Introduction

The use of statistical evidence in representing “objective” “truth” has been debated in numerous fields (Harding, 1991; Haraway, 1991). Statistics in and of themselves are often thought to be scientific and objective despite the numerous values and choices that become embedded within statistical studies. As Sandra Harding (1991) explains, “In a hierarchically organized society, objectivity cannot be defined as requiring (or even desiring) value neutrality” (p. 134). She argues that objectivity itself is a value-laden construct:

> Scientists and science theorists working in many different disciplinary and policy projects have objected to the conventional notion of a value-free, impartial, dispassionate objectivity that is supposed to guide scientific research and without which, according to conventional thought, one cannot separate justified belief from mere opinion, or real knowledge from mere claims to knowledge. (p. 138)

Within the study of recruitment and retention in science, technology, engineering, and mathematics (STEM), the value of context is often lost when the highly critiqued, yet pervasive, pipeline model discursively stands predominant as the interpretative framework. This literature review examines the ways in which identity, recruitment, and retention are commonly represented in scholarly work through a particular focus on the U.S. STEM pipeline model. This largely quantitative and statistical model has been the basis of recruitment and retention efforts aimed at women and people of color in STEM for the past forty years, yet the problems of inequity and underrepresentation are still proclaimed in the discourse of much current research and programming (Blickenstaff, 2005; Blum, 2006; Camp, 2002; Kuck, 2001).

In this critical review, I interrogate the assumptions underlying STEM workforce studies as it pertains to gender, race, class, and citizenship. First, I provide a brief overview of the pipeline model’s history and critiques. Next, I look at the contemporary use of the model in STEM workforce studies, focusing on the ways in which recruitment and retention, scientific work, and identity are represented, measured, and understood. I argue throughout that the pipeline model has a limited view of retention that is based upon socially constructed ideas about what constitutes “valid” scientific and engineering work and who counts as “real” scientists and engineers.

The Pipeline Model

U.S. STEM workforce studies over the past several decades have primarily focused on the supply side, often premising the work on claimed and predicted workforce shortages that are based on the pipeline model. This model for measuring the workforce was introduced to the National Science Foundation (NSF) in the 1970s and used to make long-term projections and policy decisions in the 1980s as fears about technological competition with Japan arose (Lucena, 2005; Metcalf, 2007). During this period, governmental involvement in education became more acceptable as competitiveness agendas within policy encouraged the use of governmental funds to assist in the commercialization of science and technology (Slaughter & Rhoades, 1996). However, this involvement was restricted to the supply side in order to adhere to the principles of the "free market" (Lucena, 2005, p. 100). The pipeline model, based on supply-side economics,[1] flow modeling, and social engineering was designed by engineers and the National Research Council's Committee on the Education and Utilization of the Engineer. Depicted as a balance equation,[2] the model describes the linear sequence of steps necessary to become a scientist or engineer and shows the large numbers of scientists and engineers that would be needed to maintain national competitiveness. Over a set time period (e.g., one year), the model attempts to quantify the flow of people who move from an entry pool of secondary school students admitted to higher education institutions, to students engaged in educational preparation for STEM occupations, to employment in the STEM community, and followed by temporary or permanent departures from the STEM community (National Research Council, 1986).

Since its inception, researchers have used the model repeatedly to predict large shortages in the workforce supply and to focus on key populations and points along the pipeline. The category "women and minorities" became especially important to the NSF as claims about the hesitancy of white males to enroll in STEM programs created a need to rely on alternative populations to fill the "pipeline." In particular, the NSF's Policy Research and Analysis Division's pipeline studies of 1984, 1987, and 1988 assumed a fixed percentage of students entering science and engineering fields and claimed that without some effort to increase the flow in the pipeline, by 2006 there would be a 675,000 shortfall of graduates with bachelor degrees in those fields (Lucena, 2000). As part of their focus on supply, researchers conceptualized those who entered the pipeline but did not exit it at the appropriate point as "leaks." Certain points along the "pipeline" were especially "leaky,"[3] such as the transition between secondary school and college, particularly for [U.S.] "women and minorities" as an aggregate demographic category (Blickenstaff, 2005; Blum, 2006; Camp, 2002; Kuck, 2001; Metcalf, 2007).

The pipeline model has survived for decades despite critiques surrounding its flawed predictions and supply-side focus (Lucena, 2005; Teitelbaum, 2003), poor measurements (Lucena, 2005; Metcalf, 2007), linearity and inability to account for varied career paths (Xie & Shauman, 2003), tendency to homogenize people, fields, sectors, and stages (Hammonds & Subramaniam, 2003; Husu, 2001, discursive view of people as passive pipeline "flow," and lack of focus on systemic change and power relations, particularly those that are raced, classed, sexed, and gendered (Metcalf, 2007). The flaws of the pipeline metaphor have become embedded, in various ways, as assumptions within the majority of STEM workforce studies and the surveys and datasets upon which they are based. Consequently, its use for understanding and measuring STEM educational and career paths is particularly problematic.

Pipeline Predictions and Supply-Side Focus

In 1992, the NSF's initial pipeline studies from the 1980s were reviewed in hearings of the House of Representatives Committee on Science, Space, and Technology. Members of the committee determined that valid criticism of the pipeline model was purposefully disregarded at the NSF (Lucena, 2000). The model was criticized in the hearings for its flawed measurements and failed predictions. Of particular influence on the pipeline model's failed projections were the Immigration Act of 1990 and the Chinese Student Protection Act of 1992. After their passing, the growth of international students in STEM programs was about 87 percent and therefore the shortage that the pipeline model would have predicted did not materialize.

Researchers conducting current studies that focus on the supply-side continue to base the motivation for their work on the assumption that there will be a mass shortage of scientists and engineers (Teitelbaum, 2003; Black & Stephan, 2005). The lack of supply argument is especially popular in research advocating for the increased representation of women, people of color, and international students in STEM (Abriola & Davies, 2006; Teitelbaum, 2003). The discourse often proceeds as follows: STEM will have a shortage of (white, male, U.S. citizen) workers, putting the nation at competitive risk. Women, people of color, and more recently, international students are populations of "untapped" resources. Therefore, STEM needs more women, people of color, and international students to fill these shortages. The supply-side focus then becomes about recruiting and retaining these students as resources, particularly at each of the "leaky" points in the pipeline, often in problematic ways. The view of women and people of color as passive resources to be harnessed not only ignores agency, but it also hides the ways in which certain populations are disciplined, produced, and used for the benefits of others. For example, in "Attracting and Retaining Women in Engineering: The Tufts Experience," Abriola and Davies (2006) write, "The United States is facing a crisis in the creation and maintenance of its scientific and technical labor force, and is no longer training enough people to fill current anticipated demand. If one is concerned about the competitive position of the United States, Engineering needs women" (pp. 1, 3). They also provide two additional arguments for why people are concerned about the participation of underrepresented populations in STEM. The first is that without demographic diversity, STEM suffers from a lack of diverse perspectives—"If one is concerned about quality, Engineering needs women" (p. 4). The second is that men and women should have equal access to the variety of career options in society—"If one is concerned about equity, Engineering needs women" (p. 4). Regardless of the argument made—patriotic competitiveness, diversity of perspective, or equity of access—it is Engineering that needs women, not women who need Engineering.

Supply-side STEM studies focus on creating supply through recruitment and retention strategies at different key points in education: PK-6, high school, undergraduate, masters, doctorate, and postdoctoral levels (Abriola & Davies, 2006; Castillo-Chavez & Castillo-Garsow, 2006; Davis, 2005). Retention becomes a short-term measure because it is defined in terms of supply at a given point in the pipeline without much concern for the demand at the next point. Supply-side studies often focus on those respondents who are enrolled in a degree program or who have graduated and are employed at the time of the survey, eliminating from their studies those with training in STEM but not currently employed (e.g., Tsapogas, 2004; Regets, 2006). These individuals could speak to the variety of reasons that a highly trained person in STEM might not be employed, including lack of job availability (i.e., demand).

Recent critiques of the supply-side focus of workforce shortage claims have much to say about the connection between supply and demand. Black and Stephan's (2005) study analyzes degree offerings, position announcements, and key firms' perceptions of the market to explore trends, placements, and job opportunities in bioinformatics from 2001-2004. They found that the number of programs and students enrolled in bioinformatics drastically increased over the time period while positions in industry largely declined. Their study demonstrates that the focus on the supply and inattention to the connection between the pipeline output and demand has created an oversupply of bioinformatics graduates who have difficulty finding jobs in industry.

Teitelbaum (2003) critiques workforce shortage claims because of the abundance of empirical evidence and unemployment rates that counter such claims. He writes, "in most areas of science and engineering at present, the available data show sufficient numbers or even surpluses of highly qualified candidates with extensive post-graduate education" (p. 45). He further notes that this is particularly evident in the academy, which has shifted increasingly to part time and temporary appointees. Teitelbaum explains that the 2003 Bureau of Labor Statistics shows high unemployment rates even in the trendy areas (e.g. computer science) of science and engineering.[4] He points out the incentives that may encourage the continued insistence on shortages for universities that seek to fill seats and utilize graduate student and postdoctoral labor, government science-funding agencies that may see increased wages as accompanying increased costs for research, corporate employers who seek to hire skilled employees at competitive rates, and immigration lawyers who want to increase their billable hours. Teitelbaum warns that these shortage claims may become self-fulfilling prophecies.

While many scholars have critiqued the supply-side focus of the majority of STEM workforce studies, little research, especially recently, has actually looked at the demand-side and unemployment rates. Shettle's (1997) study using the Survey of Doctorate Recipients (SDR) explored unemployment among science and engineering doctoral degree holders. She found that the unemployment rate of 1.6 in 1993 was the highest rate observed between 1973 and 1995. According to Shettle, the doctorate recipients most likely to be unemployed were those with hearing or mobility impairments, married women, women with children, those who were 40 years of age or older when they received their doctoral degree, those with degrees in geological and environmental sciences, those in the private sector in 1988, those with a disruption in full-time employment after receiving their doctoral degree, and those living in California. While her study considers *who* is unemployed, it leaves unexplored *why* they are unemployed. In addition, she points out that the SDR did not ask respondents whether they had ever had a postdoctoral position, leaving her unable to consider patterns of unemployment among this growing population.

Postdoctoral positions are playing increasingly important roles in the career trajectory of certain science fields largely because of immediate job unavailability (Teitelbaum, 2003; Davis, 2005). Teitelbaum explains that this is especially true for the biosciences, which account for half of the natural science PhDs, where the required post-baccalaureate time has increased from 7-8 years to 9-12 years. He argues that this may dissuade students from pursuing biosciences because it leads to starting a career, and often a family, at a later age, and also because of the opportunity costs involved when compared to other fields. He cites a study conducted by the American Society for Cell Biology which found that

> bioscientists experience a "huge lifetime economic disadvantage" on the order of $400,000 in earnings discounted at 3 percent compared to Ph.D. fields such as engineering, and about $1 million in lifetime earnings compared with medicine. When expected lifetime earnings of bioscientists are compared with those of M.B.A. recipients from the same university, the study's conservative estimates indicate a lifetime earnings differential of $1 million exclusive of stock options. When stock options are included, the differential doubles to $2 million. (p. 50)

The Sigma Xi Scientific Research Society released a report focusing on postdoctoral positions titled, "Doctors Without Orders: Highlights of the Sigma

Xi Postdoc Survey" (Davis, 2005). Writing on behalf of the researchers, the author of this preview report explains that the rationale behind the scientific postdoctoral position is to allow new PhD graduates (postdocs) to gain research experience without being burdened by other faculty roles, such as teaching, prior to obtaining faculty positions. He argues that because of this arrangement postdocs are highly productive, comprising nearly half of the first authorship on articles published in *Science* in 1999. In the report, the researchers do not consider that the position might function as a way to maintain a cheap, yet highly skilled and productive workforce.

Despite the definitional bias, the rest of the Sigma Xi report does address the satisfaction and well-being of the postdocs. The survey included questions about postdocs' satisfaction with their postdoctoral position, expectations, salaries, employment benefits, and training/education. The researchers found that about 70 percent of postdocs are satisfied overall with their position despite the inverse relation between years of education and salary beyond the high school degree level. In terms of salaries, postdocs earn more than those of similar age with a high school diploma, but less than those with bachelors degrees, considerably less than those with masters or professional degrees, and less than PhD holders regardless of age. Davis (2005) writes, "If one factors in the 51 hours they report spending on the job each week, postdocs are drawing a rather modest wage of $14.90 per hour, not much more than the $14 per hour that janitors earn at Harvard" (p. 6). While this example speaks to the level of value that the researchers attach to janitorial work, it also highlights expectations that higher levels of degrees, particularly in STEM, should also be accompanied by higher salaries. The study also included some open-ended questions, allowing for direct quotes from a number of postdocs throughout the report. Of particular interest relative to supply and demand, Davis argues that while many postdocs hope to one day secure faculty positions, this expectation is unlikely to be met:

> Given that the growth in the number of science and engineering postdocs over the past decade (2.8 percent per year) has outstripped the rate of increase in the number of full-time science and engineering faculty positions (0.8 percent per year)…despite their high hopes, most of the postdocs surveyed will probably not become faculty members at a research university. Indeed, they will likely end up outside of academia altogether. (p. 6)

Pipeline Measurements

Many STEM workforce studies, regardless of whether they focus on supply and/or demand, measure the workforce using data collected from three surveys—the National Survey of College Graduates, the National Survey of Recent College Graduates, and the Survey of Doctorate Recipients—which combine to form the NSF's Scientists and Engineers Statistical Data System (SESTAT). Embedded in these surveys are the NSF's categories for what counts as science and engineering and what does not. The NSF defines scientists and engineers as those who either received a college degree (bachelors or higher) in a science or engineering field or who work as a scientist or engineer and have a bachelors degree or higher in any field, automatically discounting those who might do scientific or engineering work without a formal education or who received an associates degree (National Science Foundation, 2008). The NSF also defines science and engineering fields and degrees through the use of six categories: computer and mathematical sciences, biological, agricultural and other life sciences,[5] physical and related sciences,[6] social and related sciences,[7] and engineering. Teaching in any of these areas at a postsecondary level also counts as science and engineering (S&E) work. The degrees and occupations listed in Table 1 do not count.

Table 1. ***Non-Science and Engineering Degrees and Occupations***

Non-Science & Engineering Degrees	**Non-Science & Engineering Occupations**
Business administration	Managers and administrators
Business & managerial economics	Health-related occupations (doctors and other health practitioners, nurses, pharmacists, therapists, health technologists & technicians)
Health fields, bachelors & masters level	Pre-college teachers
Education fields	Postsecondary teachers in non-S&E fields
Social services & related fields (social work, philosophy, religion, theology)	Social services occupations (clergy, counselors, social workers)
Technology fields (computer programming, data processing, engineering)	Technologists and technicians (computer programmers, technicians in S&E fields)
Sales & marketing fields	Sales & marketing occupations
Art & humanities fields	Artists & other humanities occupations (artists, editors, writers, non-science & technology historians)

Source: National Science Foundation (2008)

Notably, a computer science degree counts, yet a programming occupation does not. Likewise, teaching science and engineering in a higher education setting counts, but at a K-12 level it does not. Technology degrees also do not count, despite the ways in which science and technology are frequently paired. Given the trend in higher education for academic capitalist modes of knowledge production which encourage partnerships among faculty, managerial professionals, and workers in industry across a variety of different fields, there is increasing boundary blurring between the private and public sectors as well as between disciplines (Slaughter & Rhoades, 2004). As academic capitalism provides the most benefits to fields that are closest to the market (most often those which involve science and technology), numerous non-technology-based fields are building relationships with those that are technology based. Biotechnology is a prime example of this, but certainly not the only one. Graphic design in art departments, educational technology in education departments, entrepreneurial science courses, technology transfer management, and science patenting law are other examples of this blending. One might expect more fields to involve technology, scientific work to have elements of the "non-sciences" and the "non-sciences" to incorporate scientific work. These partnerships and blurred boundaries are not represented in these definitions of science and engineering/non-science and engineering, reducing the accuracy with which researchers can understand what constitutes scientific work.

An NSF Division of Science Resource Studies report, "Counting the S&E Workforce – It's Not That Easy," uses data collected from the 1995 SESTAT surveys to point out some of these measurement issues (Pollak, 1999). In this report Pollak writes:

> In addition to the 3.2 million scientists and engineers [as measured using the above definitions], an estimated 3.1 million people reported that their jobs are closely or somewhat related to their highest degrees (in science and engineering). Approximately one-third of these workers are classified as managers, and 11 percent as pre-college teachers. (p. 1)

She also explains that there are a little over two million *more* people who have *a* degree in science and engineering, but not their highest degree and that the survey does not measure the degree to which these respondents' S&E degrees are related to their current occupations.

In an NSF InfoBrief on data from the 1999 SESTAT surveys, Wilkinson (2002) also raises the issue of "what counts," saying that the 1999 S&E workforce size would be about 3.5 million if we count those who have bachelors degree or higher and are employed in S&E and more than 10 million if we count any employee with a S&E degree. He explains that there are two primary ways of defining what counts—those who are employed in S&E and those with a degree in S&E. He argues that "one limitation of counting by occupational classification is that it will not capture individuals using S&E knowledge, sometimes extensively, under occupational titles such as manager, salesman, or writer" (p. 1). Counting by degree also has its limitations, he explains, because people often get multiple degrees that are not always in the same field. He also raises the issue of degree-occupation relatedness, saying that of the 5 million S&E degree holders not working in S&E classified occupations in 1999, about 67 percent have occupations that are at least somewhat related to their degree. If the current state of the workforce is so difficult to measure, it is no surprise that studies that attempt to predict future demand so frequently fail to do so accurately. These reports not only demonstrate the complicated ways in which science and engineering work intersect with non-science and engineering work, but also call into question the ways in which this work is defined and measured.

Linearity and Homogenization

Another critique of the pipeline model related to what counts as STEM is its linearity and inability to account for varied career paths, exit, and re-entry (Metcalf, 2007; Xie & Shauman, 2003). This is reflected in workforce studies that primarily focus on "leaks" and key transition points, such as from bachelors degree attainment to enrollment in a STEM graduate program (e.g., Regets, 2006; Tsapogas, 2004). Only to a limited extent do these studies consider varied career paths and multiple ways of entering and re-entering STEM. Some account for varied paths by looking at students who obtained a bachelors degree in STEM, but went on to get a non-STEM advanced degree (e.g., Pollak, 1999; Stage & Maple, 1996; Wilkinson, 2002). Others consider exit and re-entry in the form of periods of unemployment (e.g., Shettle, 1997). None of these studies, however, consider exit and re-entry in the form of varied employment in STEM and non-STEM fields. For example, Stage and Maple (1996) interviewed women who obtained undergraduate degrees in mathematics and then pursued graduate degrees in education-related fields. They claim that their participants "left the mathematics and science pipeline in pursuit of a doctorate in a social science field" (p. 25), assuming that social science is not a "real" science and is therefore not part of the science pipeline. Furthermore, considering that most of the women left their math PhD programs to pursue math education, there is an implication that mathematics education is not "real" math.

Part of the difficulty in considering varied paths comes from the ways in which fields, levels, and people are grouped together, which has a tendency to homogenize and oversimplify the complex ways that people learn, work, and identify themselves. Many studies group science, technology, engineering, and mathematics together as STEM when discussing the workforce. How can we best understand those occupations in which people do not "count" as part of the STEM workforce but whose STEM degrees are closely related to their jobs without disaggregating the data by field and sector? At the same time, could it be just as problematic to overly disaggregate the data? Becher (1994) and Ylijoki (2000) argue that disciplines can be conceptualized as academic tribes, each with its own set of values, virtues, vices, and culture, suggesting the importance of disaggregating among them. In addition, in her dissertation on gendered boundary making in engineering, Pawley (2007) argues that the case has yet to be made for continuing to study STEM in the aggregate. She explains that while the fields comprising STEM overlap in many ways, they also have distinct histories that influence their values and demographic composition.

Some workforce studies disaggregate the data by fields, but few consider degree-occupation relatedness thereby limiting our understanding of which NSF-defined non-S&E fields have a tendency to contain employees who use S&E knowledge regularly. Tsapogas (2004) considers the employment outcomes of recent STEM graduates by field and sector. Using the National Survey of Recent College Graduates and focusing on respondents who earned S&E bachelors or masters degrees in 1999 and 2000, he found that those with degrees in computer science and engineering are more likely than those from other degree fields to find full-time employment and upon finding work are more likely to earn higher salaries.

Regets (2006) used SESTAT to explore what graduates do after earning their S&E bachelors degrees. He found that a decade or more after earning their S&E bachelors degrees, about half of these degree recipients earned no additional degrees. However, this varied greatly by field. The proportion of respondents who continued to earn an advanced degree in the same field ranged from 9 percent in the social sciences to 21 percent in the physical sciences, with engineering, mathematics, and computer science having the lowest percentages of individuals earning additional degrees. He also found that 29 percent of respondents went on to earn advanced degrees in non-S&E fields, with 38 percent of this population having their initial bachelors degrees in the life science and 17 percent in engineering, mathematics, and computer sciences.

Gender, Race, Class, and Citizenship

Many workforce studies consider identity factors in the workforce data in problematic ways. A large and limiting bias in the SESTAT surveys and the studies based off of them is that gender and racial identities are biologically based. These surveys measure gender using a dichotomous male/female variable and race with a set of mutually exclusive categories. Even if gender, which is fluid, socially constructed, and highly performative (Butler, 1997, 1999), were the same as biological sex, intersex as a category of biological sex is excluded. Likewise, not a single study in this review considers transgender as a category of analysis. Race and ethnicity are often merged together and the use of mutually exclusive and limited categories does not allow respondents to indicate various mixed racial identifications.

Not all of the assumptions in the studies, however, can be credited to survey construction. Most studies that consider gender and race look at these identity factors separately, comparing males in the aggregate to females in the aggregate (e.g., Abriola & Davies, 2006; Lal, Yoon, & Carlson, 1999; Rapoport, 2004) and whites to various racial groups, sometimes disaggregated to a limited extent and at other times aggregated to a "minority" group (e.g., Castillo-Chavez & Castillo-Garsow, 2006). Regardless of motivation, the pipeline model and many of these studies have as an end goal the recruitment and retention of historically underrepresented groups. Although this is an important aim, such a limited understanding of identity not only marginalizes those who do not see themselves reflected in the data collection instruments, but also restricts the understanding researchers could have of the STEM workforce.

Few studies consider the ways in which race and gender are intertwined and even fewer studies also add class into the analysis. The most popular trend in the few studies that consider the intersection of gender and race is to focus on women of color in the aggregate (Hines, Chinn, & Rodriguez, 1994; Committee on Women in Science and Engineering, 1995; SJB Research Consulting, Inc., 2004). These studies sometimes describe the racial categories used to define "women of color," but they are not always the same across studies. For example, Hines et al. (1994) considered Latinas, African Americans, and Hawaiians; the Committee on Women in Science and Engineering's (1995) study looked at Hispanics, African Americans, Asian and Pacific Islanders, American Indians, and Alaskan Natives; and SJB Research Consulting, Inc.'s (2004) report on MentorNet focuses on Latinas, African Americans, and Asian Americans. These studies report results for women of color but how "women of color" is defined varies greatly across studies.

In one study that considers a particular racial group and gender, Hanson (2004) used the National Educational Longitudinal Survey data to consider the science achievement, access, and attitudes of African American women throughout various points along the science pipeline. She looks at key points along this trajectory for the African American women, focusing on high school, college, and the transition from degree attainment to employment, and compares them to the experiences of white women. Through what she calls a "multicultural gender framework," she argues that the way gender functions in African American communities may provide young African American women with unique motivators for creating interest and success in science.[8] She found that, eight years out of high school, African American women were more likely than white women to report a job in science, though the kind of science job and the field and sector in which it resides is not explained.

Hanson (2004) also found that the African American women, often even more so than the white women, in her study maintained a continued interest and involvement in science and access to science courses throughout their career paths. Though, the interest does dwindle over time. She describes this decline in interest as a “cooling out” and explains it using the “chilly climate” metaphor. Pawley (2007) explains that this metaphor is closely connected to the pipeline metaphor:

> Chilly-climate based models…are a subset of the pipeline metaphor, and suggests that leaks are caused by a “chilly environment” that discourages people already under environmental stress (again, women and people of color) from remaining. Programs that attempt to stem these leaks provide metaphorical “sweaters” (survival tools for underrepresented populations to better withstand the chilly environment) or train their white, male counterparts on how to “turn up the thermostat” by implementing, for example, parent-friendly tenure procedures, gender-neutral hiring protocols, or the much-maligned idea of “sensitivity training.” (p. 7)

Here, Pawley illustrates the problematic ways in which metaphors can be used to explain away a problem rather than critically engaging with it.

In addition, workforce studies that focus on “gender” often are studies about “women” and invoke the need to consider the role that family plays in gender differences, making the assumption that gender studies are about women and that with the study of women comes the study of family. The study of “family” also becomes normatively constructed as indicators for family in these studies are most often marriage and children. While these can be used to get a sense of some aspects of family life, they certainly are not the only measures. In particular, considering the ways in which access to marriage and adoption are legally structured from state to state based on one’s biological sex and that of one’s partner, these studies take on a particularly heteronormative slant (Berlant & Warner, 2000). Berlant and Warner describe the structural and ideological functioning of heteronormativity as: “the institutions, structures of understanding, and practical orientations that make heterosexuality seem not only coherent – that is, organized as a sexuality – but also privileged” (p. 312). Heteronormativity, which has no “parallel,” is a collection of institutional, political, and foundational practices and discourses that impose and assume a heterosexual-based society and is distinct from heterosexuality, which presumes homosexuality as its opposite. In the case of these studies, the family structure, particularly in relation to biological sex and the construct of marriage, is narrowly and heteronormatively defined and measured.

One study on female-male differences in academic careers of scientists uses the Survey of Doctorate Recipients to consider how “successful” movement along the academic career path for doctorate recipients who earned a degree in S&E in the U.S. is influenced by sex (Rapoport, 2004). Rapoport (2004) argues that female scientists and engineers are less successful than their male counterparts at traveling along the career path, but that these "gender" differences are indirect—they are more related to sex differences in the influence of family on success than they are to direct sex differences in success. He finds that women with children and who are married are less likely to be on the tenure track than men with children and who are married, and women who have young children later in their careers are more likely to earn tenure. Further, women are less likely to be promoted to senior ranks then men, but this third result is statistically insignificant when gender differences in family influences are accounted for. Rapoport measures success by four outcomes: gaining tenure-track placement, earning tenure, promotion to the rank of associate professor, and promotion to the rank of full professor. Although success could be measured in a number of other ways including subjective measures of career satisfaction, we once again see a linear pipeline model applied to career success.

Another study on unemployment patterns of doctorate recipients in 1993 considers gender differences in unemployment rates and also measures family using marital status and having children as indicators (Shettle, 1997). This study found that there were no *direct* gender differences in unemployment rates, but when family was considered, for women, being married and having children were associated with relatively high unemployment rates whereas for men, they were associated with relatively low unemployment rates. In other words, gender does not directly impact unemployment rates; rather, it impacts the influence that family has on unemployment rates.

While the above studies show how marriage and children influence employment and academic career trajectories, they fail to consider how family obligations influence the career "success" of those who have non-normative family arrangements, such as queer couples, caregivers for aging parents, domestic partnerships, and non-biological chosen families.[9] Likewise, in focusing on family as the site of "acceptable" non-work responsibilities that might interfere differentially with one's work success, these studies do not interrogate the variety of personal lives that scientists and engineers have or desire to have in attempting to achieve success in the workforce. Additionally, this focus on family, its frequent connection to women under the argument that women are often unequally held responsible for household duties, and the pipeline metaphor's encouragement of surface solutions rather than systemic change often leads to the suggestion that workplaces provide childcare as the "solution" to women's underrepresentation (e.g., Cuny & Aspray, 2002). This not only perpetuates childcare as women's responsibility, but disregards the many childless women who "fail" to achieve these measures of "success."

Some STEM workforce studies also consider the role that international students and "foreign born" employees play in measuring the workforce. This is an important area to consider not only in light of global competition, but also within the context of changing immigration policies and because the vast majority of studies that consider “women and minorities” refer to U.S. citizens. Using the National Survey of College Graduates and the Survey of Doctorate Recipients from 1980 and 1990, Stephan and Levin’s (2003) study considers the costs and benefits of the increasing presence of foreign-born and foreign-educated scientists and engineers in the U.S. workforce. They found that a large percentage of foreign-born workers are primarily educated abroad, allowing the U.S. to benefit from the investments made by other countries. These workers contribute disproportionately to science and engineering and represent a highly select group. Contrary to popular belief, they explain that the costs have not been to U.S. citizen scientists and engineers. While U.S. citizen scientists and engineers have been replaced by non-U.S. citizen workers in some jobs, they show that those jobs are temporary academic jobs, suggesting a hierarchy that favors U.S. citizen scientists and engineers. They argue that U.S. citizen-scientists are most likely being pulled (rather than pushed) from temporary academic positions by higher paying and more permanent job opportunities as non-U.S. citizen scientists and engineers fill the less valued job spaces.

While Stephan and Levin (2003) focus on the influx of international students and workers to the U.S., Black and Stephan (2003) turn their attention to who stays. Their study focused on sixteen fields of science from the 1981-1999 NSF’s Survey of Earned Doctorates with particular interest in the likelihood of staying in the U.S. for those respondents who held a temporary visa at the time of degree receipt. They explain that at the time of the study one in three science and engineering doctoral degrees was awarded to a student on a temporary visa, accounting for 50 percent of the growth in PhD production between 1981 and 1999. Their study disaggregated the data not only by citizenship, but by residency status, country of origin, and field and considered the popular claims following 9/11 that students from particular countries in “sensitive” fields would take their U.S. education back to their country of origin only to work on nuclear weapons and chemical warfare. They found that students in sensitive fields and students from targeted countries actually reported higher than average stay rates. In addition, they conclude that

> stay plans as well as definite plans are clearly related to age, field, country of origin and quality of training. The field with the highest stay rate is biology/chemisty. The field with the lowest stay rate is agriculture. Individuals trained at top programs consistently are more likely to have definite plans to stay than are individuals trained at lower tier institutions. (p. 12)

The Black and Stephan (2003) study does not disaggregate the data by gender or sex which could be useful, especially when considering that post-9/11 policies focus on *males* in sensitive fields from targeted countries. In addition, the researchers assume, like many other studies, that institutional ranking is an adequate indicator for quality of training. While these studies on international populations do not disaggregate their data by race, ethnicity, class, or gender, they shed light on the increasingly influential role that international students, graduates, and employees with varying levels of residency have in the U.S. STEM workforce. In addition, in addressing and dispelling popular beliefs about job displacement and how U.S. education and training are being used, these researchers counter various xenophobic claims about "foreigners" taking "our" jobs and "terrorists" taking "our" science.

Conclusion

The context of much STEM workforce research is its reliance on a flawed linear model that views students and workers as passive flows through leaky pipes and its focus on numeric diversity at best. Overall, the STEM workforce studies reviewed highlight the complicated and often problematic ways in which discourse and survey research meet. They speak to the limitations of survey definitions, particularly those used to measure identity characteristics, family, STEM fields and degrees, and educational and career pathways and success. These studies also illustrate the importance of appropriately balancing disaggregating data by gender, race, class, nationality, citizenship status, field, and sector while considering interactions among these measures. This review indicates the need to critically consider claims, both in the popular and scientific press, about workforce shortages and desired demographics and the pervasive influences these claims have on workforce studies and policies.

This critical literature review is an initial call to actively interrogate the values, assumptions, and power structures underlying STEM workforce research, particularly as they have historically been and will continue to be embedded within policy and programs nationally and internationally (Driori, Meyer, Ramirez, & Schofer, 2003). Over the past forty years, STEM policies and programs have claimed goals of equity, diversity, increased representativeness, and access, yet little headway has been made. The same set of assumptions and models for understanding identity and career paths have been continually reproduced both discursively and quantitatively, even in the face of criticism, to the detriment of these goals and social change. As economic and national investment in STEM continues to grow, even in a time of proclaimed economic crisis, it is particularly important to take a critical eye to the assumptions, values, and limitations of the pipeline model and its manner of understanding educational pathways.

Notes

[1] Supply-side economics, sometimes referred to as "Reaganomics," "trickle-down economics," or even "voodoo economics," as a theory holds that supply is the central determinant of economic growth and as such, producers and their willingness to create products and services set the pace. Proponents of supply-side economics are in favor of creating a variety of incentives for production, such as reduced governmental regulation and conservative tax policies, and view demand as largely irrelevant (Roubini, 1997; Harper, 2005).

[2] The original pipeline equation is: "$Q_1 + \sum f_i + \sum f_o = Q_{2,}$ Where Q_1 = the number of people in stock at the beginning of the period, $\sum f_i$ = the sum of flows into the stock, $\sum f_o$ = the sum of flows out of the stock, and Q_2 = the number of people at the end of period" (National Research Council, 1986, p. 29).

[3] It has also been viewed as filtered, hurdle-ridden, and shrinking (Blickenstaff, 2005; Blum, 2006; Camp, 2002; Kuck, 2001).

[4] The national unemployment average in 2003 for the entire workforce was six percent. In the same year, high-tech areas like computer programming, electrical engineering, and electronic engineering were higher than this average. Teitelbaum explains that high skilled and educated areas like these usually have significantly lower unemployment averages than the national average.

[5] These include agricultural, food, biological, medical, and environmental life sciences as well as health sciences at the doctoral level.

[6] These include chemistry, earth science, geology, oceanography, physics, and astronomy.

[7] These include economics, political science, psychology, sociology, anthropology, and science and technology history.

[8] She argues, in a rather essentializing manner, that gender roles in African American communities tend to be more egalitarian than in white families largely because of the legacy of slavery and the long history of labor force participation on the part of African American women.

[9] A chosen family includes those who are close to us and consider as family even if they are not biologically related to us (e.g., very close friendships and adoptive, legal or otherwise, relationships). Berlant and Warner (2000) link the construction of family to intimacy and write, "nonstandard intimacies would seem less criminal and less fleeting if as used to be the case, normal intimacies included everything from consorts to courtiers, friends, amours, associates and coconspirators" (p. 323).

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