A Multiphasic Approach to Discovering How Scientists Develop Career-Related Interests and Careers

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Abstract

Currently, there is little in-depth understanding of how individuals effectively orchestrate school and work-related experiences over time from high school through college and beyond to pursue careers in Science, Technology, Engineering and Mathematics (STEM). This appears important because, unlike societies such as Germany, youth in the U.S. face an almost complete lack of structured pathways from school to work. Presently in the first year of a two-year project, this study uses a mixed methods approach to address a set of research questions from a wide variety of perspectives, and works toward developing an integrated synthesis of the important factors in this process. This study deals with the human systems that underlie all other systems, as well as those human systems' interactions with other types of systems that may range from mechanical to socio-cultural systems.

Keywords: NSF, STEM, Science, Technology, Engineering and Mathematics, S&E, Career Paths, Higher Education Disciplines, Industry, Occupation

Background

Contemporary U.S. society is characterized by an "absence of structured pathways from school to work (in contrast to the German apprentice system for example)" (Mortimer, Zimmer-Gembeck, Holmes & Shanahan 2002: 441), making career decision-making in adolescence more complicated. The disconnects between K-12 and postsecondary education systems in most states leave students and their parents with few avenues for integrating high school assessments with college and university requirements and expectations and ultimately undermine student plans and aspirations (Venezia, Kirst & Antonio, 2003). Furthermore, while approximately 60 percent of high school graduates obtain some college education, only about 25 percent actually graduate with 4-year degrees (e.g., Kerckhoff, 2002). As Mortimer has emphasized, the delay on career decision-making is now extended into the mid-20s for many young people.

Currently, there is little in-depth understanding of how some individuals effectively orchestrate school and work-related experiences over time from high school through college and beyond to pursue careers in STEM while others do not. The vast majority of U.S. citizens who attend college (75-80 percent) attend public institutions and often struggle to remain in school full-time while holding part-time jobs and juggling other responsibilities. (Digest of Education Statistics, 2001) Today, the nation's need is for greater numbers of qualified STEM graduates from all types of institutions, including a broad spectrum of public colleges and universities, as well as community colleges and technical schools.

We seek to investigate the following questions:

- What high school and post-secondary experiences, supports, opportunities, and self-initiated actions affect students' career decisions and pathways, especially as these relate to STEM careers?
- To what extent do these external factors affect students' decision processes through their effects on cognitive variables, including the quality and breadth of students' knowledge concerning STEM career options, the requirements for entry, the rewards available, and how these relate to students' own capabilities, interests, needs, and values?
- How do these external factors differ for women and other underrepresented minorities? Do patterns and processes differ for these different subgroups?
- Since STEM participation is actually multidimensional, how do factors that affect participation in one cluster of STEM occupations differ from factors that affect participation in other clusters?

Methods

Extensive data bases came from Florida's K-20 Data Warehouse, FETPIP, and NCES, among other sources for three cohorts: Florida State University System (SUS) graduates in 1996/1997; Florida SUS graduates in 2002/2003; and Florida high school graduates in 1996/1997. The first year of this study focuses on a Cohort Study of STEM Career Outcomes. We are tracking Florida high school and college graduates longitudinally in terms of course taking patterns and post-secondary outcomes in order to examine the demographic variables, experiences, structural supports, and barriers associated with successful and unsuccessful outcomes related to STEM. We are categorizing majors traditionally viewed as STEM as well as other majors that have high levels of science, mathematics or technology requirements. Finally, we are using the O*NET national job description data to identify and cluster STEM and non-STEM occupations. In the second year, a Retrospective Study of STEM Career Outcomes (in year 2) will provide a more detailed look at the range of motivations, opportunities, obstacles and structural constraints that either sustained or curtailed STEM career mobility.

Preliminary Findings and Topics for Discussion

This study is currently in a comparatively early stage of development. At this conference, we hope to gain some insights as to on how to best approach some of the issues we face, which are described in this paper, based on attendee perspectives and insights. This paper is organized into three broad areas:

1. Categorizing STEM and Non-STEM Postsecondary Degrees
2. Non-STEM Postsecondary Degrees
3. Occupational Issues
    - Clusters Developed from O*NET Occupational Knowledge and Skills Data
    - Preliminary Occupational Scans and Summaries
3. Literature Findings Relating to Representation in the STEM Labor Force

Categorizing STEM and Non-STEM Postsecondary Degrees

Because a primary objective of this research is to investigate the relationship between educational tracks, career paths and career outcomes, methods to rationally relate the several different relevant data sources were quickly recognized as being vital to the project. A starting point for postsecondary degrees was the National Science Foundation's (NSF) Science and Engineering (S&E) categories that they use to survey and "count" the science and engineering workforce. However, we discovered some shortcomings of the NSF classification system for our purposes. First, they are not targeting the STEM workforce specifically, but are focused on science and engineering. Curiously, the actual coursework and activities in a number of fields that are classified as non-S&E are considerably more STEM-like than in many that are classified as S&E. As an example, NSF classifies undergraduate Sociology as S&E, and usually this requires very few mathematics or scientific methods courses, whereas they classify Secondary Math Education and Accounting as non-STEM S&E, although the first requires at least a minor in math taken within a mathematics department and the latter requires a large amount of both math-intensive and computer courses. As a result, we used the NSF system as a starting point but substantially modified it for our purposes.

Because of the existence of 275 disciplines within the SUS, we decided that it would be necessary to combine these into larger clusters in order to conduct meaningful analyses. Many of these separate disciplines are arguably very similar to each other (e.g., all of the different engineering majors). Also, as was noted above, some of those disciplines currently included by NSF as STEM, or part of the science and engineering workforce, require considerably less math, science or technology than some of those classified as non-S&E or non-STEM (NS). We therefore added a broad class that we termed STEM-related for disciplines having substantial requirements in math, science and/or technology but not currently counted as part of the S&E workforce in surveys conducted by NSF. Additionally, several of the disciplines counted as S&E by NSF lack significant amounts of STEM courses. This is frequently true among the Social Science disciplines. We therefore added those to the STEM-related group under the classification of Disciplines Characterized by Structured Analysis (e.g. American Studies).

Following considerable discussion, research as to coursework requirements for the various majors, and numerous rough drafts, the following broad classifications that encompassed these were developed that encompassed the 29 2-character Classification of Instructional Programs (CIP) discipline areas (Below is a section titled Rationale Behind Classification Structure that explains the thinking and judgments made to create the following):

Within the following Broad CIP codes most, if not all disciplines, are STEM:

02 Agricultural Sciences
11 Computer & Information Sciences
14 Engineering
26 Life Sciences
27 Mathematics
30 Mltdsiplnry/Intrdscplnry Studies
40 Physical Sciences

Within the following Broad CIP codes fall certain STEM-related disciplines:

03 Renewable Natural Resources
04 Archtctr & Environmental Design (structured analys)
05 Area & Ethnic Studies (structured analysis)
13 Education STEM (secondary math/science, measurement)
15 Engineering Tec (technology)
42 Psychology
45 Social Sciences
51 Health Sciences
52 Business & Management (accounting, management sciences, etc.)

The following Broad CIP codes are non-STEM:

01 Agribusiness & Agriculture Prodctn
09 Mass Communication
16 Foreign Language
19 Human Sciences
22 Law
23 Letters
24 Liberal/General Studies
25 Library and Archival Sciences
31 Parks, Recreation, Leisure, Fitness
38 Philosophy, Religion, Theology
43 Protective Services
44 Public Administration and Services
50 Visual & Performing Arts

Community College Programs

Following review of course requirements for Associate of Arts (AA), Associate of Science (AS) and community college certificate programs, we decided to:

- Treat all of these programs as STEM-related, rather than STEM, and
- Set a criterion for inclusion in the STEM-related groups of 18 required hours in Science/mathematics and/or technology.

We then divided these community college STEM-related majors into three primary groups:

- Physical Sciences/math
- Technology
- Medical/Life Sciences

Rationale Behind the Classification Structure

As was noted above, the NSF classification system of S&E does not always correspond to STEM-related coursework. We therefore created the STEM-related category for those disciplines that require considerable STEM coursework, but are not primarily STEM. Also, the Technology segment of STEM in today's academic environment has increased and, in fact, comprises a comparatively substantial segment of the community college STEM-related groups.

Within the STEM and STEM-related categories, we were able to group disciplines into the following broad fields:

- Computer & Information Sciences
- Engineering
- Life Sciences
- Physical Sciences/Math
- Science Intensive
- Math Intensive – for example, accounting and epidemiology
- Social Sciences - for example, psychology, anthropology, etc.
- STEM Education (these include math or science intensive programs like secondary school math)
- Technology – for example, medical technology and construction & building technology

Finally, for all of those disciplines that simply lacked much STEM coursework, but were classified by NSF as S&E, after weeks of discussion, we decided to create a new subclass called Disciplines Characterized by Structured Analysis. This group includes several social science disciplines (Gerontology, etc.) and some from other fields as well (Linguistics, Geography, etc.). Using these three broad groups (STEM, STEM-related, and NS) and several subgroups, we plan to identify and study consistencies in student pathways to the STEM workforce.

Clusters Developed from O*NET Occupational Knowledge and Skills Data

A useful source of STEM career information is the United States Department of Labor's Occupational Information Network (O*NET; Peterson, Mumford, Borman, Jeanerett, & Fleishman, 1999). The O*NET provides standardized information about the knowledge and skills required in all occupations in the U.S. economy. It also provides information about each occupation's educational requirements. As a result, the O*NET provides a structure for organizing occupational information and identifying clusters of STEM occupations and careers.

In order to begin to identify and organize STEM occupations, we selected a subset of 343 of the over 900 occupations in O*NET based on the level of STEM-related knowledge requirements (e.g., mathematics, physics, etc.). Each of those the selected occupations was rated above the 95th percentile on one of the STEM-related O*NET knowledges. We then clustered these jobs based on STEM-related knowledge requirements and other descriptors hypothesized to distinguish between occupations that contribute to our STEM knowledge and those that involve simply applying this knowledge in routine ways (e.g. mathematical reasoning and complex problem solving). We used Ward's agglomerative clustering procedure to cluster these 343 occupations into 15 clusters, which are summarized below.

Major Cluster Job areas:

1 Management, counseling, psychology, and social sciences
2 Computers, mathematics, data analysis, drafting
3 Medical doctors, medical scientists
4 Technicians and assistants
5 Verbal Professions – law, counseling, education, social service, museum related professions, recreation
6 Post-Secondary biomedical, agricultural, natural resources, health and medical sciences
7 Post-secondary education, sociology, history, anthropology, archaeology, psychology, economics
8 Technical, mechanical, repair and production – assemblers, operators/technicians, repair services, engineering technologies, drafting, testing,
9 Mixed traveling – transportation professionals, geography professionals, natural resource professionals
10 Drivers, translators and communicators
11 Engineering, physics and chemistry intensive professions, lower-level
12 Agricultural and life scientists
13 Financial professionals, statisticians and information systems
14 Engineering, physical sciences, technical and managerial
15 Miscellaneous – dispatchers, tour guides, teaching assistants, park naturalists, city planning aids, sales agents, sheriffs, etc.

Preliminary Occupational Scans and Summaries

This section focused on the 1996-97 STEM-related bachelor's degree holders for whom both discipline data and industry data were available. It is quite interesting that a small subset of occupational industry areas show up consistently across the apparently disparate disciplines investigated: Engineering, Engineering Technology, Computer Science & Information Systems, Physical Sciences, Mathematics, Health Sciences and Professions, Social Sciences and Psychology. Within that group of disciplines, the industry areas listed in the table below account for 4,841, or 57% of the 8,504 degree holders for whom all data are available. In Florida it is not surprising that health care services would be common, and since education is the second only to the military as an employer in the United States, that Education Services ranks number one is not surprising either. Of course, one would expect STEM-related degree holders to work in the Professional, Scientific and Technical Services area also, but these data suggest that technically trained individuals are also heavily recruited in Administrative and Support Service Industries.

Occupation Area	N of Grads
Educational Services	1,199
Professional, Scientific, and Technical Svcs	1,032
Hospitals	997
Administrative and Support Services	765
Ambulatory Health Care Services	493
Computer & Electronic Prodct Manufctring	213
Ambulatory Health Care Services	144
Social Assistance	142

Related Findings from the Literature

The literature makes some interesting points regarding STEM career paths, and indicates that socialization for careers in STEM appears to begin very early, well before high school. For example, both girls and young women and boys and young men who excel in high-level university course work in computing routinely engaged in play with Legos, Transformers, and violent computer games as young children (Margolis & Fisher, 2002). Correll (2001) posits that cultural beliefs about sex roles bias individuals' perceptions of their competence at career-relevant tasks, controlling for actual ability. The root causes of lower participation and achievement related to STEM career pathways for blacks and Hispanics appear to be different than those for women.

Baseline family disadvantages have been shown to explain a substantial portion of racial variation in mathematics achievement, and inequalities in instructional expenditure and crime at the school level appear to be particularly important (Roscigno, 2000). Finally, it is important to consider differences between men and women within each racial subgroup. College major choices made by minority women in science and engineering are more similar to those of white women than they are to those of minority men (NSF 1999).

Discussion, Questions and Future Directions

Although it is clear that this research is yet in an early stage, as has been shown above, several rather interesting findings have already occurred:

- The NSF classification system for college degrees has been used as a starting point for a new classification system that eliminates many inconsistencies.
- A comparatively meaningful group of clusters relating to required knowledge and skills for STEM careers has been derived from the O*NET data sources.
- Preliminary analyses of occupations for STEM college graduates suggest that a few primary industry areas draw comparatively large percentages of such graduates, at least in Florida. However the data suggest that salaries are higher in not-so-popular industry groups for STEM or STEM-related degree holders.
- The literature suggests that a broad variety of cultural, personal and system-related (educational, cultural, personal, etc.) factors impact the representation in STEM disciplines and perhaps in occupations for underrepresented minorities and females.

Related to the preceding, and given their lack of representation in the traditional STEM workforce, surprisingly large numbers of minority and women attain degrees in many STEM disciplines within Florida public universities. This raises a question regarding where the career path disjoint actually lies, and suggests that it may occur in the hiring process, during the process of career choice after college, or during the process of applying to, and undertaking graduate study, rather than in the educational career path itself.

Two additional issues that will be addressed in this study, but have not been dealt with here are:

- Creating functional crosswalks between and among the several classification systems used by various segments of the K-12, higher education and occupational groups. These include: Higher Education General Information Survey (HEGIS), Classification of Instructional Programs (CIP), Occupational Information Network (O*NET), North American Industry Classification System (NAICS), Standard Occupational Classification (SOC) System and NSF's two systems: Science and Engineers Statistical Data System (SESTAT) and Scientific & Engineering (S&E) classifications.
- Preliminary identification of key factors relating to high school experiences that associate with greater or lesser probability of entering STEM or STEM-related career pathways in college and STEM or STEM related occupations.

For all of these questions we seek input from the diverse and multidisciplinary participants in this Multi-Conference.

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