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Title: WHAT ATTRACTS HIGH-ACHIEVING, SOCIOECONOMICALLY DISADVANTAGED STUDENTS TO THE PHYSICAL SCIENCES AND ENGINEERING?

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Abstract: Socioeconomically disadvantaged (SED) students are less likely to major in physical sciences or engineering. To guide recruitment and retention of a diversity of talent, this study examined what attracts high-achieving SED students to these fields. Participants were 50 undergraduates majoring in physical sciences or engineering enrolled in the McNair mentoring program. Ninety-two percent were first-generation in college and/or low-income; 56% were female, 40% Hispanic, and 36% White. This group of SED students mostly explained their attraction to physical sciences or engineering in terms of scientific curiosity and a passion for research. They also reported being excited about the possibility to use their science and engineering education for social purposes. Securing a good job emerged as another important motivator, particularly for male and ethnic minority respondents. These findings suggest common as well as unique reasons for majoring in physical sciences or engineering among a diversity of SED students. [ABSTRACT FROM AUTHOR]

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WHAT ATTRACTS HIGH-ACHIEVING, SOCIOECONOMICALLY DISADVANTAGED STUDENTS TO THE PHYSICAL SCIENCES AND ENGINEERING?

Socioeconomically disadvantaged (SED) students are less likely to major in physical sciences or engineering. To guide recruitment and retention of a diversity of talent, this study examined what attracts high-achieving SED students to these fields. Participants were 50 undergraduates majoring in physical sciences or engineering enrolled in the McNair mentoring program. Ninety-two percent were first-generation in college and/or low-income; 56% were female, 40% Hispanic, and 36% White. This group of SED students mostly explained their attraction to physical sciences or engineering in terms of scientific curiosity and a passion for research. They also reported being excited about the possibility to use their science and engineering education for social purposes. Securing a good job emerged as another important motivator, particularly for male and ethnic minority respondents. These findings suggest common as well as unique reasons for majoring in physical sciences or engineering among a diversity of SED students.

Socioeconomically disadvantaged (SED) individuals, that is, persons who are the first in their families, to attend college and/or those who come from low-income families represent a growing proportion of students enrolled in post-secondary institutions in the United States (U.S.) (Chen, 2005; Longwell-Grice & Longwell-Grice, 2008). These students however have lower rates of enrollment and retention than their more advantaged peers (Chen; Ishitani, 2003; Naumann, Bandalos, & Gutkin, 2003; Olenchak & Hebert, 2002; Pascarella, Pierson, Wolniak, & Terenzini, 2004). In addition, they are less often drawn to physical sciences and engineering majors (Chen).

The underparticipation of SED students in physical science and engineering is problematic on at least two accounts. First, it is a missed opportunity for these students to improve their socioeconomic opportunities because an education in physical sciences and engineering opens the door to high-status and lucrative careers (Nauta, Epperson, & Waggoner, 1999). Second, it is a loss for physical science and engineering fields because they are understaffed and in need of a diversity of talents (Congressional Commission, 2000; National Science Board, 2006; Tapping America's Potential (TAP) Coalition, 2008). According to recent analyses, increasing the participation of talented individuals from underrepresented groups, such as SED students, could ameliorate staffing shortages as well as improve creativity and innovation. A growth in the physical sciences and engineering labor force is considered critical if the U. S. is to maintain scientific and economic competitiveness (Congressional Commission; National Science Foundation, 1999; TAP).

What Attracts Individuals to Physical Sciences and Engineering Education and Careers?

Research on what motivates individuals to enter science and engineering fields has been driven by structured interest inventories based on Holland's (1959,1997) RIASEC (Realistic, Investigative, Artistic, Social, Enterprising, and Conventional) personality types. These inventories assess what the typical person in a certain field is like to predict what the future workforce for each field should look like. The findings of these inventories, while informative in some way, are limiting because they take a static, circular view of what counts for success in an occupation (Deng, Armstrong, & Rounds, 2007; Hansen, 2005; LeBold, Linden, Jagacins-ki, & Shell 1983). The inventories approach does not consider that the skills required for success in any occupation evolve over time, as occupations change. For example, structured vocational interest inventories describe, and thus predict, successful physical scientists and engineers as individualistic, realistic, investigative, nonsocial, nonartistic and nonenterprising (LeBold et al., 1983). Although this may be the personality profile of the successful physical scientist or engineer in the past, it may not be a good recipe for the successful physical scientist of the present and future — not only because work in the physical sciences and engineering has changed and has become more socially and globally grounded, but also because past criteria for success may have been limiting. In fact, social, artistic and enterprising skills might have been an asset to physical scientists and engineers in the past had they not been filtered out from the pool due to social biases against individuals who had these skills. In other words, the structured-inventory perspective on vocational behavior does not often take into account of the fact that homogeneity (e.g., by sex) of personal characteristics for individuals in a particular vocational domain may reflect arbitrary social filters rather than meaningful predictors of interest or talent. Consider the fact that in the United States, women represented and still are a minority of engineers. This is not because they are less likely to be talented in math. Rather, math-talented women enter math-intensive-fields other than engineering, such as medicine, fields which in this country are perceived as more feminine, and where math-talented women can use their often equally high verbal skills (Ceci, William, & Barnett, 2009).

Another limitation of research on what motivates individuals to enter science and engineering fields is inattention to issues of diversity. When diversity questions are asked, it is usually about gender, and typically from a descriptive, individual-difference perspective. For example, men's vocational decisions are described as motivated by investigative and financial interests, and women's by social and artistic interests (Achter, 2005; Hansen, 2005; LeBold et al., 1983; Price, 2003; Rutherford, 2007; Wender, 2004), without consideration for the sources of these differences, nor for the stability of these differences across a diversity of women and men. Particularly limited consideration is given in vocational research to SED issues, and how SED experience may interact with gender and ethnicity experiences in influencing interests and achievement. As noted by Lent and colleagues (Lent, 2005; Lent, Brown, & Hackett, 1994), socioeconomic, gender and cultural experiences have a profound influence on vocational interests in the way they facilitate, restrict, and override personal choices via socialization patterns and the availability of opportunities.

In conclusion, structured-measures approaches have dominated vocational research for decades. These approaches have contributed to systematizing the field and to facilitating comparisons across studies. Given their longevity, these approaches may however now have more costs than benefits. One likely cost is that they constrain researchers to worn paths and reduce sensitivity to new trends, including the human diversity of today's workforce as well as the evolution of occupations.

The Current Study

This study investigated what attracts individuals to physical sciences and engineering majors using an open-ended method, and with a focus on the interaction of socioeconomic, gender, and ethnicity factors. Consistent with a positive psychology perspective, it focused on SED individuals who were doing well as physical sciences and engineering college students.

Method

Sample

The sample for this study was students (JV= 50) majoring in physical sciences and engineering and participating in either the yearlong or in the summer McNair Program at a large, public Mountain West University. The McNair Post-Baccalaureate Achievement Program is one of six federal TRIO Programs funded by the U.S. Department of Education to assist SED students with strong academic potential through their undergraduate education in science, technology, engineering, or mathematics (STEM) disciplines and to encourage their entrance into graduate programs (U.S. Department of Education, 2002). To be eligible for the McNair Program, students have to be either first-generation, low-income, or ethnic minorities underrepresented in higher education. Admission in the McNair Program also requires a 3.00 GPA or higher, or the potential for achieving that criterion by graduation. This study included data for 50 out of the 56 students enrolled in the McNair program at our institution between 1996 and 2005. During our study period, 12 participants per year were enrolled in the 9-month McNair program, typically for two years, and an additional four to six participants were enrolled in the summer-only McNair program.

This study's participants were nearly all first-generation in college (84%) or low-income (82%), with these two statuses strongly related to each other, $\varphi = .52$, $p > .0001$. Fifty-six percent of respondents described themselves as female; 40% as Hispanic, 36% as White, and 8% or fewer identified as belonging to other ethnic groups (i.e., American Indian, Native Hawaiian or Pacific Islander, African American, or multiethnic). The sample demographic profile is represented in Figure 1; 72% of the sample met at least two eligibility criteria, and 32% met all three. Demographic information by field of study is shown in Table 1.

Measures

To evaluate motivation for vocational choice, we used McNair students' written responses to the open-ended question: "What is most attractive about your current major/career?" Demographic information was also gathered.

Procedure

Data collection. Data were collected from students upon admission into the McNair Program. Recruitment into the McNair Program was accomplished via mailings targeted at eligible students. This study's procedures were approved by our University's Institutional Review Board.

Data coding and analysis. Participants' responses were transcribed into Word format, and entered into the qualitative data analysis program NVivo for the purpose of template analysis (King, 1998). The first stage of template analysis involved developing a coding template. During the second stage, the template was applied to the data. During these two coding stages, participants' demographic information remained masked. The last stage of data analysis involved examining the coded data according to demographic information, such as sex or ethnicity of respondent.

Consistent with the tradition of template analysis, a number of coding-quality checks were employed to establish rigor and trustworthiness. One such check is independent scrutiny of the data. In this study, independent scrutiny was accomplished by involving two individuals (the first and the last author of this article) in the process of developing the coding template. These two individuals met weekly until they reached agreement on a coding template. Independent scrutiny was also achieved by consultations with an external qualitative-analysis expert regarding the development and application of the coding template. Finally, independent scrutiny was accomplished via participation of the full authors team in the application of the template codes to the data.

A second coding-quality check used in this study was keeping an audit trail. Included in this study's audit trail were coding templates as well as notes on how and why coding decisions were made.

Reflexivity was the third quality check employed in this study. Reflexivity requires researchers to make explicit their personal perspectives on the research topic, and to reflect on how these perspectives may have influenced research strategies and outcomes. The authors' interpretation of the evidence regarding the limited diversity of individuals engaged in STEM education and careers is that social and economic influences are dominant. Specifically, consistent with the conclusions reached by Eccles (1994,2007), Lent (2005), and Rojewski (2005), we think that differences in socialization and access to resources have a primary role in vocational interests and achievement. This interpretation influenced our preference for a qualitative method and our focus on diversity questions. Our stance also likely made us sensitive to cultural, social, and gender issues in the data — a sensitivity that can be viewed as a strength as well as a limitation in our study.

Findings

Four dominant themes as to what attracted SED individuals to physical science or engineering were identified in this study. The themes were: (1) a passion for scientific research, (2) the potential social applications of physical science or engineering training and expertise, (3) employment and financial prospects, and (4) Having fun doing physical science or engineering. Another motive mentioned by a few participants was that they had had (5) meaningful relationships with faculty and peers in the field. None of the group differences we found were statistically significant, using chi square.

A Passion for Scientific Research

Sixty-four percent of participants described being attracted to the physical sciences or engineering because of their passion for scientific inquiry. Many mentioned that it was exciting to be in a field that is new, changing, and cutting edge. This theme emerged among participants of all ethnic backgrounds but was especially prevalent among Hispanic (75%) and White (72.2%) participants. Also, 71.4% of female participants as compared to 54.5% of male participants had responses within this theme. This theme is represented by three quotes from participants who said they were attracted to their fields of study because of:

```
The ability to encompass all of science and learn constantly
throughout my life.
The discovery of new knowledge and the potential for a deep
understanding of the universe and reality.
It's still relatively new, so there is a lot to be discovered
and researched.
```

The Social Applications of Physical Sciences and Engineering

The second most common (36%) reason for specializing in physical sciences and engineering was the prospect that education in these fields would allow individuals to contribute to the well-being of their communities and of society as a whole. This theme was particularly prominent among American Indian, Native Hawaiian/Pacific Islander, and multiethnic individuals. This theme emerged in both female (39.3%) and male (31.8%) participants' responses. However more female participants than male participants specifically mentioned interests in medical and health applications, and only women mentioned interests in teaching. The social applications theme is illustrated by following three quotes from participants who said they were interested in their majors for:

```
[The] opportunity to help less fortunate (Third World countries).
… the opportunity to be involved with different people
in their communities and improve their quality of life.
Helping [sic] mankind, while still making a decent living.
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Employment and Financial Prospects in Physical Sciences and Engineering

Job opportunities and potential earnings played a role in what attracted some (20%) SED students to physical sciences or engineering. This theme was nearly twice as prevalent among males (27.3%) than females (14.3%), and among engineering (44.4%) than physical science majors (14.6%). Mentions of employment and financial opportunities were prominent among ethnic minority participants — except among those who describd themselves as Hispanic. The following quotes are representative of responses highlighting the importance of employment and financial prospects in vocational choices:

```
The job prospects are very good for all types of engineers.
I will get paid a lot to build and play with the stuff I build.
[The profession] offers much security.
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Have Fun Doing Physical Sciences and Engineering

For 20% of SED students in this sample being excited about work in the physical sciences or engineering was a reason for their attraction to those disciplines. This theme was nearly twice as prevalent among males (27.3%) as females (14.3%). Some individuals specifically noted that what most attracted them to the physical sciences or engineering was that it was fun. This theme is illustrated by the following quotes:

```
I think it is something I can be good at and will enjoy.
Chemistry is challenging but is still fun and interesting.
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Meaningful Relationships with Mentors and Peers in Physical Sciences and Engineering

A handful (6%) of respondents noted the importance of having had meaningful relationships with faculty and peers. Receiving attention from professors and having peers in the field had been vital to these participants' educational interests and choices. Examples quotes within this theme are presented below:

```
… establishing caring relationships with students/ coworkers
I would have to say the one-on-one with my professors
and grad students.
I also tend to connect with other chemists.
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Discussion

This study explored what attracted to physical sciences and engineering a sample of high-achieving, SED students in the McNair mentoring program. For most SED students, interest in the physical sciences or engineering was inspired by scientific curiosity and a passion for research. SED students also reported being excited about the possibility to use their science and engineering education for social purposes. Securing a good job emerged as another motivator, particularly for male and ethnic minority SED respondents, while enjoying work in the physical sciences and engineering was especially mentioned by male SED respondents. Finally, having had good relationships with mentors and peers in the physical sciences or engineering served as a vocational catalyst for a few respondents.

Past structured studies hypothesized and found gender differences in vocational attitudes and behavior. In fact, most previous studies were based on the assumption that engineering and physical sciences require "masculine" skills. In this qualitative study, SED female and male physical sciences and engineering students shared many perspectives with regard to their vocational choice. For both women and men, the top reason for their attraction to the physical sciences and engineering was a passion for scientific inquiry. This study's observations are in contrast to the longstanding assumption, and structured-measures findings, that men, not women, are motivated by investigative interests. In this study, women and men were similar also with regard to the second most important reason for pursuing physical sciences and engineering. For both women and men social, altruistic purposes were important in vocational choices. Once again, this study's findings contradict past vocational theory and findings that women are the ones who are moved by altruistic motives (LeBold et al., 1983; Rutherford, 2007; Wallace, Haines, & Cannon, 1999). The fact that women and men in this study valued the investigative aspect of the physical sciences and engineering might be the result of common discipline-socialization experiences. Perhaps more surprising is that both women and men in this study mentioned altruistic motives for their physical sciences or engineering vocational choice. This shared social value might indicate the influence of SED experiences. It has been suggested that socioeconomic status may be more important than ethnicity with regard to career interests and aspirations (Schoon & Parsons, 2002). Perhaps SED women and men share a sense of responsibility to give back to others. A social motive for choosing physical and engineering students may also be indicative of a paradigm shift (Coyle, Jamieson, & Oakes, 2006), with physical sciences and engineering currently being viewed as involving social responsibility. Finally, in this study, consistent with past findings, we found that male students, more often than female students reported being interested in physical sciences or engineering because of good job prospects. This trend may reflect persistent gender-differentiated socialization with regard to expectations of family responsibilities, with men more than women anticipating a provider role (Eccles, 1994).

Study Limitations and Implications for Future Research

This study drew on data gathered by the McNair Mentorship Program about SED students at a large public university. Because the study participants embodied multiple STEM minority identities (and thus met multiple criteria for under-representation in physical sciences and engineering and for eligibility in the McNair Mentorship Program) (see Figure 1), their responses cannot be attributed to the influence of a single minority variable. The data set we accessed did not include information on non-STEM minority students. To address the questions raised by this study, future studies might explore what current generations of non-STEM minority students (e.g., White students whose parents went to college) say about their attraction to physical sciences and engineering.

Implications for Engaging a Diversity of Students in the Physical Sciences and Engineering

A recent report from the National Science Foundation (2004) indicates that there is a "troubling decline in the number of U.S. citizens who are training to become scientists and engineers, whereas the number of jobs requiring science and engineering (S&E) continues to grow" (p. 1). This study's findings point to a common core of scientific and social passions animating the vocational choices of SED physical sciences and engineering female and male students. As such, they suggest that structured interest inventories do not adequately represent the occupational motives of individuals in physical sciences and engineering, especially those who are minorities in these disciplines (Deng, Armstrong, & Rounds, 2007; Bonous-Hammarth, 2000). As noted by many commentators (e.g., Ceci et al., 2009; Gas-barra & Johnson, 2008; Lam, Ugweje, Mawasha, & Srivatsan, 2003; Próspero & Vohra-Gupta, 2007; Washburn & Miller, 2007), expanding and diversifying the U.S. physical sciences and engineering labor force will require attention to, and nurturing of a broader pool of interests and motivations.

This study was completed for Ms. Conrad's University Honors Program thesis. She is now serving in the Peace Corps. This study was supported in part by U.S. Department of Education grants (A. Wilcox. V. Gallegos,& D. MacPhee) to fund the McNair Program, and by the National Science Foundation Center for Multi-Scale Modeling of Atmospheric Processes, (D. Randall. S.S. Canetto, D. MacPhee et. al.) managed by Colorado State University under cooperative agreement No. ATM-0425247. OSP No. 533045. An earlier version was presented at the 2009 annual meetings of the American Psychological Association. Toronto. Correspondence about this study should be sent to Silvia Sara Canetto Department of Psychology. Colorado State University. Fort Collins, CO 80523. email: silvia.canetto@colostate.edu

Table 1: SED Student Characteristics (n and proportion of subsample) by Major Field

	Physical Sciences (n= 41)	Engineering (n = 9)
First Generation	34 (.83)	8 (.89)
Low-Income Family	33 (.80)	8 (.89)
Sex (% Female)	25 (.61)	3 (.33)
Ethnicity		
Hispanic	18 (.44)	2 (.22)
White	14 (.34)	4 (.44)

American Indian	3 (.07)	1 (.11)
Other Native American	1 (.02)	2 (.22)
African American	2 (.05)	0
Multiethnic	3 (.07)	0

GRAPH: Figure 1. Number of individuals in subsets of the sample, by multiple categories of disadvantage.

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