AC 2010-109: COMPARING THE RELATIVE CONTRIBUTION OF INDIVIDUAL AND ENVIRONMENTAL FACTORS TO THE INTENT TO REMAIN IN AN ENGINEERING MAJOR, BY GENDER

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Comparing the Relative Contribution of Individual and Environmental Factors to the Intent to Remain in an Engineering Major, by Gender[1]

ABSTRACT

A series of hierarchical linear regressions were run to determine the differences by gender among undergraduates (N=1629) in the relative contribution of individual and environmental factors to predicting interest in remaining in an engineering major. Individual and environmental factors played a significant role for both men and women in predicting the dependent variable, but individual variables, particularly motivation, explained more of the variance. Elements of the collegiate experience had a stronger impact on women's than men's intentions, with perceptions of care/respect having the strongest positive effects and competition, grades, and time required for coursework the most negative effects.

INTRODUCTION

Diversifying the profile of engineers in the workforce occurs at many critical junctures in the educational process, including through encouragement to enroll in advanced courses in math and science during high school and outreach activities about career opportunities that occur as early as elementary school. While research outcomes are not entirely consistent on this point, evidence is that the gender and racial gap in persistence once enrolled in an engineering major has narrowed to near parity. In a recent analysis, for example, Lord et al.[1] determined that contrary to prevailing perceptions, women and men persist in engineering majors at approximately the same rate across all ethnic groups. Less encouraging is evidence that a gender gap persists after completion of an undergraduate major in engineering, when women were significantly less likely than men to express interest in pursuing jobs in engineering[2,3,4].

Conceptual Framework

The literature about the persistence and success of women in science, technology, engineering, and mathematic (STEM) fields is generally implicitly or explicitly framed from either an individual or environmental/structural perspective[5,6] . An individual perspective examines the impact of individual variables, such as motivation and interest in science and engineering[7], on retention and career interests. On the other hand, an environmental or ecological perspective shifts attention to the wider social context, including not only societal expectations and stereotyping of a field as masculine or feminine[8], but experiences in and out-of-the classroom. From this worldview, the shaping and monitoring of group assignments[9], negative experiences in the classroom[10], emphasis placed on competition, opportunities for meaningful and supportive interactions with faculty[11], and peers[12] play a more critical role than individual qualities in promoting a commitment to engineering as a long-term pursuit.

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Mary Frank Fox, a leading scholar in the field of gender and success in STEM fields, has long been a champion for the environmental perspective, firmly taking an "institutional/structural centered" position where she argues that policies and practices implicitly reflect cultural assumptions and, when gender-related, a generally unstated philosophy about the root causes of the under-representation of women[13,14]. Using this perspective, Fox and her colleagues found systematic patterns of differences between departments that have been the most and least successful in increasing the proportional representation of women STEM degree recipients. Administrators in less successful programs looked more to addressing the perceived deficits in women, such as to improve self-efficacy and leadership skills, while those in the more successful programs had more all encompassing views of the factors contributing to the gender imbalance and implemented a more diverse set of activities.

Elements of the educational environment play a critical role in persistence and success for both men and women, but are considered to be particularly crucial to the success and persistence of women. The reasons for this are complex and not easy to pinpoint. The under-representation of women accelerates the development of gender stereotypes[15] and limits access to same-sex role models[16] . The low number of women in the typical engineering classroom limit opportunities for social interactions and because students tend to form study groups with individual who share their personal characteristics[17], inhibit women's ability to participate in informal study groups and to form supportive peer networks[18, 19]. The under-representation of women in engineering is mirrored by the relatively low proportion of women on the faculty, which translates to few available role models that demonstrate that it is possible for women to succeed in the field[20,21]. The stereotyping of the field as masculine adds to concerns that the field is incompatible to maintaining a healthy personal and family life[22].

The numeric and proportional enrollment of women significantly affects the long-term plans of both men and women to pursue engineering as a career[23]. Greater numeric representation of women has a positive effect on both men's and women's interest in engineering as a career that remains significant above and beyond other individual and environmental factors. The higher the number of women completing a degree in engineering, the more both men and women agree that there is a "fit" between their own interests and skills and those required to earn a degree in engineering.

One way to interpret the research literature and the "war stories" that emerge from leaders of women in engineering programs, is the common perception that for women, persistence in engineering requires not only a supportive environment, but above average ability and motivation. Evaluating the merits of this widespread perception requires procedures to measure the contribution of both individual characteristics and elements of the educational experience to interest in engineering.

This research addresses the absence noted by Astin and Sax[24] of multivariate and multi-institutional studies from research about undergraduates in science and engineering. This research uses multivariate analysis and questionnaire data from undergraduate students enrolled in engineering majors (N=1629) at eight colleges and universities geographically dispersed throughout the United States to provide an empirical calculation of the relative contribution of a cluster of individual and environmental factors on the intent to remain in an engineering major.

The study is framed by the following research questions:

> RQ1: What amount of the variance do individual and environmental factors predict in the intent to remain in an engineering major?
>
> RQ2: Are there differences by gender in the total amount of variance in the intent to remain in an engineering major explained by individual and environmental factors?

RESEARCH METHODS

The analysis presented in this paper was produced as part of a multi-institutional mixed methods study that was conducted between 2003 and 2009 and included both a qualitative and quantitative phase. During the first phase, an individual designated as the liaison at each of the participating institutions distributed an on-line version of a faculty and student questionnaire. Data collection for the qualitative phase occurred during a campus visit that followed preliminary analysis of questionnaire data and included interviews with students and faculty members in two departments selected by institutional liaison as having the most hospitable environment for women. In the following section, the nature of the participating institutions, the questionnaire, and analysis are described briefly. Fuller details about the research methods are provided elsewhere[25]. Only results from the quantitative analysis of the student data are presented here.

Participating Institutions

At the onset of the research, a group of participating institutions with a college or school of engineering was collected to be geographically dispersed throughout the United States and to represent both public and private institutions with both above and below proportional enrollment of women among degree recipients in engineering in 2003. While not sensitive to dramatic changes in the enrollment that may have occurred since the point of time is was measured, the proportion of degree recipients that are female is often used in research because it allows for institutional comparisons, accounts for persistence, and provides an index of what might at some point in the future be reflected in the composition of the workforce.

The final pool of participating institutions consisted five private and three public doctoral/research universities of varying sizes. Four of the institutions are located in the Northeast, one in the Mid-Atlantic Region, and three in the West.

The Engineering Student Survey and Respondents

The survey distributed to students in the participating colleges of engineering was based on *The Student Persisting in Engineering Survey* developed as part of the Women's Experiences in Colleges of Engineering (WECE) Project[26]. Response options used a Likert scale. Depending on the item there were either four or five response options; most often from strongly disagree to strongly agree. In instances that used five response options students reported the frequency with which they engaged in certain behaviors. Key sections from the survey used in the analysis represented here were sections about (a) importance of items that influence the decision to remain in an engineering major, (b) a self-assessment of ability in different domains, (c) degree of encouragement or support from parents, friends, and faculty members, (d) frequency of different measures of engagement, and (e) attitudes about different items reflecting both in- and out-of-class experiences and climate. The items measured students' perceptions of these elements of the undergraduate experience.

Despite a number of proactive strategies used to counter the generally low rate of responses to on-line questionnaires, the response rates to the on-line student questionnaire were disappointing and averaged only 10.6% across all institutions (N=1629). Response rates remained low despite an individualized email invitation from within the institution signed by the dean of the college of engineering and three to four follow-ups of non-respondents. The low response rate limits what conclusions that can be empirically supported about individual institutions, but does not diminish that the relatively large number of respondents reflects experiences in diverse institutional settings.

Analysis

Exploratory factor analysis was used in the initial phase of the analysis to identify a set of moderate or highly reliable factors or scales for use in the analysis. Dependent variables were not included in the analysis. The final set of factors measuring institutional and environmental constructs each contained multiple questionnaire items and demonstrated moderate to high reliability.

The dependent variable in this study was students' level of agreement (strongly agree, somewhat agree, somewhat disagree, strongly disagree, or no opinion) with the questionnaire item: "If I had to do it again, I would still major in engineering." In this paper, this is variously called satisfaction with an engineering major, short-term interest in engineering, or commitment to remaining in an engineering major.

Hierarchical regression was used in the second phase of the data analysis in order to determine what set of variables accounted for the most variance in the dependent variable. Hierarchical regression makes assumptions about which of the variables and factors are added to the regression models in steps or stages, depending on theoretical considerations. At each stage, an additional set of variables is added and the total amount of variance explained (R^2) up to this point is calculated. A significant F statistic signals that a block of variables adds significant statistical power to the model. The standardized

Beta weight indicates variables or factors that are significant even when all other variables entered up until this point are considered simultaneously. When the variables are the same, the cumulative predictive power of the models do not vary in the last step, regardless of what order the block of variables are entered.

The results presented in this paper are the output of six different hierarchical regression models (results for each variable or factor by model are not shown). In each case, two characteristics of the institution (number and proportion of women completing undergraduate degrees in engineering) were entered as exogenous variables in the first step of the model. The effects of this first block of institutional variables are discussed elsewhere[27] . The block of variables entered second was switched in each set of models in order to provide a way to isolate the total amount of variance explained (Adjusted R^2) by, first, the individual factors and, second, the environmental factors when only two institutional characteristics were considered.

The first two models included all respondents, with individual qualities entered first and environmental qualities entered at the second step in one model and, in the second model, the positions switched with the environmental factors entered second and the individual third. The remaining four models followed the same procedures but disaggregated data by gender, in order to answer the question about whether individual and environmental factors had a different degree of power in explaining male and female student's intent to remain in an engineering major.

Factors Used in the Analysis

Beyond the two institutional factors entered in the first step of all the hierarchical regression, the factors used in the analyses included three individual measures and four measures of the collegiate environment. Each factor contained multiple questionnaire items. The *individual factors* were measures of (a) three questions that measured motivation or reasons for remaining in engineering [salary, enjoyment or interest, and future employment opportunities], (b) self-assessment of math, engineering, science, and overall ability, and (c) two questions about perceived support from parents and friends for engineering as a good fit. The four measures of the *collegiate environment* were (a) eight questions about engagement, largely in class; (b) five questions about department and university climate [largely about issues, such as female role models, generally assumed to be related to the enrollment and persistence of women]; and a third factor that is calculated with the largest number of questionnaire items (c) respect/care shown by engineering faculty members and fellow students.

RESULTS

This research provides evidence to weigh the accuracy of the long-standing dividing line that has been drawn by STEM scholars between the relative power of individual qualities, such as motivation and ability, and elements of the undergraduate collegiate experience to predicting women's success and persistence in STEM majors like engineering. While at first glance it is easy to jump to the conclusion that gender is significant in the equation because there are huge differences in the persistence rates in engineering across institutions by gender, the question central to this investigation is whether it is accurate to say that undergraduate women need to have more ability and motivation, as well as more environmental supports, to remain interested in engineering at rates comparable to their male colleagues.

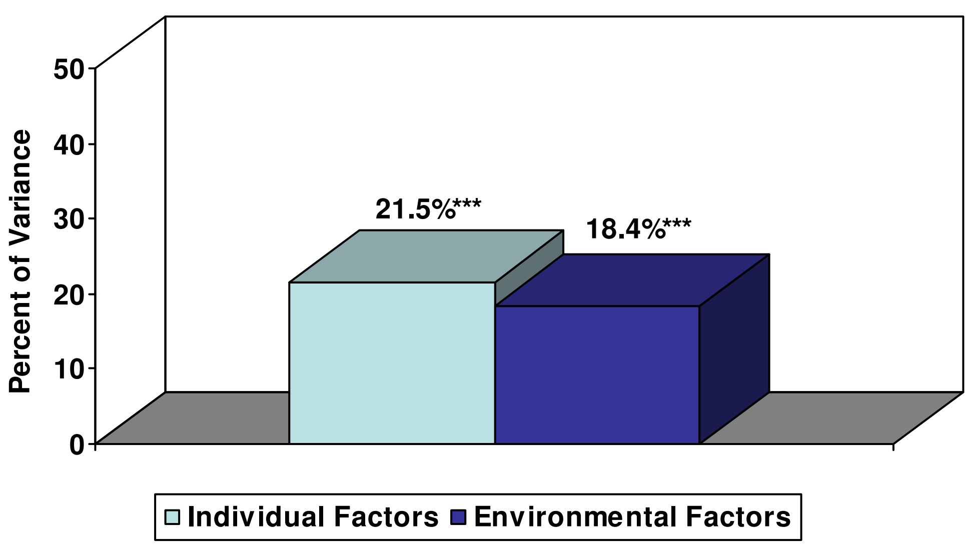
The Dependent Variable: Intent to Remain in Engineering

There are not significant differences by gender in the percentage of respondents that agreed that if they had to it over again, they would still major in engineering. Overall, the vast majority of questionnaire respondents somewhat or strongly agreed that if they had to do it again, they would still major in engineering (90.8%). The gap between men and women agreeing with this question was larger among engineering majors enrolled at private (female 89.7%; male 96.9%) than public colleges and universities (female 90.2%; male 92.1%), but the differences are not statistically significant.

The Relative Contribution of Individual and Environmental Factors

The first research question about the relative contribution of individual and environmental factors was answered by comparing the relative contribution or Adjusted R^2 produced by two regression models that combined both male and female respondents. Table 1 displays the percentage of variance explained by one cluster of individual and one cluster of environmental factors for both men and women, prior to the final step in the regression analysis when the effect of both sets of factors are considered at the same time. The three asterisks indicate that in both cases, the factors are statistically significant and predictive at the level of p=.001. The use of pairwise deletion explains the difference between the total number of respondents and those used in each of tables presented below.

Amount of Variance in the Dependent Variable Explained by Individual and Environmental Factors (N=1560)



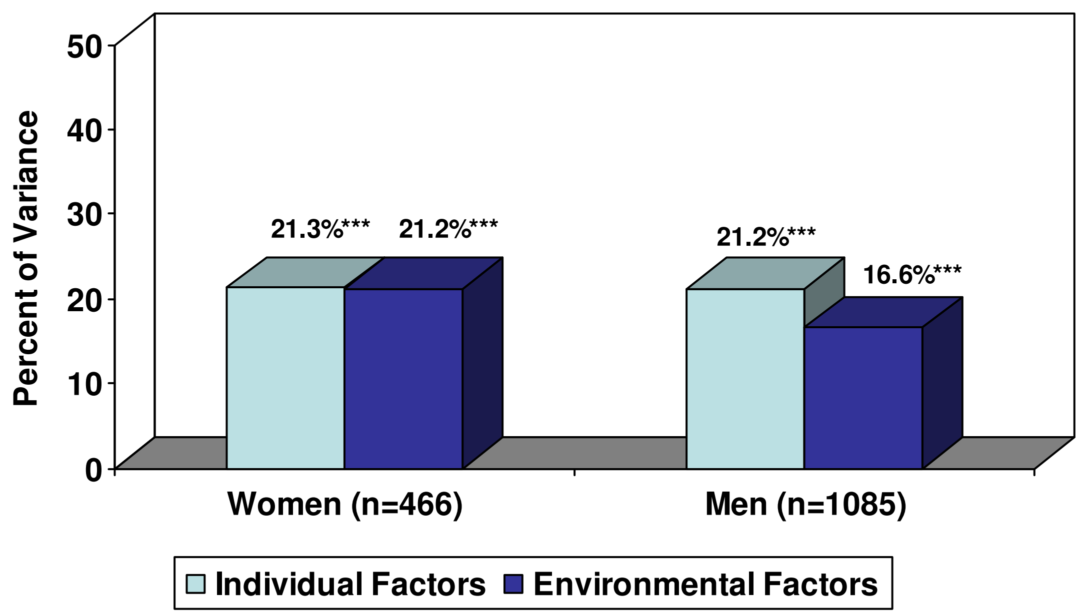
***p ≤ .001

Results shown in Table 1 indicate that while both are significant, individual factors play a somewhat stronger role in explaining student's level of agreement with the questionnaire item about their choice of an engineering major. When the responses of both men and women were combined, each of the three factors in the cluster of individual qualities (Self-Reported Academic Ability, Support, and Motivation) were significant when entered as the second step. Two of the four factors in the environmental block (Respect/Care and Discouraging Educational Experiences) were significant when added in the second step. The two factors, Engagement and Departmental/University Climate, played no significant role in predicting commitment to an engineering major when entered in the second block of environmental factors. The effect of Discouraging Education Experiences was significant and negative.

Comparing the Contribution of Individual and Environmental Factors by Gender

The second research question addressed differences by gender in the amount of variance in the dependent variable, conviction about remaining in an engineering major, by gender.   Table 2 displays the Adjusted R^2 produced by a set of separate hierarchical regression models for men and women when individual factors were entered as a second block and, following that, when two more calculations were performed to determine the variance explained when the block of environmental factors were added second.

Table 2: Amount of Variance in the Dependent Variable Explained by Individual and Environmental Factors by Gender



***p ≤ .001

The Adjusted R^2 shown in Table 2 support the conclusion that even when separated out, individual and environmental factors explained a significant percentage of the variance in the dependent variable for both men and women. The contribution of the individual factors to explaining the variance is nearly identical for women and men, explaining 21.3% of the variance for women and 21.2% of the variance for men. Bigger differences are seen on the effect of entering the environmental factors as the second block. The environmental factors measured proved to be a more powerful predictor of the variance for women (21.2%) than for men (16.6%). When added second, environmental and individual factors had almost equal weight for women, while for men the individual factor had more predictive power.

DISCUSSION

Results from the analysis indicate mixed support for the adage that undergraduate women have to be brighter, more motivated, and are in need of more environmental supports than their male counterparts to persist in engineering. Statistical support for the statement lies only in the later part of the proposition. Self-reported academic ability did not play a statistically significant role for either men or women when entered in the regression equation in the second step with other individual variables. The measure of motivation, another individual variable, was a significant predictor for both men and women, but it was a stronger predictor for men ($ß=.307$, $p \leq .001$) than for women ($ß=.270$, $p \leq .001$) when the individual block was entered second.

The outcomes are different for the contribution of environmental factors to explaining interest in an engineering major, which played a more significant role in sustaining interest in engineering for women than men. When entered in the second block, the environmental factor, Respect/Care, had stronger predictive power for women than men (Women: $ß=.343$, $p \leq .001$; Men: $ß=.270$, $p \leq .001$). Negative Educational Experiences, a factor identified by Goodman et al.[10], had a statistically significant effect in the regression equations for both men and women, but the effect was stronger for women ($ß=-.211$, $p \leq .001$) than men ($ß=.-141$, $p \leq .001$).

Contrary to Fox et al.'s assertion[14], the block of individual variables, particularly the factor measuring motivation, had more explanatory power for both men and woman than the environmental factors. The variable, Motivation, played the most powerful role, but was weaker for women than men. The weaker power of the measure of motivation for women than men is probably due to the fact that three questionnaire items used to calculate the factor tapped more into the top reasons given by men than women for remaining in an engineering major (salary potential, employment opportunities, and interest or enjoyment in engineering). The social and economic potential of engineering to improve the human conditions is generally recognized as playing a key role in both attracting and retaining women in engineering[28, 29].

Consistent with most previous research, while significant predictors of the intent to remain in an engineering major for both men and women, supportive and non-supportive elements of the collegiate environmental played a stronger role for women than men in satisfaction with the choice of an engineering major. This is explained by differences in two factors in the environmental block, one of which -- Respect/Care -- made a positive contribution, and a second -- Discouraging Educational Experiences -- which was negative, particularly for women. The factor, Respect/Care, contained results of eight items on the student questionnaire; half of which are related to respect shown by male and female peers and the remaining related to the quality and concern for students care shown by teachers and the university as a whole. These are more important to women's than men's intent to continue in an engineering major. Similarly, elements of the collegiate environment that were seen as negative, such as competition for grades and amount of time required for coursework, had a greater impact on women's than men's commitment to an engineering major.

CONCLUSIONS

Results from the statistical procedures reported here are not entirely consistent with previous research. Results both confirm and contradict some of the assertions made by Fox et al.[30] and Goodman et al.[31]. Consistent with Fox et al.'s argument, environmental factors play a more significant role for women than men in predicting persistence in engineering, but contrary to their argument, the individual factors measured had more predictive power than the environmental factors. Results are consistent with Goodman et al. in pointing to how competition for grades and the time required for coursework affect both men's and women's interest in engineering, but have a stronger negative effect on women than men, perhaps because of wider interests. Most notably different from Goodman's results, however, is the failure to find a significant role for the variable designed to measure engagement. While Goodman's team emphasized how engagement in- and out-of-class enhanced both satisfaction with the major and self-confidence, particularly for women, the measure of engagement used in this research did not survive as a significant factor in the regression equations. Differences in these results may be due to different emphasis placed in the two studies on in- and out-of-class engagement. Goodman's measures emphasized engagement in out-of-class activities, such as in activities sponsored by a Women in Engineering Club, while most of the questionnaire items in the engagement variable used here, involve in-class behaviors such as serving as a leader in a group project in an engineering class.

The single most important message from this research is that attending to elements of the educational experience, such as students' perceptions about the competition for grades and respect shown by peers, have more impact on women's than men's persistence, but they play a significant role in both. Institutions that focus on altering individual factors among female students in order to improve retention should consider diversifying their approach so that environmental factors such as the practices and policies that apply directly to the classroom experience are attended to as well. Laboratory and group assignments may be a particularly critical nexus in shaping interest in engineering, both in communicating the social and economic significance of the subject matter and acceptable ways for individuals to work together that communicate respect and care of individual's commitment and ability to be successful as an engineer. These are examples of practices raised in the context of accelerating the presence of women in engineering, but whose effects contribute positively to men's interest in engineering as well.

REFERENCES

[1] Lord, S. M., M. M. Camacho, R. A. Layton, R. A. Long, M. Ohland, and M. H. Washburn. 2009. Who's persisting in engineering? A comparative analysis of female and male Asian, Black, Hispanic, Native American, and White students. *Journal of Women and Minorities in Science and Engineering* 15: 167-190.

[2] Amelink, C. T. and E. G. Creamer. In press, 2010. Gender differences in elements of the undergraduate experience that influence satisfaction with the engineering major and the intent to pursue engineering as a career. *Journal of Engineering Education*.

[3] Goodman, I. F., C.M. Cunningham, C. Lachapelle, M. Thompson, K. Bittinger, R.T. Brennan, and M. Delci. 2002. *Final Report of the Women's Experiences in College Engineering (WECE) Project*.

[4] Society of Women Engineers. 2008, Summer. *SWE Magazine*.

[5] Fox, M. F., G. Sonnert, and I. Nikiforova. 2009. Successful programs for undergraduate women in science and engineering: Adapting versus adopting the institutional environment. *Research in Higher Education*, 50: 333-353.

[6] Sonnert, G., M.F. Fox, and K. Adkins. 2007. Undergraduate women in science and engineering: Effects of faculty, fields, and institutions over time. *Social Science Quarterly,* 88 (5): 1333-1356.

[7] Larose, S., C. Ratelle, F. Guay, C. Senecal, and M. Harvey. 2008. A sociomotivational analysis of gender effects on persistence in science and technology: A 5-year longitudinal study. In Gender and occupational outcomes, eds. Helen Watt and Jacqelyn Eccles, 171-192. Washington, D. C.: American Psychological Association.

[8] Margolis, J., and A. Fisher. 2003. *Unlocking the clubhouse: Women in computing*. Cambridge, MA: MIT Press.

[9] Tonso, K. L. 2006. Teams that work: Campus culture, engineer identity, and social interactions. *Journal of Engineering Education* 95 (1): 25-37.

[10] Goodman, I. F., C.M. Cunningham, C. Lachapelle, M. Thompson, K. Bittinger, R.T. Brennan, and M. Delci. 2002. *Final Report of the Women's Experiences in College Engineering (WECE) Project*.

[11] Chen, H., L. R. Lattuca, and E. Hamilton. 2008. Conceptualizing engagement: Contributions of faculty to student engagement in engineering. *Journal of Engineering Education* 97 (3): 339-54.

[12] Amelink, C. T. and E. G. Creamer. In press, 2010. Gender differences in elements of the undergraduate experience that influence satisfaction with the engineering major and the intent to pursue engineering as a career. *Journal of Engineering Education*.

[13] Fox, M. F. 2000. Organizational environments and doctoral degrees awarded to women in science and engineering departments. *Women's Studies Quarterly* 28 (Spring/Summer): 47-61.

[14] Fox, M. F., G. Sonnert, and I. Nikiforova. 2009. Successful programs for undergraduate women in science and engineering: Adapting versus adopting the institutional environment. *Research in Higher Education*, 50: 333-353.

[15] Kanter, R.M. 1977. Some effects of proportions on group life: Skewed sex ratios and responses to token women. *American Journal of Sociology,* 82 (5): 965-990.

[16] Sonnert, G., M.F. Fox, and K. Adkins. 2007. Undergraduate women in science and engineering: Effects of faculty, fields, and institutions over time. *Social Science Quarterly,* 88 (5): 1333-1356.

[17] Rosser, S. 1997. Consequences of ignoring gender and race in group work. In S. V. Rosser (Ed.), *Re-engineering female friendly science*, 38-52. New York Teachers College Press.

[18] Etkowitz, H., C. Kemelgor, and B. Uzzi. 2000. *Athena unbound: The advancement of women in science and technology*. Cambridge, UK: Cambridge University Press.

[19] Zhao, C.M., R. M. Carini, and G. D. Kuh. 2006. Searching for the peach blossom Shangri-La: Student engagement of men and women SMET majors. *Review of Higher Education*, *28*(4): 503-525.

[20] Etkowitz, H., C. Kemelgor, and B. Uzzi. 2000. *Athena unbound: The advancement of women in science and technology*. Cambridge, UK: Cambridge University Press.

[21] Xie, Y., and K. A. Shauman. 2003. *Women in science: Career processes and outcomes*. Cambridge, MA: Harvard University Press.

[22] Ahuja, M. K. 2002. Women in the information technology profession: A literature review, synthesis, and research agenda. *European Journal of Information Systems* 11: 20-24.

[23] Creamer, E. G., and C. T. Amelink. (in progress). The effects of numeric and proportional representation of women in undergraduate engineering on short- and long-term term interest in engineering.

[24] Astin, H. and L. Sax. 1996. Developing scientific talent in undergraduate women. In C. S. Davis, A. Ginorio, C. Hollenshead, B. Lazarus, and P. Raymen (eds), *The equity equation: Fostering the advancement of women in the sciences, mathematics, and engineering*. San Francisco, CA: Jossey-Bass.

[25] Creamer, E. G., C.T. Amelink, P.S. Meszaros, and C.J. Burger. 2009. *Investigating the gender component: Cultures that promote equity in undergraduate engineering. Integrated report.* Retrieved June 18, 2009 from http://www.wepanknowledgecenter.org/c/journal_articles/view_article_content?groupId=1013&articleId=1111&version=1.0&p_l_id=PUB.1.81

[26] Goodman, I. F., C.M. Cunningham, C. Lachapelle, M. Thompson, K. Bittinger, R.T. Brennan, and M. Delci. 2002. *Final Report of the Women's Experiences in College Engineering (WECE) Project*.

[27] Creamer, E. G., and C. T. Amelink. (in progress). The effects of numeric and proportional representation of women in undergraduate engineering on short- and long-term term interest in engineering.

[28] Goodman, I. F., C.M. Cunningham, C. Lachapelle, M. Thompson, K. Bittinger, R.T. Brennan, and M. Delci. 2002. *Final Report of the Women's Experiences in College Engineering (WECE) Project*.

[29] National Academy of Engineering. 2008. *Changing the conversation: Messages for improving the public understanding of engineering*. Washington, DC. National Academies Press.

[30] National Academy of Engineering. 2008. *Changing the conversation: Messages for improving the public understanding of engineering*. Washington, DC. National Academies Press.

[31] Goodman, I. F., C.M. Cunningham, C. Lachapelle, M. Thompson, K. Bittinger, R.T. Brennan, and M. Delci. 2002. *Final Report of the Women's Experiences in College Engineering (WECE) Project*.