Women in Engineering: Statistical Analysis of ACT Data and Proposed Procedure to Reverse Trend

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Abstract

Women have historically been underrepresented both in college majors and professional careers in STEM fields. This disparity can be observed in many countries, though it is most evident in the US. In this paper we analyze historical ACT data over a 30-year span and correlate gender differences with ACT scores and expressed interest in STEM (Science, Technology, Engineering, and Math) related college majors. SPSS software was used to analyze the data and examine the historical trends of students' expressed interest in STEM related majors. Results show that there is a significant discrepancy between the number of men and women students who expressed interest in engineering majors. The data also show that social influences such as the emergence of computer fields including computer gaming and the dot.com era have profound influence in students' interest in STEM fields. To help develop specific strategies for timely remediation and help reverse this trend students were grouped into three categories -- well prepared (ACT $\geq$ 28), under prepared ($27 \leq$ ACT $\geq$ 19), and unprepared (ACT < 19). Of the total number of students who expressed interest in engineering majors there are many who appear either completely unprepared or relatively under prepared for the demands of these fields. Results from this analysis demonstrate the importance of earlier interventions to encourage students who still have enough time to prepare for opportunities that interest them. It is also probable that students are making college major choices based on little or no data, and may, therefore, be at retention risk if they are admitted into an engineering program.

This paper also highlights ongoing efforts to share data and work with high school counselors in an effort to help students identify more realistic career options or to timely target students for effective math remediation and help encourage increased participation in STEM majors and careers. Based on the data found in these analyses, we will next be surveying high school career guidance counselors. This survey will help gain insight into the high school counselors' understanding and potential biases regarding engineering and engineers.

I. Introduction

Over the lifespan, women are nearly twice more likely to have interests in fields such as arts, education and language as opposed to engineering fields. In engineering, women's interest is about one third that of men [1]. Further, women make up almost half of the total workforce but represent only 25 percent of the workforce in STEM (Science, Technology, Engineering, and Math) related occupations [1]. In a recent study, the National Science Board of the National Science Foundation reported that between the years 1983 and 2002 the number of women who received their bachelors in biology and the physical sciences were 61 percent and 43 percent respectively. In contrast, women made up only 21 percent of the bachelors recipients in engineering [2]. Furthermore, the number of women freshman with intent to major in engineering decreased to 16 percent in 1982 and further dropped to 14 percent in 1989 where is remained stagnant until 1998 [1]. More recent data shows that though the percentage of women's interest in engineering increased to 20.1% in 2000, it once again continued to drop from 18.9% in 2002, to 17.8% in 2004, and finally 17.4% in 2006 [3]. Conversely, men showed a slight increase from 79.9% in 2000 to 82.6% in 2006 [3]. The percentage of freshman women majoring in engineering was 2.7% from 1994 to 2007, while men maintained an average of 15.7% during the same 14 years period [3].

Given that an undergraduate degree is a prerequisite for enrollment in graduate programs, it is not surprising that these gender discrepancies persist in graduate training programs [1]. Specifically, in 1980 only 9% of full time graduate students in engineering programs in doctorate granting institutions were women. Eighteen years later this rate increased to 19.6 %. Although similar increases were observed in other science and mathematics intensive fields (e.g., 33.4 % to 45.2 %) the absolute number of women students in these graduate programs is now over twice that of engineering [1]. It has been reported that although female participation in less mathematics intensive graduate programs may be as high as 67 %, the participation in more mathematics intensive fields such as engineering has been as low as 17% [4].

These data display the continued under-representation of women in STEM preparatory undergraduate and graduate programs and further suggest that this gender discrepancy is most pronounced in engineering. This is disquieting given the significant efforts by government agencies, private organizations and foundations to increase gender diversity in this area. Despite these efforts female involvement in engineering fields has either continued to decrease or stayed stagnant for the last 30 years [5]. It is encouraging to see that other science related fields are finding ways to entice women into their college majors, but based on recent data, engineering fields seem to still lag behind. Efforts and resources allocated to change this long-standing trend of female lack of interest in engineering include scholarship opportunities, mentorship programs in a wide variety of K-12 activities, and a higher recruitment rate than male counterparts after graduation [5]. Specific examples of programs supported by the National Science Foundation include: increasing the participation and Advancement of Women in Academic Science and Engineering Careers (ADVANCE), Research on Gender in Science and Engineering (GSE), Louis Stokes Alliances for Minority Participation (LSAMP), Research Experiences for Undergraduates (REU), and Research Experience for Teachers (RET) [2]. As for the efforts by the National Academy of Engineering in promoting STEM in K-12 classrooms, they include hundreds of studies conducted, many written reports, organization of thousands of extra-curricular activities, and the establishment of dozens of web sites to inform and increase interest in young people of both genders and various age levels [7]. Most of these approaches, however, target individual students as opposed to persons who influence students' education and career decisions [7]. Additional research is needed to understand the trend and relative continued lack of female interest in engineering majors and occupations.

From the above sections it is clear that there is a disparity in female participation in STEM majors despite many programs by government and private organizations attempting to ameliorate the situation. Available solutions, thus far, have provided marginal improvements at best. Therefore, it seems necessary to investigate the origin of the disparity, which has been theorized in career development literature. In this literature, the central role that career and academic interests play in decision-making of young male and women students has been amply emphasized. Therefore, we analyze 30 years span of ACT data to examine correlation between expressed interests in majors of high school students, highlighting recent historical trends, and describing how the data will be used to explicate the relations between interests and academic achievement. Based on obtained data associated observations, procedures for effective and timely remediation to reverse this long-standing trend are described.

II. Methods and Participants

The method is based on analyzing the expressed interest in STEM courses by high school students who took the ACT exam over 30 year period (1974 - 2006). Over a million high school students took the ACT over this period, responding to questions beyond the ACT test itself including demographic information, and interest in college majors. Specifically, the profile section of an ACT exam contains 190 questions, 79 of which relate directly to high school activities, interests, and accomplishments outside of the classroom [8]. The questions relate to students' activities in a variety of disciplines and interest areas. They also include student-selected college major aspirations and are answered in yes/no format [8]. In the present study, we used the student-selected college major aspiration data and correlate it with the associated students' ACT scores. Students were also asked how certain they were of their college major choice (Very certain, Fairly Certain, Uncertain). Only students who indicated that they were fairly or very certain of their choice were included in subsequent analyses; thus ensuring that students with measured interest were the focus of this study. Furthermore, as mathematics preparation has been consistently observed to be an important measure for student success and retention in STEM fields [9], ACT mathematics test scores were, therefore, used to evaluate the relationship between career aspirations and mathematics preparation. Specifically three groups were created to capture differing levels of mathematics achievement. Highly prepared students included those with ACT mathematics score greater than or equal to 28, moderately prepared students included those with ACT mathematics scores between 19 and 27, and inadequately prepared students had ACT mathematics scores less than or equal to 19. All analysis was conducted on using SPSS software from IBM.

III. Results

Figure 1 shows the expressed interests of men and women students in electrical engineering and highlights the importance of historical analysis of interests. As may be noted, pronounced gender differences can be clearly observed beginning in the 1970's and persisting through the present. While

male interest in electrical engineering is presently on the decline, female interest remains relatively stagnant in this major during that same time period. It is important to note the steep increase in male interest that occurred in the early 1980's, which may be attributable to the rise of personal computers and their associated hardware and applications. This increase was not seen in women students.

Figure 2 shows the student interest in computer engineering. As seen in the other engineering fields, similar trends are observed for other majors with 'computer' in the title (computer science, computer programming, and computer and engineering systems). The very strong peak expressed during the early 1980's was similar for both men and women students. This may be attributed to the hype in computer-related careers and the emergence of the era of the home computer. This peak was also seen in the electrical engineering major for men but not women students, perhaps suggesting women's lack of interest in the newer field of computing, or in computer programming. The expressed interest peaks seen in figure 2 are the most profound of all of the engineering majors examined in this project. Within a six-year period expressed interest in computer and information sciences increased nearly fourfold while in subsequent years these areas experienced equally precipitous drops. A similar spike can be observed in the mid to late 1990s (dot com, Y2K, consumer demand for internet-enabled services) but only for male students. This second peak may have been due to male interest in computer gaming. Notably, women's interest did not experience this second peak, perhaps because far fewer women display interest in computer games than their male counterparts.

Figure 3 shows results from an analysis of engineering college major and occupational interests of students by past achievement (ACT math scores). This research analyzes the last year (2006) of the available data in order to understand the current level of disparity between interest (intended college major) and actual measured ability (student's ACT score). Students who have ACT math scores below 19 are poorly prepared, and those with scores of 20-27 are marginally prepared for the major they have expressed interest in. Students who scored 28 or above on the ACT were prepared for their intended college major. By examining majors where the majority of students are poorly or marginally prepared, we can foresee probable challenges for retaining students in these majors, despite their expressed interest. The data in Fig 3 clearly highlight the large number of students who are expressing interests in engineering-related college majors and careers, but who may lack sufficient mathematics preparation to succeed in these pursuits. High school counselors might use data such as those shown in Figure 3 in an effort to help students identify more realistic career options or to timely target students for effective math remediation.

These observations including statistical differences between states, historical trends in different disciplines within engineering and women's retention rates in engineering will be described in the presentation. In moving forward with the data we will analyze the results from a survey that has been distributed to school counselors. This survey aims to gain insight into the high school counselors' understanding and potential biases regarding engineering and engineers. Copies of this survey will be presented together with the summary of the collected data, and an engineering feedback session will be held in order to help improve the effectiveness of this process.

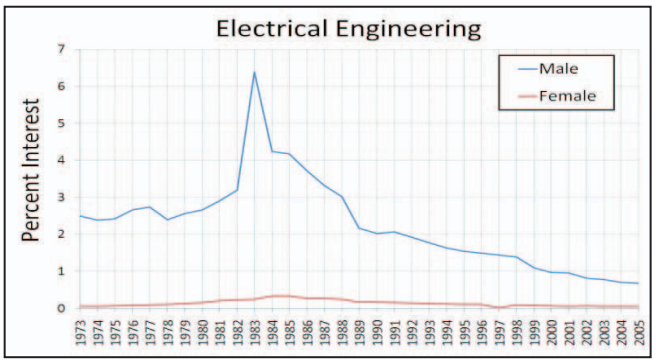

Fig.1, ACT data on students expressed interest in electrical engineering with focus on gender difference.

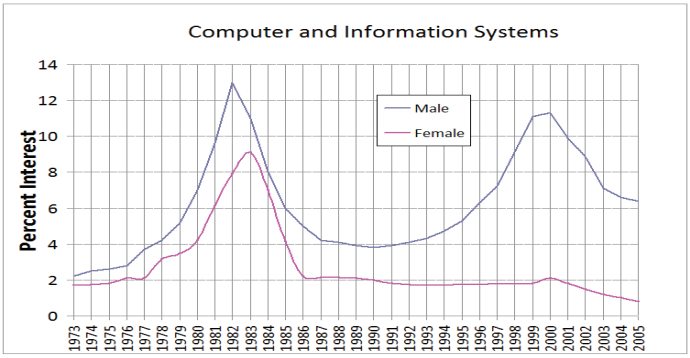

Fig.2, ACT data of students expressed interest in engineering majors.

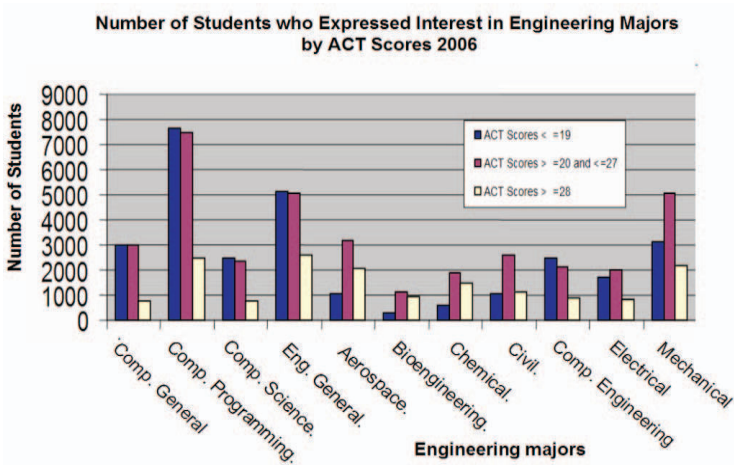

Fig.3, ACT data of students expressed interest in engineering majors.

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