Self-assessed confidence in EC-2000 Outcomes: A study of gender and ethnicity differences across institutions [1]

Magaly Moreno, Mary Besterfield-Sacre, Larry J. Shuman, Harvey Wolfe
Industrial Engineering/School of Engineering, University of Pittsburgh, Pittsburgh, PA 15261
Cynthia J. Atman
Industrial Engineering and CELT, University of Washington, Seattle, WA 98195

Abstract - *With the establishment of the challenging Engineering Criteria 2000 accreditation guidelines, institutions must obtain a more informed understanding of students' underlying knowledge, skills, and attitudes as they begin, matriculate, and eventually complete their engineering studies. As engineering educators collect information about how students demonstrate achievement in the "a-k" outcomes, questions arise as to whether differences exist between student groups, specifically gender and ethnicity differences. Such differences may potentially affect a student's performance and persistence in engineering. Prior research indicates that engineering student's initial attitudes, along with gender and ethnicity, are linked to first term probation and retention in the freshman year. How they are linked to achievement of the EC-2000 outcomes is still an open question.*

At the University of Pittsburgh we are investigating how confidence in the outcomes changes throughout a student's undergraduate engineering career and how these self-assessed outcomes correlate with other 'a-k' outcome metrics. As part of the larger study, this paper will explore the issue of how confidence in the outcomes are influenced by gender and ethnicity factors at the freshman level. Using the Pittsburgh Freshman Engineering Attitude Post Survey© and data from 16 US engineering schools, who took the questionnaire during the 1998-99 academic year, we have found a number of significant and consistent differences in the 11 outcomes with respect to student gender and ethnicity.

Introduction and Background

Since the recent adoption of ABET's new criteria, EC-2000, engineering educators have focused much attention on evaluation and assessment. Engineering faculty must now be proactively involved in the goals that each program tries to accomplish. Equally important, institutions must be able to measure how effective their programs are by demonstrating that their students are achieving the desired outcomes [1]. To accomplish this, engineering educators and administrators are now interested in the application of useful metrics to assess engineering students and programs.

An important aspect in evaluating and assessing engineering programs is the identification of those factors in which students significantly differ in their measured outcomes. Differences in engineering outcomes with respect to issues such as gender and ethnicity can provide insights on the direction that each engineering program should take. Gender and ethnicity factors are important to investigate since studies have shown that retention rates are lower among female students [2,3,4] and certain ethnic groups [5]. The use of evaluation tools, such as the one presented in this study can help determine if special intervention programs are required for underrepresented minority groups (i.e., female students and African-American students, in particular).

Many researchers have addressed the issue of academic performance, retention and graduation in engineering programs [6,7,8,9] and the use of attributes and outcomes to evaluate engineering programs [10,11,12,13]. For example, one research study [14] investigated whether certain characteristics of students, such as gender, is associated with a higher level of persistence and performance. However, the literature has yet to contain studies on how the EC-2000 outcomes differ among male and female students and among the different ethnic groups.

At the University of Pittsburgh we are investigating how self-assessed confidence in the 'a-k' outcomes changes throughout a student's undergraduate engineering career and how these self-assessed outcomes correlate with other factors that may affect a student's academic performance. As part of this larger study, this paper contributes to the engineering education literature by exploring the issue of how confidence in the outcomes is influenced by gender and ethnicity factors at the freshman level and across many institutions. Results indicate that while there are several differences in outcomes relative to gender, the current data suggest that differences between minority and non-minority students at the freshman level are minimal at best.

This document is structured as follows. We first present the instrument and approach used to conduct the cross-institutional study, as well as provide an explanation of the analyses performed and how cross-institutional trends were determined. Next, we present the findings along with a discussion of the possible implications behind these results. Finally, we outline areas of current and future investigation.

[1] This research is being funded by a grant from the Engineering Information Foundation, EiF 98-4, and by a grant from the National Science Foundation, EEC-9872498.

Methodology

The primary data gathering instrument used in this study is the *Pittsburgh Freshman Engineering Attitude Survey©* (PFEAS). The "pre" version of the survey contains 50 items that are rated on either a Likert scale or an ordinal-based self-assessed confidence scale. The 50 items in the questionnaire have been statistically clustered into 13 attitude and self-assessment measures of students' opinions about the engineering profession and their own engineering abilities. These measures were derived using survey results across many institutions. Thus, the questionnaire's attitude measures are reflective of a true cross-institutional instrument.

The "post" version of the questionnaire includes the same 50 statements from the pre-questionnaire plus 20 additional items. These added statements ask students to assess their confidence level in the engineering outcomes to date. These 20 statements, which were carefully developed by several engineering educators and evaluation experts, reflect the eleven themes of the EC 2000 Criterion 3, as described in Table 1. The individual statements were then averaged to form the outcome measure.

The pre version of the survey is administered at the beginning of the students' freshman year, generally during their orientation sessions or during the first week of classes. The post-survey is administered at either the end of the freshman year or during the last week of the first semester, at the discretion of each engineering institution. The post survey results are the principal focus of the work presented in this paper.

Table 1. Freshman Post-Survey EC2000 Outcomes and Their Definition

	EC2000 Criterion 3 Outcome	**Corresponding Statements**
a	An ability to apply knowledge of mathematics, science, and engineering	Can use my knowledge of mathematics to solve relevant engineering problems Can use my knowledge of chemistry to solve relevant engineering problems Can use my knowledge of physics to solve relevant engineering problems Can use my knowledge of engineering to solve relevant problems
b	An ability to design and conduct experiments, as well as to analyze and interpret data	Can design and conduct an experiment to obtain measurements or gain additional knowledge about a process Can analyze and interpret a set of data to find underlying meaning(s)
c	An ability to design a system, component, or process to meet desired needs	Can design a device or process to satisfy a given set of specifications
d	An ability to function on multi-disciplinary teams	Can function as a technically contributing member of an engineering team Can function as an accountable member of an engineering team
e	An ability to identify, formulate, and solve engineering problems	Can formulate unstructured engineering problems
f	An understanding of professional and ethical responsibility	Understand the professional responsibilities of an engineer Understand the ethical responsibilities as an engineer
g	An ability to communicate effectively	Can write effectively Can make professional presentations Can effectively express engineering-related ideas to others Can listen to and impartially interpret different viewpoints
h	A broad education necessary to understand the impact of engineering solutions in a global and societal context	Understand the potential risks and impacts that an engineering solution or design may have to the public
i	A recognition of the need for, and an ability to engage in life-long learning	Can recognize the limitations of my engineering knowledge and abilities and know when to seek additional information
j	A knowledge of contemporary issues	Can apply knowledge about current issues (economic, environmental, political, societal, etc.) to engineering-related problems
k	An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	Can use appropriate engineering techniques to include software or lab equipment for problem solving

A. Cross-Institutional Study

The larger cross-institutional study is aimed at identifying those pertinent factors that affect students' attitudes and retention at the freshman level, where literature (and our experience) indicates that at least half of all engineering attrition occurs. As part of this study, students' attitudes are measured prior to beginning their first year studies (using the pre survey) and over the course of their first year (using the post survey). By obtaining these measures, we wish to determine how these attitudes differ among gender and ethnicity, to help identify if there are certain programmatic initiatives that can impact these attitudes, and to determine if relations can be found between the attitudes and retention and performance during the crucial first year.

For the 1998-99 academic year, eighteen engineering schools participated in the cross-institutional study and sixteen engineering schools participated in the post version of the questionnaire. Of these, ten institutions administered the survey at the end of the first semester and six institutions chose to administer the survey at the end of the first year.

Overall, there were 6,721 students who took the questionnaire during the 1998-99 academic year. Of the 5,987 students who completed the demographic portion of the questionnaire, 21.9% of the responding students were female; 69.8% were Caucasian; 5.0% were African-American, 10.0% were Asian Pacific, and 10.3% were Hispanic. Almost all of the students (96.9%) were full time, and 93% were 'true' first semester students whom had not attended another post-secondary institution.

B. Data Analysis

The Mann-Whitney non-parametric test of comparison was used to determine if significant differences existed between male and female students' self-assessed confidence level for each of the eleven EC 2000 outcomes. This procedure is a non-parametric equivalent of the t-test, commonly used to test whether two independent samples are from the same population. The same procedure was used to determine if statistical differences existed between the different ethnic groups. A Bonferroni adjustment for multiple comparisons (to protect against a Type I error) was applied at a significance value of 0.05 resulting in an adjusted P-value ≤ 0.004 for both gender and ethnicity differences. All analyses were performed using SPSS for Windows 10.0 software.

For many of the outcomes, several individual schools showed significant differences (P-value ≤ 0.004) or substantial differences (P-value ≤ 0.05) for gender and for differences in ethnicity. We determined that a cross-institutional tendency or trend existed if at least one-third of the schools showed a trend or significant difference between the two student groups and that this difference was displayed in the same direction for all the schools. For example, male students at each school exhibited higher self-assessed confidence in outcome 'a' than did female engineering students. Further, at five of these schools the difference was substantial or significant statistically.

Discussion of Results

A. Gender Differences

The gender differences for the 11 outcomes are illustrated in two separate figures (Figure 1 and Figure 2).

Figure 1 presents the set of outcomes that showed clear cross-institutional tendencies. Figure 2 illustrates those outcomes for which a statistical difference between male and female students was not found. Figures 1 and 2 will be discussed separately.

For each outcome displayed in Figure 1, at least five of the schools showed either a substantial difference (*P*-value = 0.05), a trend, or a significant difference (*P*-value = 0.004), between male and female engineering students. According to this description, four out of the eleven outcomes showed differences.

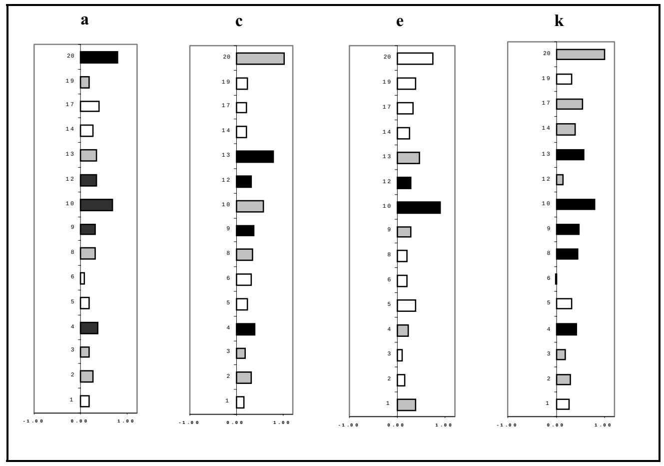

Figure 1. Gender Differences – Cross Institutional Tendencies

Each bar graph in Figure 1 represents a particular outcome. Similarly, each bar in the figure represents an engineering school that participated in the study. The horizontal scale on each individual graph ranges from –1.0 to 1.0, and it represents the male to female difference for that specific outcome. For example, if a bar shows a difference of +0.8 then, for that particular item, males rated their confidence level 0.8 points higher than did female students. Outcome differences found to be significant at the *P*-value = 0.05 are shown in the light-shaded bars. In the same manner, differences found to be significant at the Bonferroni-protected *P*-value of 0.004 are illustrated as dark bars. Intuitively, clear bars represent institutions where no statistically differences were found.

According to Figure 1, outcomes 'a,' 'c,' 'e,' and 'k' cross-institutionally show differences by gender. (As stated, a cross-institutional tendency is identified when a statistical difference between the groups of students if found for at least one-third of the schools and that difference between students is in the same direction.) In general, male students tended to rate their confidence level higher than did female students for all schools. For outcome 'a,' *an ability to apply knowledge of mathematics, science, and engineering*, males rated their confidence level statistically higher than females at ten institutions (five schools at the 0.05 level, and five schools at the 0.004 *P*-value levels). A statement analysis of this outcome indicated that two of the four statements: 'can use my knowledge of physics to solve relevant engineering problems' and 'can use my knowledge of engineering to solve relevant problems' were found to be significant; the other two statements were not significant. This indicates that male students are more confident than female students in their physics and engineering knowledge and how this knowledge is used to solve problems at the end of their freshman year. For outcome 'c,' *an ability to design a system, component, or process to meet desired needs*, male students expressed higher confidence in their design abilities than did female students. This consistency is apparent across nine institutions. Statistical difference at the *P*-value = 0.05 was found for five schools, while differences at the adjusted *P*-value = 0.004 was observed for four other schools. For outcome ‘e,’ *an ability to identify, formulate, and solve engineering problems*, again, male engineering students rated their problem solving abilities higher than did female students. This tendency is statistically prevalent across seven engineering schools. Statistical differences at the *P*-value of 0.05 were found for four schools and for three others at the 0.004 *P*-value. Finally, for outcome ‘k,’ *an ability to use techniques, skills, and modern engineering tools for engineering practice*, male students at 11 of the 15 engineering schools rated this ability significantly higher than did female students. This gender difference at a *P*-value of 0.05 was observed for five schools and at the adjusted *P*-value of 0.004 for another six schools.

A notable characteristic of these four particular outcomes is that male students consistently rated their confidence level higher than did female students at <u>all</u> the schools, regardless if the difference was significant.

Alternatively, seven of the outcomes yielded no institutional tendencies, as shown in Figure 2. Outcomes ‘b,’ ‘d,’ ‘f,’ ‘g,’ ‘h,’ ‘i,’ and ‘j’ present no clear trends meaning that less than 5 schools showed either a possible or significant difference. These outcomes are interesting in that they can provide additional insights as to those areas in which male and female students share the same confidence level (at least statistically).

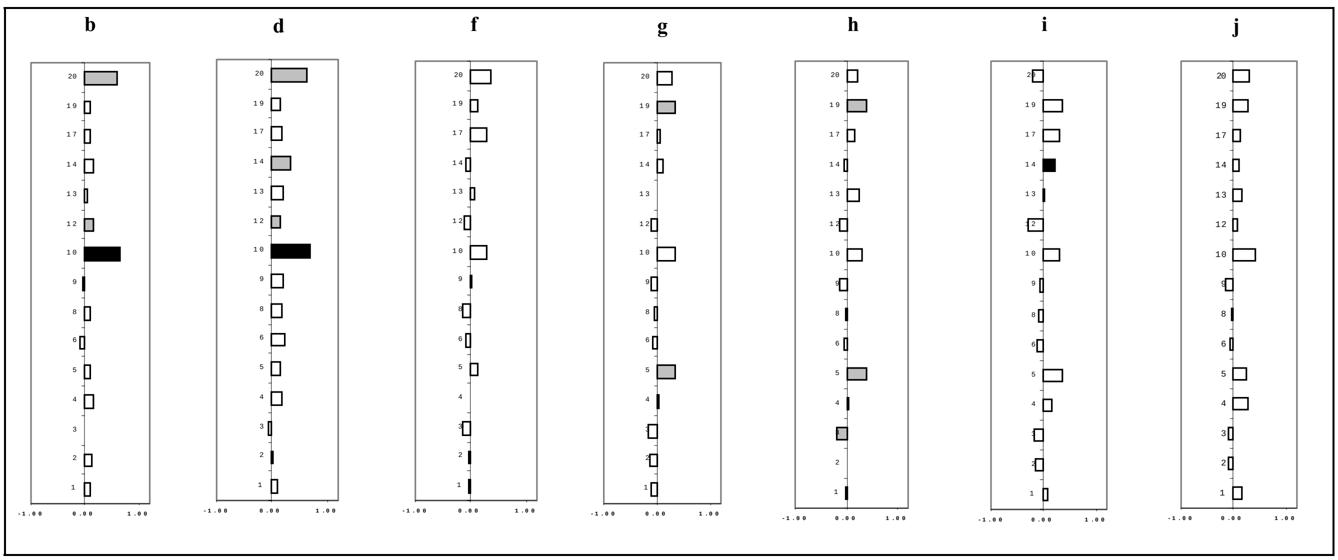

Figure 2. Gender Differences – No Institutional Tendencies

The consistent ‘inconsistency’ of these outcomes can be attributable to a variety of phenomena in engineering education. First, unlike the outcomes that showed cross-institutional tendencies, these outcomes represent the relatively ‘soft’ issues in engineering education. Traditionally, the following outcomes:

- *an understanding of professional and ethical responsibility*,
- *an ability to communicate effectively*,
- *a broad education necessary to understand the impact of engineering solutions in a global and societal context*,
- *a recognition of the need for, and an ability to engage in life-long learning*, and
- *a knowledge of contemporary issues*

are areas not specifically taught in an engineering curriculum. Rather these outcomes are usually inferred in the curriculum and vary from instructor to instructor. As a result, it might be difficult for freshman students to relate to any specific “soft” experience in their freshman engineering studies. Conversely, a student who is enrolled in freshman courses that cover specific content knowledge (outcome ‘a’), engages himself or herself in engineering design and problem solving, (outcomes ‘c’ and ‘e’), and uses engineering tools, such as Matlab (outcome ‘k’), may better relate to his/her experiences when making self-assessments about these outcomes. Gender differences may be magnified for these more ‘hard’ outcomes, thus contributing to the cross-institutional tendencies.

Outcomes ‘b,’ *an ability to design and conduct experiments, as well as to analyze and interpret data*, and ‘d,’ *an ability to function on multi-disciplinary teams*, exhibited some significant gender differences at three and four schools, respectively. Unlike the other outcomes in Figure 2, there is a propensity for male students to have more self-assessed confidence than female students. These may also be considered ‘hard’ outcomes, as students may be able to better relate to their experiences and they may be more measurable. However, as with the other outcomes, the lack of consistent significance across the institutions may be attributable to differences in engineering curriculum at the freshman level. Some schools may specifically teach the use of laboratory equipment and data analysis, as well as teamwork; however, the majority of schools may develop these outcomes later in the engineering curriculum. Further, the EC-2000 outcomes studied here are measured at the end of the first semester or at the end of the freshman year. Therefore, differences in students' stated confidence or their absence might be a function of when the student took the post questionnaire.

B. Ethnicity Differences

Differences between minority and majority students are presented in a similar manner as gender differences. The minority groups studied included African American, Asian Pacific, and Hispanic engineering students. Further, because the number of minority represented students at some institutions is very small, a school was only analyzed if the particular minority group was equal to or larger than 15 students. We did this to avoid reporting misleading conclusions as a result of statistically comparing substantially large sample sizes against small sample sizes. As a result, only a handful of institutions were actually compared in the study. Students from the majority group (White Caucasian) were compared to each minority group individually. No clear trends were present for African American versus White Caucasian or for Hispanic versus White Caucasian. This was an interesting result, as many cross-institutional trends were found for several attitude measures found on the pre and post questionnaires [see 15]. However, there were some interesting trends for Asian Pacific versus White Caucasian engineering students. The results for the Asian Pacific group show a cross-institutional trend for five out of the 11 outcomes, as shown in Figure 3. There were six participating schools that had a sufficiently large enough population of Asian Pacific students.

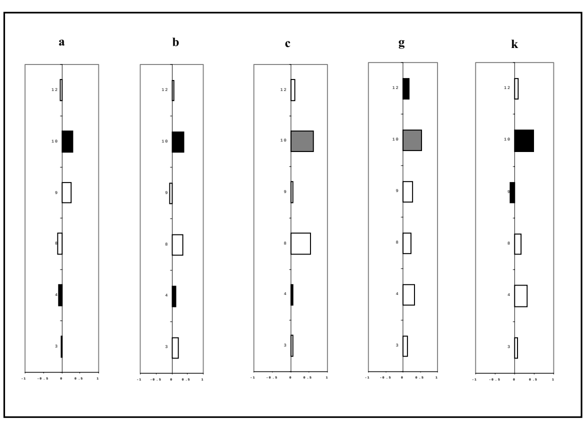

Figure 3. Asian Pacific vs. White Caucasian – Cross Institutional Tendencies

For outcome 'a,' *an ability to apply knowledge of mathematics, science, and engineering*, two engineering schools showed a possible statistical difference between the majority of the students and the Asian Pacific students. This finding, though, is not consistent across schools. For outcome 'b,' *an ability to design and conduct experiments, and analyze and interpret data*; two schools demonstrated a substantial difference, where Asian Pacific students rated their confidence level lower at both schools. For outcome 'c,' *an ability to design a system, component, or process to meet desired needs*, one school showed a significant difference and one school showed a substantial difference. Asian Pacific students demonstrated lower self-assessed confidence at both schools. For outcome 'g,' *an ability to communicate effectively*", the same result was found as for outcome 'c.' Similarly, two schools presented a possible significant difference for outcome 'k,' *an ability to use techniques, skills, and modern engineering tools for engineering practice*". Again, Asian Pacific students rated their confidence in their technical skills lower than the majority group. Though the sample of schools is small, it appears that Asian-Pacific students have lower confidence than do White Caucasian students for many of the outcomes. Nevertheless, because of the small number of schools it is difficult to determine if there is a true cross-institutional trend for outcomes 'c' and 'g.'

Conclusions And Future Work

This paper describes the consistencies across institutions on the Engineering Criteria 2000 accreditation guidelines with respect to gender and ethnicity issues. At the freshman level, it was shown that male and female engineering students differ in the confidence level on EC-2000 outcomes 'a,' 'c,' 'e,' and 'k' and that these results are validated by the presence of a cross-institutional trend. This tendency indicates that male students rate their confidence level higher than do female students. Conversely, students' confidence level on the remaining Criterion 3 outcomes (outcomes 'b,' 'd,' 'f,' 'g,' 'h,' 'i,' and 'j') does not appear to be affected by the gender factor. Interestingly, the latter outcomes are considered more 'soft,' less determinable, in engineering education such as the students' ability to recognize the need for life-long learning. It was suggested that the educational experience at the freshman level may not provide students with the necessary experience to rate their specific confidence level; thus, gender differences may be or may not be apparent for these particular outcomes. For ethnicity groups, it was found that only Asian-Pacific engineering students showed differences from majority students across institutions in their confidence level for outcomes 'a,' 'b,' 'c,' 'g,' and 'k.' This distinction was present in at least two out of the six institutions with a sizable Asian-Pacific population. No clear and consistent trends were found for African-American or Hispanic ethnicity groups.

As engineering schools seek to improve their students' engineering abilities and competencies as they matriculate, it is valuable for institutions to gain an understanding of their students with regards to the new criteria early on in their studies and how gender and ethnicity factors are present in the educational experience. By investigating these issues and their effect on the EC-2000 accreditation guidelines, the engineering schools involved in this study can identify and focus on areas of improvement for female and minority groups.

The results of this study also suggest paths for future research. First, still to be determined is whether or not the same tendencies exist as students matriculate and eventually graduate from their engineering programs. As part of a larger study, we are investigating this issue through the use of sophomore and junior companion attitudinal surveys, as well as senior graduation surveys. This longitudinal study will enable us to track any changes in students' confidence level in the EC-2000 outcomes. Second, the study will involve a comparison of the different engineering programs and how the outcomes are addressed in the programs in order to identify other considerable factors present in the cross-institutional tendency.

Acknowledgements

We greatly thank the institutions who are participating in this study and for their assistance and cooperation: Arizona State University, University of Arizona, Colorado School of Mines, University of Colorado, University of Dayton, University of Delaware, Drexel University, George Washington University, University of Massachusetts – Dartmouth, Mercer University, North Carolina State University, University of Pittsburgh, Polytechnic Institute, Purdue University, Rose-Hulman Institute of Technology, University of Texas – El Paso, and the University of Washington. We would also like to thank Mr. Ronald D. Peeler and Ms. Melissa K. Richards, undergraduate research assistants at the University of Pittsburgh, for their assistance in this work.

References

[1] Besterfield-Sacre, M., N.Y. Amaya, L.J. Shuman and C.J. Atman, "Implications of Statistical Process Monitoring for ABET 2000 Program Evaluation: An Example Using Freshman Engineering Attitudes," *American Society of Engineering Education 1998 Proceedings,* Seattle 1998.

[2] Seymour, E. and N. Hewitt, *Talking About Leaving – Factors Contributing to High Attrition Rates Among Science, Mathematics and Engineering Undergraduate Majors, A Final Report to the Alfred P. Sloan Foundation and Ethnographic Inquiry at Seven Institutions,* Bureau of Sociological Research, University of Colorado: Boulder, April 1994.

[3] Brainard, S.G. and L. Carlin, "A Longitudinal Study of Undergraduate Women in Engineering and Science," *Journal of Engineering Education*, Oct. 1998.

[4] Henderson, J.M., D.A. Desrochers, K.A. McDonald, and M.M. Bland, "Building the Confidence of Women Engineering Students: A New Course to Increase Understanding of Physical Devices," *Journal of Engineering Education*, October 1994.

[5] Reichert, M., and M. Absher, "Taking Another Look at Educating African American Engineers: The Importance of Undergraduate Retention," *Journal of Engineering Education*, July 1997.

[6] Besterfield-Sacre, M., N.Y. Amaya, L.J. Shuman, C.J. Atman, and R.L. Porter, "Understanding Student Confidence as It Related to First Year Achievement," *1998 Frontiers in Education Conference*, November 1998, pp. 258-263.

[7] Blumner, H.N., H.C. Richards, "Study Habits and Academic Achievement of Engineering Students," *Journal of Engineering Education*, April 1997.

[8] Felder, R.M., G.N. Felder, and E.J. Dietz, "A Longitudinal Study of Engineering Student Performance and Retention. V. Comparisons with Traditionally-Taught Students," *Journal of Engineering Education*, October 1998.

[9] Besterfield-Sacre, M., C.J. Atman, and L.J. Shuman, "Characteristics of Freshman Engineering Students: Models for Determining Student Attrition in Engineering," *Journal of Engineering Education*, April 1997.

[10] Besterfield-Sacre, M., C.J. Atman, and L.J. Shuman, "How Freshman Attitudes Change in the First Year," *Proceedings of the 1998 ASEE Annual Conference*, Seattle, June 1998.

[11] Schaeiwitz, J., "Outcomes Assessment in Engineering Education," *Journal of Engineering Education*, July 1996.

[12] Olds, B.M., and R.L. Miller, "An Assessment Matrix for Evaluating Engineering Programs," *Journal of Engineering Education*, April 1998.

[13] Besterfield-Sacre, M., C.J. Atman, L.J. Shuman, R.L. Porter, R.M. Felder, and H. Fuller, "Changes in Freshman Engineers' Attitudes – A Cross Institutional Comparison What Makes A Difference?," *Frontiers in Education Conference*, November 1996 (CD-ROM).

[14] Takahira, S., D.J. Goodings, and J.P. Byrnes, "Retention and Performance of Male and Female Engineering Students: An Examination of Academic and Environmental Variables," *Journal of Engineering Education*, July 1998.

[15] Besterfield-Sacre, M., M. Moreno, L.J. Shuman, H. Wolfe and C.J. Atman, "Perceptions of Engineering: The Effects of Gender and Ethnicity Across Engineering Schools," Working Paper, March 2000.