrition.

Tinto identified a range of issues affecting students’ reasons for leaving college. He claims that most reasons for departure from college result from a low level of interaction between students
and faculty—not from inability to meet academic or financial obligations. One of his primary recommendations for retention is increasing the college’s commitment to student welfare and education. Many of his findings support Seymour and Hewitt\(^4\), as do the findings in this study. Achieving the goal of retaining members of underrepresented groups in engineering, such as women and minorities, may depend on revising the educational environment and culture in engineering colleges to be more supportive and inclusive of alternate views of and interests in engineering, as well as differences in learning styles and talent.

The focal institution of this study states that the purpose of post-secondary engineering programs is the instruction and education of students.\(^{16}\) Yet, according to some, of all the studies addressing engineering education, only a few have sought direct input from engineering students.\(^{1,3}\) We assume that a primary objective of engineering students is to receive an education preparing them for a career in engineering. From that perspective, we gathered direct input from engineering students related to their learning experiences. The principal question this study addresses is to what extent student survey responses and focus group comments provide support for the presence of the best-practice factors in education. These factors include higher levels of student interaction other students and with faculty, cooperative and active learning, useful feedback and guidance, and accommodation of diverse learning needs. This paper will present the views of students engaged in engineering education at this institution. In addition, we will present some implications for engineering education. We proceed with a brief overview of the study design.

**Study Design, Methods, and Implementation**

This study was an extension of the Academic Pathways Study (APS) developed by the Center for the Advancement of Engineering Education (CAEE). As such, it attempted to understand the perceptions of engineering students’ educational experiences and knowledge of engineering in the Institute of Technology (IT) at the University of Minnesota (UMN).

The CAEE APS research is a multi-methods longitudinal study comprised of quantitative and qualitative methods. These methods include online surveys, semi-structured interviews, ethnographic interviews, and ethnographic observations. The overall goal is to increase understanding of engineering students’ educational experiences, as well as how these students develop knowledge of and identification with the profession of engineering. In addition, the research sought to answer the question of what factors and decisions affect students’ commitment to and persistence in engineering education.\(^3\) The question of persistence in engineering was the primary focus of the longitudinal survey and interviews in the APS study. Our study was cross-sectional and, therefore, we do not have persistence data with which to correlate the findings. However, we gathered a wealth of information related to the level and type of engineering knowledge, as well as the educational experiences of students across various class levels.

CAEE identified four samples of students for the APS study:

- Cohort 1—a longitudinal sample of 160 students (40 at each of four institutions) surveyed and observed over four years (freshmen through senior years).
- Cohort 2—students who have transitioned recently into the workplace.
• Cohort 3—a cross-sectional sample of at least 560 students (freshmen through alumni) across the four institutions
• Cohort 4—a cross-sectional sample of over 1000 students selected from a diverse range of collaborating institutions.

The Minnesota study, dubbed Cohort 1’, was a sampling variation of the CAEE study. Rather than following 40 students longitudinally across four years of undergraduate schooling, the online survey cross-sectionally targeted 160 students across the four undergraduate classes: freshmen, sophomores, juniors, and seniors. In addition, the second administration of the survey included an additional sample of transfer students. And, as a supplement to the quantitative data, we conducted a series of six focus groups—two each for non-transfer women, non-transfer men, and mixed gender transfer students. These groups helped enrich the quantitative information obtained by the surveys.

Survey Instruments

A multi-disciplinary research team from CAEE designed a questionnaire based on an extensive review of previous research related to undergraduate students’ in general and engineering students in particular (see Eris et al. for a detailed description of the development of the instrument). The questionnaire attempted to measure student perceptions on 24 different variables (see Table 1), such as intent to major in engineering; intent to practice, study, or teach engineering after graduation; motivation to study engineering; confidence in and importance of engineering-related and non-engineering skills; knowledge of the profession; academic experiences and engagement; curriculum overload; interaction and satisfaction with instructors; satisfaction with the facilities, and overall satisfaction. The two questionnaires used at Minnesota were the fifth and sixth administrations of the instrument and were identical to the questionnaires used by the other institutions in the APS study (except for the customization of questions related to program majors and transfer status). The focus group interviews generally addressed the same questions with more emphasis on motivations to study engineering, knowledge of the profession, academic experiences, curriculum overload, as well as interaction and satisfaction with instructors and facilities.

Implementation

To align as closely as possible to the core APS study, we attempted to recruit 40 participants from each of four undergraduate classes (160 total participants). The recruitment process included a preliminary invitation to participate from the Associate Dean of the Institute of Technology and an incentive of a gift card redeemable at the university bookstore. The initial invitation went out to students twice, followed by two notices to complete the survey, and three follow-up reminders. We gathered 123 completed surveys during the first administration during fall semester 2005. The second administration of the survey (spring 2006) collected 217 completed surveys, which included 98 students who also completed the fall survey and a new sample of 55 transfer students.
Table 1: Descriptions of Persistence in Engineering (PIE) Survey Constructs.

<table>
<thead>
<tr>
<th>PIE Survey Construct</th>
<th>PIE Survey Construct Definition and Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Persistence in Engineering (Academic, Professional)</td>
<td>Level of persistence in engineering. This variable is defined at two levels: “Academic persistence” is an intention to major in engineering, whereas “professional persistence” is an intention to practice engineering for at least three years after graduating with a bachelor’s degree.</td>
</tr>
<tr>
<td>Motivation (Financial)</td>
<td>Motivation to study engineering due to the belief that engineering will provide a financially rewarding career.</td>
</tr>
<tr>
<td>Motivation (Family Influence)</td>
<td>Motivation to study engineering due to family influences.</td>
</tr>
<tr>
<td>Motivation (Belief that Engineers Improve Social Welfare)</td>
<td>Motivation to study engineering due to the belief that engineers improve the welfare of society.</td>
</tr>
<tr>
<td>Motivation (Mentor Influence in College)</td>
<td>Motivation to study engineering due to the influence of mentor(s) while in college.</td>
</tr>
<tr>
<td>Confidence in Engineering Knowledge &amp; Skills (Math &amp; Science, Professional &amp; Interpersonal)</td>
<td>Confidence in engineering knowledge and skills. Professional and interpersonal knowledge and skills refer to proficiency in business, communication and teamwork.</td>
</tr>
<tr>
<td>Confident in Solving Open-Ended Problems</td>
<td>Level of confidence in the ability to engage problems with multiple solutions; confidence in critical thinking and creative thinking skills.</td>
</tr>
<tr>
<td>Perceived Importance of Engineering Knowledge &amp; Skills (Math &amp; Science, Professional &amp; Interpersonal)</td>
<td>Perceived importance of math and science, and professional engineering knowledge and skills in becoming a successful engineer.</td>
</tr>
<tr>
<td>Knowledge of the Engineering Profession</td>
<td>Level of familiarity with the engineering profession. Familiarity is measured by the extent of interaction with professional engineers and/or exposure to professional engineering environments.</td>
</tr>
<tr>
<td>Exposure to Project-Based Learning (Individual, Team)</td>
<td>Level of exposure to project-based learning (PBL) pedagogies in courses. Level of opportunity to engage problems that have multiple solutions in coursework.</td>
</tr>
<tr>
<td>Collaborative Work Style</td>
<td>Preference for collaborative work.</td>
</tr>
<tr>
<td>Extra-Curricular Fulfillment</td>
<td>Desired vs. actual level of involvement in extra-curricular activities.</td>
</tr>
<tr>
<td>Curriculum Overload</td>
<td>Level of difficulty in coping with the pace and load demands of engineering-related courses.</td>
</tr>
<tr>
<td>Financial Difficulties</td>
<td>Level of comfort with obtaining financial support for studying engineering.</td>
</tr>
<tr>
<td>Academic Disengagement (Liberal arts-related, Engineering-related)</td>
<td>Frequency of events signaling disengagement from engineering and liberal arts-related courses.</td>
</tr>
<tr>
<td>Frequency of Interaction with Instructors (Faculty, TAs)</td>
<td>Frequency of interactions with faculty and teaching assistants.</td>
</tr>
<tr>
<td>Satisfaction with Instructors (Faculty, TAs)</td>
<td>Level of satisfaction with faculty and teaching assistants.</td>
</tr>
<tr>
<td>Satisfaction with Academic Facilities and Services</td>
<td>Level of satisfaction with academic facilities, such as classroom and laboratories, and services, such as academic advising.</td>
</tr>
<tr>
<td>Overall Satisfaction with Collegiate Experience</td>
<td>General satisfaction with the overall quality of the college experience. This question is asked at the end of the survey to obtain a Gestalt judgment response.</td>
</tr>
</tbody>
</table>

A similar process was used to recruit students for the focus groups (i.e., invitation from the Associate Dean and follow-up reminders). Each group lasted from 1 ½ to 2 hours and included students from each of the four years—freshman through senior years. The questions followed the topics covered in the survey and were designed to elaborate on the information gathered in the
survey (see Table 1)—namely we discussed students’ motivations to pursue an engineering degree and their educational experiences in engineering.

Findings

The population of students in the Institute of Technology at the University of Minnesota is primarily male (85%) and Caucasian (80%). The demographics of the sample surveyed included a lower ratio of men (72%) and a higher ratio of Caucasian students (85%). Due to the limited numbers in some cells of the sample (e.g., minorities and individual class levels), the analysis of data was limited to looking at overall differences by gender and division (upper division: juniors and seniors; lower division: freshmen and sophomores). With the addition of transfer students in the spring, we also analyzed the differences between non-transfer and transfer students in the second administration (spring 06) of the survey. The findings below present perceptions from the questionnaires and focus groups related to students’ educational experiences, as well as their motivations for and dreams of a career in engineering.

Students’ Motivations to Study Engineering

The survey asked students about four different sources of motivation to study engineering: financial (pay and job assurance), family (parental approval and experience), social good (solving and fixing society’s problems), and mentor influence (faculty or non-university mentor). Survey findings reported that social good was rated the highest of the four motivations, followed by financial motivation (see table 2). There were no significant differences between men and women or upper and lower division students regarding motivations to study engineering, however, non-transfer students were more highly motivated than transfer students to study engineering due to financial reasons, $t_{(215)} = 2.360, p = .019$.

Qualitatively, in the focus groups, students described motivations to study engineering due to fascinations with problem solving, math and science, as well as parental influence and financial motivation.

… and then I realized, okay, I'm good at math. I'm good at science. I like science a lot. And I like problem solving and I like making things work and, like, building stuff. So mechanical engineering, I was like, hmm, guess it has all those and I get a good paycheck in the end so I think I like that. –female student

I took a class in high school. It was called Engineering Technology and, like, we just built a bunch of, like, wooden stuff and some metal stuff. And it -- I don't know, it was really fun. The class was great and the teacher was good, so I figured, you know, this is something I want to do. –male student

Well, my dad works at [company] He works on -- like, researching for pacemakers and stuff. And so I used to love to go into work with him and help him take apart pacemakers and test them. –female student
Table 2: Normalized mean scores on Persistence in Engineering (PIE) survey constructs for fall '05 and spring '06 (non-transfer and transfer students) ($0 < m < 1$)

<table>
<thead>
<tr>
<th>PIE Survey Construct</th>
<th>Fall05 non-t</th>
<th>Spring06 non-t</th>
<th>Spring06 trans</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$n = 123$</td>
<td>$n = 163$</td>
<td>$n = 55$</td>
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<td></td>
<td>$m$</td>
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<td></td>
<td>$s.d.$</td>
<td>$s.d.$</td>
<td>$s.d.$</td>
</tr>
<tr>
<td>Motivation (financial)</td>
<td>.6405</td>
<td>.6305</td>
<td>.5364</td>
</tr>
<tr>
<td></td>
<td>.2427</td>
<td>.2316</td>
<td>.2546</td>
</tr>
<tr>
<td>Motivation (family influence)</td>
<td>.1301</td>
<td>.1339</td>
<td>.1273</td>
</tr>
<tr>
<td></td>
<td>.2244</td>
<td>.2036</td>
<td>.2290</td>
</tr>
<tr>
<td>Motivation (social welfare)</td>
<td>.6475</td>
<td>.6965</td>
<td>.6545</td>
</tr>
<tr>
<td></td>
<td>.2454</td>
<td>.2133</td>
<td>.2397</td>
</tr>
<tr>
<td>Motivation (mentor influence)</td>
<td>.2778</td>
<td>.2822</td>
<td>.2152</td>
</tr>
<tr>
<td></td>
<td>.2549</td>
<td>.2628</td>
<td>.2519</td>
</tr>
<tr>
<td>Confidence in math &amp; science skills</td>
<td>.6988</td>
<td>.6869</td>
<td>.7182</td>
</tr>
<tr>
<td></td>
<td>.1762</td>
<td>.1689</td>
<td>.1867</td>
</tr>
<tr>
<td>Confidence in professional &amp; interpersonal skills</td>
<td>.6660</td>
<td>.6760</td>
<td>.6227</td>
</tr>
<tr>
<td></td>
<td>.1590</td>
<td>.1461</td>
<td>.1763</td>
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<tr>
<td>Confidence in solving open-ended problems</td>
<td>.7036</td>
<td>.6951</td>
<td>.7455</td>
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<td></td>
<td>.1485</td>
<td>.1365</td>
<td>.1605</td>
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<tr>
<td>Perceived importance of math &amp; science skills</td>
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<td>.7992</td>
<td>.8182</td>
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<td></td>
<td>.1779</td>
<td>.1878</td>
<td>.2044</td>
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<tr>
<td>Perceived importance of professional &amp;</td>
<td>.6325</td>
<td>.6379</td>
<td>.6465</td>
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<tr>
<td>interpersonal skills</td>
<td>.1676</td>
<td>.1508</td>
<td>.1838</td>
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<td>Knowledge of engineering profession</td>
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<td>.4362</td>
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<td></td>
<td>.3027</td>
<td>.2861</td>
<td>.3719</td>
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<td>Exposure to project-based learning (individual)</td>
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<td>.3815</td>
<td>.4073</td>
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<tr>
<td></td>
<td>.3146</td>
<td>.2800</td>
<td>.3355</td>
</tr>
<tr>
<td>Exposure to project-based learning (team)</td>
<td>.4033</td>
<td>.4259</td>
<td>.3527</td>
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<td></td>
<td>.3019</td>
<td>.2713</td>
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<td>Collaborative work style</td>
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<td></td>
<td>.1743</td>
<td>.1448</td>
<td>.1646</td>
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<tr>
<td>Extra-curricular fulfillment</td>
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<td>.6449</td>
<td>.5679</td>
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<td></td>
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<td>.2660</td>
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<tr>
<td>Curriculum overload</td>
<td>.6050</td>
<td>.5736</td>
<td>.5787</td>
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<td></td>
<td>.1713</td>
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<td>.1892</td>
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<td>Financial difficulties</td>
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</tr>
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<td></td>
<td>.3389</td>
<td>.3112</td>
<td>.3252</td>
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<tr>
<td>Academic disengagement (liberal arts)</td>
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<td>.3313</td>
<td>.4123</td>
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<tr>
<td></td>
<td>.2086</td>
<td>.2018</td>
<td>.2380</td>
</tr>
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<td>Academic disengagement (engineering)</td>
<td>.3271</td>
<td>.3134</td>
<td>.3409</td>
</tr>
<tr>
<td></td>
<td>.1963</td>
<td>.2001</td>
<td>.2049</td>
</tr>
<tr>
<td>Frequency of interaction with instructors</td>
<td>.2879</td>
<td>.2743</td>
<td>.2784</td>
</tr>
<tr>
<td></td>
<td>.1566</td>
<td>.1501</td>
<td>.1699</td>
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<tr>
<td>Satisfaction with instructors</td>
<td>.6375</td>
<td>.6443</td>
<td>.6138</td>
</tr>
<tr>
<td></td>
<td>.1490</td>
<td>.1638</td>
<td>.2141</td>
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<tr>
<td>Satisfaction with academic facilities and</td>
<td>.7276</td>
<td>.7105</td>
<td>.6820</td>
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<td>services</td>
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<td></td>
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Many students in the focus groups also described a strong preference for objectivity in the form of logical, concrete content and process in their studies, as well as the practical or applied nature of engineering. Several described a disdain for the “fluffy” and subjective character of liberal arts classes. Some described the appeal of having one right answer and if you know the correct procedures, you will get the answer regardless of your opinions about it. They held little interest and found little value in debate, subjectivity, and opinion, which they claimed were the attributes of liberal arts classes.

I always enjoyed that challenge of the problem-solving part where actually it's -- for example, more than just your opinion, you know, and you're saying, well, because of this and this that I think. But in math you can say, well, it's because of this, this and this, and you can just -- you very clearly reasoned about your -- your, like, arguments and so you get a clear answer. – male student

And engineering, you just, like, think -- it's a whole different process of thinking. Like, there's a more logical approach. And usually in business, the managers with engineering background, they know the whole structure, like, bottom up versus management or, like, business people don't really grasp that whole concept. – female student

I like it 'cause it's logical. Like, I was frustrated. Like, I'd get good grades in high school, but like, the band and the English classes, they're kind of fluffy like and subjective. But then you could write your paper in one way, but if it wasn't the teacher's way, then it -- like, it wasn't right or it just depended on how much the teacher liked you or things like that. But here, like, science and math, you either have it or you don't. – female student

**Students’ Knowledge of Engineering and Confidence in Skills**

Overall, students reported moderate levels of confidence in their engineering and non-engineering skills and rated math and science skills as more important than professional and interpersonal skills for engineering success. However, students rated their level of knowledge of engineering relatively low (see Table 2).

There were significant differences between the following:

- Compared to women, men were more confident at solving open-ended problems, $t_{(158)} = -2.274, p = .024$.
- Upper division students reported higher levels of knowledge of the engineering profession, $t_{(134)} = -4.323, p < .001$.
- Transfer students reported lower confidence in personal and interpersonal skills (non-engineering skills), $t_{(213)} = 2.272, p = .024$
- Transfer students reported higher confidence in solving open-ended problems, $t_{(214)} = -2.082, p = .039$.

Comments from students described their uncertainty about engineering skills and about the practices of the profession.
I'm not confident in my decisiveness. I feel like I need to make the absolute right decision and maybe part of that is me learning that there isn't one all the time. There's a good decision as opposed to the best. –female student

Like I had no idea up until my junior year, you know, and then I actually got my job and found out, oh, wait. They just sit in cubicles most of the time. –male student

Well, I guess there's two parts to engineering. I think there's -- what I've found since I've been here is that I think they're really trying to teach you two things while you're here. And one is to problem solve and that's where all the technical comes in, and the other is to work with other people. I don't think they stress working with other people as much, but I think they're trying to get towards it if they know how important it is –male student

Students’ Perceptions of Their Educational Experiences

At this institution, students are admitted to the engineering program in the Institute of Technology as freshmen, but not to a specific major until their junior year. During the first two years, students completed the prerequisite science and math classes. In addition to the stress of their transition from high school to college, students recounted the pressures of a highly competitive and demanding program. Often courses are large and comprise what is largely viewed as content not directly related to engineering—and oftentimes it is not congruent with student interests and motivations for pursuing engineering. Students often reported that their most important learning occurred in labs and small group discussion sessions, as well as in study groups. The results of the survey indicated that:

- Women reported significantly more difficulty coping with the pace and load demands of engineering-related courses, $t_{(158)} = 3.625, p < .001$.
- Women reported higher levels of involvement in extra-curricular activities, $t_{(158)} = 2.311, p = .022$.
- Compared to non-transfer students, transfer students reported higher levels of academic disengagement for liberal arts classes, $t_{(161)} = -2.351, p = .020$, and lower levels of overall satisfaction with their collegiate experience, $t_{(214)} = 2.943, p = .004$.

Comments by students related to their coursework elaborated upon the findings of the surveys. These perceptions described their views of the coursework and frustrations with instruction.

I think that, like, the introductory classes, it's kind of frustrating because you are there for, like, a year and a half before you even get to take your first engineering class. I know for chemical engineering you have to take, like, all these pre-reqs and, you are taking chemistry and stuff like that, but you don't get into the engineering aspect of it which I find a little frustrating because then you're, like, well, what if I really suck at it or what if, like, you know, I actually end up, like, hating doing the work and I've just got this idea of what it might be and then you actually go and do it and you're, like -- you're, like, two and a half years into a major and it doesn't really translate to much else. So that's kind of frustrating.

–female student
Like, you go to lecture and, yeah, I haven't missed any, for example, physics lectures and, like, I'm paying attention the entire time, yet I don't -- I'm not really understanding the material and I don't understand it until, like, five hours of, going through problems and -- understanding the process. And even then, you get to the test and you're, like, this -- this isn't what I studied. –female student

I have a couple electrical engineering classes that -- and, like, one of them the professor's really good and he tells us how it's going to apply in the real world and we put, like, real - - like, real life situations to it and I understand just, like, the basic concepts better. And in the other class we -- like, I don't even know, like, where you'd use it. Like, he doesn't explain that. He just tells you equations and stuff like that. And so I don't-- I think the other class, it gives you a better backbone just like- just for the basic concepts. Like even if it's ideal situations, it still gives you -- like, you understand where it could be used in real life where, like, my other class where I don't know where it's going to be used –male student

Students also told us about their frustrations with the grading procedures (the curve) and problems with their TAs. These problems were most acute for lower division students. Upper division students had fewer TAs, and the TAs they had were involved more in their major topics. Upper division students also experienced, what to them, were more reasonable grading procedures in their major classes.

When you get, like 50s and things on your tests, I don't think that means I know anything and then I get -- I end up getting, like, a B or an A in the class and I don't actually understand how that works out. Like, in my physics class -- I'm in Physics 3 right now. And the best -- like, in order to get a C in the class -- on the exams you have to get a six out of 25 and that's a C. A four to a six is a C. A ten to eleven is a B. So I mean, like, I'm getting not even 50 percents on my tests and I'm getting a B plus in the class. I mean, I don't see how that is helping my, education. I guess that discourages me from studying when I know no matter how much I'm going to study, I'm still going to get, like, 30, 40 percent, but I'm still going to be getting a B or an A in class. So I guess -- I don't know -- that actually really bothers me because I don't understand how I'm learning anything. –female student

It's like black boxing these things. Like we learn this equation. We understand it. It's really theoretical and conceptual, not a whole lot of application unless you make all these assumptions and taking a lot of design constraints and things like that and then it becomes something you can apply. But we learn it, we put it in our little black box and then we move onto the next thing, you know. That's why I like -- they're always -- teachers are always telling me, when you get out of school, you're not going to remember anything because you don't need to really 'cause it's just -- it's just background stuff, you know. –male student

Even though the instruction and grading seemed to improve for upper division students, the pressure and competition did not abate.
I felt like every semester I would say to myself, well, it can't get worse than this and every semester I say that. And really it's reached a pinnacle right now and I was just discussing with another friend of mine who I feel is twice as smart as me and, you know, I always felt like he always got such better grades than I did and he and I were just debating, what are we going to do if we fail this class, because we're going to have to retake it. We couldn't graduate; then we won't get the job that we were supposed to have lined up. And I mean, it's really, really hard right now. And I feel like all of the other aerospace people I've talked to have the same feeling. So it's pretty bad this semester. It just gets worse and worse. –*female student*

Additional student concerns related to faculty and TAs’ teaching skills, advising, and lab equipment. Student experiences with these concerns generally were mixed—having positive and negative experiences with each. Overall, the most debilitating experiences related to course load and pedagogy.

**Discussion and Conclusions**

This paper argues that the learning environment of the engineering program includes structural, cultural, and processual factors that may undermine student learning. Astin’s study identified the crucial importance of interaction among students and between students and faculty. He also stated that how students approached their education and how the institution delivered their education were more important than what was delivered. The findings of this study indicate that the system through which students acquire their education affects not only what and how they learn, but also informs students’ as they develop a set of values and beliefs about the profession of engineering. An educational system that promotes competition, individual effort, and test results with limited attention to the learning process, including opportunities for practical and hands-on experiences seems to create unnecessary difficulties for students.

Conceptually, there is merit in students’ decisions to leave engineering programs if they conclude there is not a good fit with their interests, aspirations, and goals. However, it seems that, in some cases, fully capable and eager students are leaving, not because the discipline is a poor fit, but because the educational experience is a poor fit. Regarding the concern of attrition and the goal of increasing the number of women and minorities in engineering programs, it seems counter-productive to drive away talented and capable students with pedagogical practices that create unnecessary difficulties.

Effective pedagogical practices were synthesized at the Wingspread conference as the Seven Principles for Good Practice in Undergraduate Education (Cross and Astin participated in this conference, along with other leaders in higher education). The principles are:

1. Encourage contact between faculty and students.
2. Develop reciprocity and cooperation among students.
3. Encourage active learning.
4. Provide prompt feedback.
5. Emphasize time on task.
6. Communicate high expectations.
7. Respect diverse talents and ways of learning.
The following discussion briefly reviews the *Seven Principles of Good Practice in Undergraduate Education* in light of the survey and focus group findings from this current study:

1. **Encourage contact between faculty and students**: Chickering and Gamson\(^\text{18}\) state that this is the most important factor in student motivation and involvement. It seems that the first two years of students’ learning experience are critical to fostering a commitment to engineering. Seymour and Hewitt\(^\text{2}\) found that oftentimes the difference between switchers and non-switchers was the chance intervention by faculty or other mentor. As students told us, they came into the program not knowing much about the profession, but with a keen interest and enthusiasm for applied sciences. This high level of interest and enthusiasm soon dissipates under the frustration of navigating what appears to them to be a dysfunctional and counter-productive learning environment. It seems likely that a certain amount of attrition is inevitable. It also seems likely that attrition is caused, in part, by the culture, structure, and procedures of current engineering pedagogy. The demotivational aspects of the current system, not only frustrate and discourage students, but may also drive out some of the best and brightest candidates—especially if they are women and minority students.

2. **Develop reciprocity and cooperation among students**: Students described their informal collaborations for studying and homework. Students initiated these experiences outside of the formal program. These experiences seemed to inspire higher levels of motivation, confidence, support, and learning for students. Also, students indicated that the smaller group discussions and labs were far more helpful for learning than the large group lectures. This speaks to the benefits of reciprocity and cooperation among students to foster learning. Savery\(^\text{19}\) described a case study of a typical lecture and lab-based course redesigned into a collaborative and problem-based learning environment, in which student motivation and learning increased dramatically compared to course results prior to the redesign. Meta-analyses of cooperative learning provide extensive support for the importance of cooperation among students.\(^\text{20,21}\)

3. **Encourage active learning**. From a review of several studies, Bonwell and Sutherland\(^\text{22}\) concluded that active learning promotes student learning and mastery by fostering higher levels of student engagement in the material. Cognitive learning theories profess that learning is an active process whereby the learner must not only acquire information, but must process that information into his or her knowledge structures. This new knowledge must also be retrievable in the form of problem solving, not simply regurgitated on exams. The best learning experiences for engineering students came from the application of abstract knowledge and theory in problem-based assignments. And some students recounted higher levels of learning during lectures that included clear applications to practical problems.

4. **Provide prompt feedback**. Students need feedback regarding their developing knowledge and competence. To a great extent, this is an individualized process, which is even more critical with diverse student groups. The current cultural and structural norms for providing feedback—primarily through exams and homework may be missing important opportunities to help students develop mastery of engineering—especially for lower division students.
5. *Emphasize time on task:* As Chickering and Gamson\(^{18}\) described this principle, time plus energy equals learning. Seymour and Hewitt\(^{2}\) described the frustrations of students 15 years ago as a lack of time to absorb difficult concepts despite high levels of energy devoted to study. The high load and pace of coursework places additional strain on students’ capabilities to learn and master difficult material.

6. *Communicate high expectations:* High expectations are necessary to high quality learning. However, an overemphasis on performance goals (e.g., grades) at the expense of mastery goals has a negative effect on motivation and learning.\(^{23}\) Students told us that they were attracted to the challenges of these disciplines. However, often the challenges were beyond their capabilities or perceived as counter-productive for learning. This often led to high levels of stress and frustration. Also, there was some indication that the high expectations were unrealistic and disconnected from reality. Students questioned the need for and benefit of what they perceived as unnecessary levels of pressure and competition.

7. *Respect diverse talents and ways of learning:* Fifteen years ago, Seymour and Hewitt\(^{2}\) challenged the assumption behind the selection (weed-out) system that some students did not have the aptitude for science and, therefore, should not continue. However, this selection system seemed to disproportionately affect women and minorities—the very groups that engineering was trying to encourage. While there are opportunities to accommodate different ways of learning, e.g., coops, internships, multi-disciplinary group projects, there is little room in the program’s schedule for such learning. Students perceived a critical disconnect between their ways of learning and the program’s processes for instruction. Engineering’s quest for increased diversity may be undermined by a strong cultural, structural, and procedural organization that stifles different ways of learning and drives out diverse talents.

Recently, Shapiro\(^{24}\) lamented the low priority given to the scholarship of teaching and learning in the research university. From his years of experience as a central administrator involved in promotion and tenure, he witnessed the marginalization of scholarly teaching and the lack of attention paid to student learning in higher education. Furthermore, beyond the moral obligations to students, he contends that the increasingly competitive environment facing research universities will ultimately reward those that attend to learning and the subsequent outcomes of learning that benefit students.

The self-reported responses of self-selected individuals are limitations of this study. However, as an exploratory study using multi-methods we found student perceptions to be congruent with many previous studies. And we found student frustrations stemming from difficult and dysfunctional educational practices to be consistent with other studies and with learning theory. Even though the broader sample of students responding to the survey indicated overall high levels of commitment to engineering and moderate levels of satisfaction with their program of study, the overwhelming majority of students at this institution are white males. Consistent with the literature cited above, this program works best for this select group. Unfortunately, it is also apparent from other studies that talented and capable individuals may be leaving engineering because of poor fit with the culture, structure, and procedures entailed in the program.

While we found important examples of high quality scholarship in teaching and learning, we were also dismayed at some of the well-founded responses from students that criticized the
teaching practices of the institution. We can point to apparent improvements in the general problems that Seymour and Hewitt noted earlier. Also, we can point to problems they identified 15 years ago that have not changed. It is important to recognize that what students learn about engineering may be at odds with our best intentions, the needs of students, and the future of the profession. Furthermore, it may confound our best efforts to recruit and retain students who are, not only fully capable of contributing to this profession, but may be our best resource for creativity and innovation in the future.

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