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Women in the GIS Profession

Livia Betancourt Mazur and Dr. Jochen Albrecht

Abstract: *In many technical professions, women are underrepresented. While a gender imbalance also has been assumed to exist in the realm of professional GIS, no data existed to corroborate it. The original survey presented here was developed by the authors to add both quantitative and qualitative research about the numbers and current experience of women in GIS to address this knowledge gap. A total of 484 women responded to the survey, providing a healthy sample size and a reliable and informative data set.*

A key finding is that some 42 percent of women are, overall, not grossly underrepresented in the GIS workforce. This does not mean, however, that underrepresentation in more specific areas or that other gender equality issues are not present. The survey results suggest that women in GIS might be more underrepresented in certain sectors and in certain types of positions, and use a higher proportion of "soft" versus technical skills in their current positions. Based on the research findings, GIS seems like a good field for female participation, with its good work-life balance, strong sense of community, opportunities for networking and mentoring, and importance placed on continuing development.

BACKGROUND

This research grew from two original questions. The first is whether there is an underrepresentation of women in the professional GIS field and the second is whether women in GIS have experienced gender-based obstacles to career success. To our knowledge, the work presented here is the first substantial piece of empirical research on this topic. While a number of authors have looked at the role of women in the science, technology, engineering, and mathematics (STEM) departments in the academe, there is a distinct lack of research for the professional field. Schuurman's "Women and Technology in Geography: A Cyborg Manifesto for GIS" (2002) and Pavlovskaya's and St. Martin's "Feminism and Geographic Information Systems: From a Missing Object to a Mapping Subject" (2007) are the only publications that directly report on women who conduct GIS research and who are GIS practitioners; but there is no empirical foundation for their arguments. What this research borrows from the latter is the notion of identifying women as suitable "objects" of research as well as "subjects" who perform GIS work. Our research was based on two hypotheses: First, that there is indeed an underrepresentation of women in GIS, and, second, that women experience gender-based obstacles to success. Both of these hypotheses will be shown to not hold true, although some caveats will be explored at the end of this article. Before that, however, we will present a short literature review, describe our pilot study, present and analyze the aforementioned survey, and interpret the results.

LITERATURE

As mentioned before, most publications on gender bias deal with STEM fields in academia rather than in the professional world (Landivar 2013, X, Y), although given the fairly clear underrepresentation of women in college-level STEM courses, it then comes as no surprise that they are subsequently underrepresented in these professions as well. The current state of discussion can be summarized by three questions that form the basis of this review:

1. Why is it important to increase the number of women working in STEM?
2. Why are women not significantly represented in STEM and what is the status of those women who do work in STEM?
3. How can both the relative absence of women in STEM, as well as problems with the status of those women who do work in these fields, be addressed?
4. Why is it important to increase the number of women working in STEM?

While these seem like straightforward and fair reasons for increasing diversity, equity arguments typically are not employed by the authors of contemporary diversity literature. Some are economic in nature (Glover 2002). One idea proposed is that given the shortage of skilled workers in STEM, women and minorities represent an untapped resource (Adam et al. 2006, Ahuja 2002, Beede et al. 2011, George et al. 2001, Sonnert 1999, Trauth 2002). Not only are women a potential resource, but the existing "skills crisis" could even be partially attributed to the lack of inclusion of women and other demographic groups in STEM fields (Trauth 2002, 98).

The alleged shortage of skilled STEM workers in the United States is puzzling when examined next to 2011 figures from the U.S. Census Bureau that reveal the proportion of employment in STEM versus non-STEM occupations by those holding bachelor degrees in STEM disciplines. According to these figures, only a quarter of men and women with science and engineering bachelor degrees work in STEM (Landivar 2013). Eighty-five percent of women and 70 percent of men with science and engineering bachelor degrees do not end up working in STEM (Landivar 2013). The rate at which both women and men educated in these STEM disciplines do not continue onto STEM careers is staggering, but among women this phenomenon is even more pronounced. These numbers suggest that there are perhaps other

issues beyond a shortage of skilled labor. Arguments for increasing women's participation in science and technology because of a shortage of skilled workers are problematic. If women are called to fill roles because of an alleged shortage, eventually, when there is no longer a shortage, will women be the first to be eliminated?

Other economic arguments advocate for increasing the number of women in STEM. Judith Glover, in her 2002 article, "Women and Scientific Employment: Current Perspectives from the UK," calls for the collection of more quantitative and qualitative data on women in science to better understand this underrepresentation. Glover (2002, 40-41) asks whether businesses are "incurring financial losses because they are not retaining particular social groups to whom they have devoted training resources." Once the reasons for the poor retention of certain employees are better understood, companies might implement better workplace policies, eventually enhancing their profitability. To that end, getting businesses to see their female employees as valuable assets and investments that they do not want to lose seems like a good idea. Nonetheless, there could be unintended outcomes in using only economic arguments in appealing to the business community. What if companies determine that, in fact, they can attain greater profitability without actively seeking to improve female participation?

A particularly interesting study is by Cross and Linehan (2006), in which they look at the high-tech sector in Ireland. Because that sector had developed after many gains had been made in women's participation in the labor force, it was expected that it would be a "genderless environment in which female managers would emerge in equal numbers to their male counterparts" (Cross and Linehan 2006, 28). Instead, they found that despite the relative newness of this field, previous workplace gender norms were upheld and the environment was far from "genderless." Despite prevailing optimistic beliefs about the innovative nature of technology and the professional fields and cultures from which technologies arise, in combination with the fact that women have been actively engaged in the labor force for decades, the diverse workforce that might logically be expected to arise given these two conditions still does not exist.

What are the stubbornly persistent norms and conditions that prevent such diversity in both STEM career fields and in the workforce in general? An example of the conditions that perpetuate the status of women in STEM, despite their active engagement in the labor force, is vertical and horizontal segregation. This can be generally described as the pattern of women being more prevalent at lower levels and in less technical positions, as well as being clustered into certain disciplines and not others (Blickenstaff 2005, Glover 2002, Heilbronner 2012, Kohlstedt 2004, Prescott and Bogg 2011, Sonnert 1999).

Sociocultural and philosophical arguments are very different in nature from the economic arguments and could add the needed depth that some economic arguments lack. One contention is that career fields and disciplines themselves could benefit from increased diversity (Adam et al. 2006, Ahuja 2002, Blickenstaff 2005, Glover 2002, Singh et al. 2007, Sonnert 1999). That is, the inclusion of more diverse workers will yield better approaches and novel solutions to research in science and technology. Research agendas and the connection between science and society could improve with the inclusion of a "larger spectrum of society" (Glover 2002, 40).

Regardless of the lines of reasoning employed by authors in answering why the underrepresentation of women in STEM should be addressed, the underrepresentation itself poses an interesting puzzle that is worthy of examination and unraveling. "Given the importance of these technical fields in our modern economy, and the rapid expansion of employment opportunities in technical occupations, the dearth of women in these areas is puzzling from an academic perspective" (Rosenbloom et al. 2008, 544). The following section looks at authors' attempts to explain this perplexing dearth.

Why are women not significantly represented in STEM and what is the status of those women who do work in STEM?

This section looks at these two interconnected elements from the literature. First, the landscape of women working in STEM fields is described and then specific barriers that are both part of and that shape the landscape are detailed.

Patterns of Participation—Vertical and Horizontal Segregation

The literature shows a predominant pattern in both the STEM education and careers of women, in which the higher up the organizational structure one looks, the fewer women one encounters. Many different metaphors and terms are employed to describe this phenomenon—the leaky pipeline, the pyramid structure (Ahuja 2002), the glass ceiling, and vertical (and horizontal) segregation. The glass ceiling, in combination with other barriers and patterns unique to women's participation, works to create the vertical and horizontal segregation of women at the professional level. Glover explains, "In horizontal segregation, women and men are concentrated in distinctive scientific fields. In vertical segregation, women and men within the scientific fields are not distributed equally in the hierarchy of jobs, with women typically being concentrated in the lower-level jobs and men in the higher-level ones" (2002, 29).

Looking at vertical segregation helps to drill deeper into the STEM landscape, going beyond identifying the fields in which women work, to looking at the types of roles they occupy. Vertical segregation also can be conceptualized as what another author terms the "pyramid structure," in which women are found in increasingly smaller numbers at top managerial levels as well as in advanced technical positions (Ahuja 2002). Vertical segregation not only impacts the types of roles women occupy, but it also underlies the pay gap between men and women in the same position status (Ahuja 2002, Glover 2002, Prescott and Bogg 2011).

Beyond simply describing what the pyramid structure looks

like, Ahuja also puts forth some ideas that might partially explain that structure (2002). Essentially, she outlines what she calls the "stage model of barriers," where a woman's career is comprised of distinct stages (Ahuja 2002). At each stage there are unique, albeit similar, barriers that combine in myriad ways, and as a woman's career path unfolds, the barriers might actually intensify (Ahuja 2002). Different barriers might become more pronounced at later career stages and, therefore, be more likely to interfere with a woman's success, contributing to the pyramid structure (Ahuja 2002). In addition to the characteristics of STEM fields that pose particular challenges to women, there also are characteristics of their own lives and career development that shape their experiences (Ahuja 2002). Ahuja (2002) finds it useful to break women's life and career paths into stages to better understand the challenges they face as they commence and then navigate through their careers. In Ahuja's model, a woman moves from the career choices stage to the persistence and advancement stages while progressing through her IT career (2002). Glover describes very similar career stages, and her discussion of vertical segregation is partially connected to the idea that a woman's life and career have stages that interact with one another (2002).

"Hybrid" jobs constitute another theme uncovered in literature on women in IT (Guerrier et al. 2009, Roan and Whitehouse 2007) and one that is useful to discuss in parallel to a consideration of gendered roles and disciplines. The theme of "hybrid" IT jobs is one that enters gender diversity in IT literature in the 2000s. Hybrid roles are those that require a mix of technical and interpersonal skills (Guerrier et al. 2009, Roan and Whitehouse 2007). They are described as being a potential entry point for women into the IT workforce because of the interpersonal skills women purportedly possess or have had more opportunities to draw upon (Guerrier et al. 2009, Roan and Whitehouse 2007). While hybrid roles have been touted as potential solutions to the underrepresentation dilemma, in fact these jobs seem to have merely propagated the already prevalent biases of the IT field (Guerrier et al. 2009, Roan and Whitehouse 2007). These jobs require more "soft" skills such as communication, the ability to empathize (largely with clients), and alternative modes of leadership, in combination with technical ability (Guerrier et al. 2009). It is assumed that because these positions require "soft skills," which women "inherently" possess (and men lack), they, therefore, will naturally attract women and be a gateway of sorts to the technical realm of IT (Guerrier et al. 2009).

Drivers of Underrepresentation and Barriers to Participation

It is helpful to understand a few theoretical concepts that underpin many concrete explanations of women's status in STEM. The essentialist argument posits that female representation in STEM derives from "fixed, unified, and opposed female and male natures" and that there are "inherent differences between men and women" (Trauth 2002, 100). The essentialist viewpoint is criticized and regarded as being outdated (Blickenstaff 2005, Trauth 2002). Other points of view demonstrate that women's roles in society are socially constructed, and STEM fields themselves also are socially constructed and are viewed as masculine—and these two constructions are incompatible (Adam et al. 2006; Bastalich et al. 2007; Guerrier et al. 2009; Orser, Riding, and Stanley 2012; Prescott and Bogg 2011; Trauth 2002). "Women's more general exclusion from technology may be seen in terms of the historical and sociocultural construction of technology as a 'masculine domain'" (Adam et al. 2006, 372). Explanations "driven by [women's] reproductive roles" (Bastalich et al. 2007, 385) link work-family conflict to the socially and culturally shaped views of women's work and domestic roles. They position women's traditional role as caretakers in opposition to, or as incompatible with, the demands of working in the IT field and in STEM in general (Ahuja 2002, Bastalich et al. 2007, Blickenstaff 2005, Castaño and Webster 2011, Sonnert 1999, Watts 2009, Wentling and Thomas 2009).

Aside from the social construction (or sociological) explanations and criticisms presented previously, some literature also examines more concrete barriers. The concrete barriers often interact with or stem from the social ones, and, as such, many of the barriers detailed below refer to notions presented previously. IT's unique demands require long hours and a work culture that rejects the possibility for part-time or flexible work arrangements. These demands are possibly incompatible with the other life demands of women (Ahuja 2002, Guerrier et al. 2009, Watts 2009). Jacqueline Watts (2009) examines the idea that the perceived total separation of the work and nonwork spheres is behind the expectation of long working hours, and that this poses a particular challenge for women. Although most of the female subjects in her study critiqued the long-hours situation they encountered, they nonetheless felt compelled to participate in it, finding it "virtually impossible to avoid this practice" (Watts 2009, 48).

Another aspect of the IT culture is the need for employees to constantly update their skills and to stay current with new technology developments (Ahuja 2002; Castaño and Webster 2011; Guerrier et al. 2009; Orser, Riding, and Stanley 2012). "This can be done more readily by those in the labor market than by those on career breaks," with the implication that this drives a further wedge between male and female workers, with the latter being more likely to spend a greater amount of time out of the workforce (Castaño and Webster 2011, 374).

The lack of mentors also is cited as a barrier to women in IT and STEM (Ahuja 2002, Bastalich et al. 2007). The fact that the IT world is male-dominated is the principal cause behind women being unable to find and build suitable mentor relationships (Wentling and Thomas 2009). Significant to this is that a result of vertical segregation is that women entering the field have very few female role models in more prestigious positions (Ahuja 2002; Orser, Riding, and Stanley 2012). "The lack of role models at all levels, particularly at senior levels" also could be "a major problem in attracting and keeping women in computing" (Ahuja 2002, 26). In one study conducted of women in the advanced technology sector in Canada, "mentoring was identified

as a primary means to resolve career challenges" (Orser, Riding, and Stanley 2012, 87). The authors of this study say that this is a significant finding because it confirms what other research says about the importance of mentoring to career development.

Most authors tend to agree that networking is also of extreme importance and, in addition, that women having insufficient access to informal networks is a problem (Ahuja 2002, Bastalich et al. 2007, Wentling and Thomas 2009). There are many overlaps between the benefits of mentoring relationships and networking, but "Peer relationships are different from mentoring relationships in that they often last longer, are not hierarchical, and involve a two-way helping" (Cross and Linehan 2006, 34). Informal networks also are important because of another characteristic of the IT work world, which is its "lack of clear career structures" (Guerrier et al. 2009, 496).

Addressing just one area determined as being problematic to women's participation will not necessarily lead to the desired levels of diversity or to more completely palatable conditions for diverse participants (Ahuja 2002, Castaño and Webster 2011). The patterns and barriers described in this literature review are entangled in such a way that one issue could be both the basis for and the outcome of another issue. For example, the condition of needing to work long hours conflicts with women's traditional roles outside of work; the demands of women's personal lives could make it impossible for them to participate in informal networks thus causing women to miss out on certain opportunities. Therefore, the issue of informal networks cannot simply be solved by providing women with more opportunities to network, for example. Any other connected issues must be addressed in tandem. The same goes for any other issue to women's participation in STEM.

How can both the relative absence of women in STEM, as well as problems with the status of those women who do work in these fields, be addressed?

The final question then is "How can both the underrepresentation of women in science and technology, as well as problems with the status of women who work in these fields, be resolved?" Two overarching themes emerged from the previous sections, providing a framework for the following investigations: the issue of framing women as *other* (Bastalich et al. 2007, Ullman 2013) and the need to account for diversity among women (Cech and Blair-Loy 2010, Trauth 2002).

Is it problematic to frame women as *other*? That is, is attaching the word *woman* or *female* to any occupation, for example, *woman scientist* or *female engineer,* enough to cast her as an *other*? Or would omitting the word *woman* do women a disservice? Bastalich et al., in attempting to look at why there is an underrepresentation of female engineers and why women drop out of the field in greater numbers than men do, look at "what it means to be a woman engineer" (2007, 385).

The preference to include or not to include gender in one's professional identity influenced part of the survey conducted for this research, and was addressed by asking whether women in GIS prefer to identify themselves as either a *woman working in GIS* or as a *GIS professional*. Beyond women's preferences for how they identify themselves lies another question about use of the term *women in GIS*: Does the very act of saying *women in GIS* serve to lump all women who work in GIS into one category and, if so, is that problematic?

Trauth explains and argues for the emerging theoretical perspective of individual differences versus that of approaching and analyzing women and IT from a group perspective (2002). She argues that women in IT, and women in general, are not a monolithic group that shares the same set of experiences and societal shaping and, as such, that the current status of women in IT should be examined on a more individual basis. Unique sets of cultural, familial, educational, and career experiences shape each woman's relationship to technology and to working in IT. Trauth argues for the importance of empirical research and conducts qualitative interviews to support her theory that women should be addressed, or talked about, as individuals.

During the pilot study that we will describe in the next section, it was similarly observed that women in GIS are not a monolithic group and that there are a range of experiences and responses shared by the pilot-study subjects. This confirmed what was learned in the literature review of the importance of incorporating a research approach that would allow different women to share different experiences, as well as conducting the analysis in such a way that the diversity of participants is taken into consideration. As such, the design of the survey includes allowing participants to submit comments for many of the questions as well as analyzing all survey results by breaking down the overall population into discrete categories.

The following are supplemental research questions resulting from the literature review:

- Is GIS similar or dissimilar to IT in terms of its culture and women's experience of it? Would the work conditions in IT—having to work long hours, inflexible work arrangements, the need to constantly update skills, and the presence of a male-dominated, exclusionary culture—also be present in GIS?
- Are vertical and horizontal segregation as prevalent in GIS as they are in IT and in science professions? For example, would women in GIS be in roles where certain skills would be more utilized than others ("soft" versus technical skills)? Can knowledge learned about the skills used by women in GIS be utilized to compare GIS work to other "hybrid" jobs discussed in the literature?
- What are the experiences and preferences of women in GIS in regard to mentoring relationships and to networking? Do women in GIS face similar issues as women in other STEM fields in finding mentors? Do women in GIS leverage the power of mentoring and networking?

- Do women in GIS have a good level of work-life balance? What are their opinions on issues uncovered in the literature review? For example, do they think that work-life policies that specifically address them alienate them?
- Does breaking down survey results by different demographic categories have any impact on responses given to survey questions? This is influenced by the recommendation made by some authors (and refined through analysis of the pilot study results) not to view women in STEM fields as a monolithic group.
- Is putting the word *women* in front of *GIS* to derive the phrase *women in GIS* wrong? Does the mere act of saying this simply serve to reinforce women's alienation and their being seen as *other*?

PILOT STUDY

The purpose of the pilot study was to narrow the research agenda and thus lead to a better survey design. The pilot study provided access to the expert advice of professional women active in the GIS field, which helped to ensure the relevance of the survey questions. The insights shared by the key informants led to additional questions not derived from the literature review included in the survey.

The pilot study involved one-on-one interviews with nine key informants lasting between 45 and 60 minutes. These are women who work in GIS in the United States, many of whom are well established in their careers and who have had firsthand experience with the research topic. Most of the subjects in the pilot group were women with significant amounts of GIS experience (up to 26 years), who had lengthy exposure to the GIS professional field. Two additional women, one who has led a roundtable discussion on the topic of women in GIS and who is actively interested in the topic, and the other a professor who had recently collected data on women in GIS through a crowdsourced map (Dr. Linda Loubert), also were consulted.

The pilot study helped to confirm and partially reframe one of the original primary research questions and some of the underlying expectations. Prior to the pilot study, the original primary research questions were: (1) Is there an underrepresentation of women in the GIS professional sphere and (2) What is the experience of struggle, if any, of women in the GIS field? The importance and relevance of the first research question regarding the numerical underrepresentation of women in GIS was confirmed.

Caveats, such as the perception that women's representation is changing over time and that women's representation in certain roles might be uneven, helped to guide two further components of the survey. First, it was decided that survey population analysis filters based on years of experience in GIS should be applied in examining the survey results, because women with a greater amount of GIS experience could potentially have different views than do newcomers to GIS (and generally respond to the survey questions differently). Second, the information uncovered in the pilot study confirmed what was learned in the literature review regarding women's specific underrepresentation in technical and managerial roles, and it was decided, therefore, to include questions to measure what skills women use more or less frequently at work (for example, would women use their technical skills in equal measure to other workplace or communication skills?).

Through the pilot, it also was found that the wording of the second, original research question, "What is the experience of struggle, if any, of women in the GIS field?", was inappropriate. All the women interviewed in the pilot study could be seen as highly successful. We thus decided that the word *struggle* contained bias and would not allow for the full range of women's experiences in GIS, including positive experiences. To make this research question more neutral it was amended to "Do women in GIS experience gender-based obstacles to success? What are the experiences of women in GIS?"

Mentoring and networking were other themes that emerged as being important to the topic of women in GIS and as two themes that should be included in the survey. The pilot made it clear that mentoring and networking were important to and for women in GIS, and questions about those two topics also should be included in the survey.

There were other specific questions that appeared in the survey that were inspired by the pilot study and that are not discussed in the previous paragraphs. These questions reflect commentary made by multiple or individual women in the pilot study regarding feelings of isolation and possible desire to connect with other women and regarding opportunities to learn on the job.

THE SURVEY AND ITS ANALYSIS

The survey was designed to collect quantitative and qualitative information using the online tool SurveyGizmo. It was announced through a general invitation sent to various listservs, as well as promoted via social media networks (Twitter as well as "Women in GIS" groups on Facebook and LinkedIn). The target audience was adult professional females who work in the field of GIS. We were aiming for some 200 respondents and were pleasantly surprised to receive 484 completed surveys. The survey was available online from June 30, 2014, through September 26, 2014, and was estimated that the survey would take on average 30 to 45 minutes for a survey taker to complete.

Given the promising sample size, we were able to apply numerous filters to the survey responses, such as GIS sector, race/ethnicity, number of years working in GIS, and age groups. Each survey question has an underlying hypothesis, and so the first analyses test for whether the hypothesis is confirmed or rejected using the BINOM and CHISQ functions in MS Excel. SurveyGizmo provides some basic open-text analysis functionality that allows for the creation of comment categories or labels (Charmaz 2003).

A total of 59 survey questions are grouped under the following ten research questions:

1. Is geographic information systems (GIS) similar or dissimilar to information technology IT) in terms of its culture and women's experience of it?

2. Is vertical (and horizontal) segregation as prevalent in GIS as it is in IT and in science professions? Are women relegated to the lower ranks across GIS niches? Are they more represented in certain niches (e.g., more programmers versus analysts)? Are they more represented in certain industries/sectors (i.e., more in state government but less in startups)?
3. To gather information that might help in forming and influencing thought on mentoring relationships and networking groups
4. GIS's "hybrid" nature
5. Pipelines to GIS
6. Does the number of years in the GIS field have any bearing on the results of the survey questions? Specifically, do women with more years in GIS have different perceptions of the status of women in GIS—will they respond differently to questions such as "Do you think there in underrepresentation of women in GIS?" or "Do women face bias as GIS professionals?" Additionally, will women with more years in GIS have different experiences than do newcomers (thereby altering their perceptions)? Do the observations derived from these questions point to a change in the GIS field over time (to a field that is becoming increasingly better for women)?
7. Exploration of factors relating to work-life balance. Is this important to women in GIS? Do GIS jobs allow for flexible arrangements that might enhance work life? What are women's opinions about work life/family?
8. Demographic information
9. Is continuing education an important aspect of enhancing GIS careers that is both encouraged by employers and that is taken advantage of by women? Are women GIS professionals being given opportunities to obtain the knowledge and training that they need?
10. Is putting the word *women* in front of *GIS* to come up with the phrase *women in GIS* wrong? Does the mere saying of this just serve to reinforce women's alienation and their being seen as *other*?

(a) Is GIS similar or dissimilar to IT in terms of its culture and women's experience of it?

While IT and GIS share some similarities, they differ in many respects. As far as dissimilarities go, the survey responses show that those who work in GIS are not required to work long hours as is common in IT, and also that GIS workplaces allow for more flexible work arrangements. However, IT and GIS are very similar in their constant need to update knowledge and skills. This seems to be an inherent aspect of technology itself—because technology constantly evolves, GIS workers too must constantly evolve. The survey results also disprove the hypothesis that a male-dominated culture is present and/or perceived in GIS.

Regarding socializing after work in GIS-related meet-ups and general departmental outings, many participants report taking part in such activities. To determine to what degree women participate, further testing through other research studies would be required. However, many women seem to participate in socializing and list many benefits. Some participants also have listed helpful reasons why they do not participate, which might aid social group leaders in future planning.

Essentially, through the findings of this portion of the survey, there is enough information to conclude that while GIS and IT are both technical fields, GIS differs in its work conditions and work culture, as well as in women's experience of it. Therefore, GIS is a field that requires its own research and body of diversity literature. Another conclusion is that GIS seems to provide an overall better environment, in terms of schedule, flexibility, and gender-balanced culture, not only for women, but for people in general.

(b) Is vertical (and horizontal) segregation as prevalent in GIS as it is in IT and in science professions?

The questions in this survey serve several purposes. The most important purpose was to address the primary research question of "Is there an underrepresentation of women in GIS?" It was found that the GIS professional workforce (reflected by the GIS departments of the survey participants) is 42 percent female. While this is not a 50–50 balance, 42 percent could be considered a good level of representation, especially in light of the fact that according to 2014 DOL figures women make up 47 percent of the overall labor force. However, representation varies by sector. There seems to be a greater issue in start-ups and the greater private sector, which only have 28 percent and 32 percent female representation, respectively. But other sectors such as state government and nonprofits have a better-balanced representation (state government = 41 percent female; nonprofit = 45 percent female). Local government has greater female representation than male representation with 60 percent women.

This section also served the purpose of finding out more about where women in GIS work —in what sectors and in what specialized areas are women predominantly found? More participants work in certain sectors such as local government or in private companies. While more women might be found in these sectors as compared to others, however, it is not guaranteed that they will be represented in equal measure to men. For example, while the largest portion of participants (30 percent) works in the private sector, that sector is made up of 68 percent men and only 32 percent women.

Next, the question, "How would you categorize your work (programming, analysis, cartography . . .)," serves to offer a preliminary sense of how many women are doing specific kinds of GIS work. It was found that the participants perform analysis much more than programming, and, by establishing this pattern, the question emerged of why more women perform one type of technical task compared to another. The skills that women use in work are explored in greater depth in research question (d) below.

The last question, "Do you feel that there are enough women in your department?", is one of the first questions in the survey that starts to address whether women perceive an underrepresentation, as opposed to trying to ascertain whether such an underrepresentation exists in reality. Thirty-two percent of

the participants answered that there are not enough women and 36 percent responded there are enough women. As is explored through this and other questions in the survey, whether or not there is a significant underrepresentation of women in GIS, "uneven" representation (for example, with more male managers or with fewer women in highly technical roles) might well increase women's perceptions that such an underrepresentation does exist.

Returning to the research questions that were posed at the beginning of this section, one of the aims of the survey was to uncover if vertical and horizontal segregation exist in GIS as they do in other STEM fields. Specifically, the survey sought to determine if women are in managerial roles or are performing managerial tasks and whether women are called on to leverage highly technical skills (in addition to what are termed "soft" skills). The responses from research question (d) below are necessary to fully explore these issues and, as such, the discussion of vertical and horizontal segregation will continue there.

(c) Mentoring relationships and networking groups

This section of the survey was formulated to gather more information about women's preferences and experiences in mentoring and networking. To summarize the findings, participants are very neutral when it comes to the gender of a potential mentor, with 77 percent reporting that they do not have a preference. Similarly, most participants are neutral to gender with regard to networking (37 percent indicating no gender preference and 55 percent indicating an interest in networking with males and females). Despite the neutrality in response to these two questions, participants are overwhelmingly in favor of female professional groups—90 percent say female professional groups are good, and 73 percent indicate a desire to participate. Even though female professional groups are well regarded, however, only 29 percent of participants participate, suggesting that among those who are in favor of these types of groups, there is still a need to increase participation and participation opportunities.

There also are questions presented in this section that target women's feelings about being women in GIS, or their perceptions around female participation in the field. These include: "Do you feel that you would like to meet other women who work in GIS?" and "Have you ever been the only woman in the room (at meetings, events, etc.)?" The previous section includes the question, "Do you feel that there are enough women in your department?" The two questions show that, by and large, women in GIS want to meet other women in the field and that many women have had the experience of being "the only woman in the room." These feelings and experiences further highlight that while there might not be a gross underrepresentation of women in GIS, women's participation still calls for serious attention.

The question, "Have you ever obtained a job through a personal connection?", helps to highlight the importance of having connections (e.g., mentoring and networking aid women in growing their GIS connections). Fifty-three percent of the women who answered this question found at least one job through a personal connection, which supports this notion.

Lastly, finding out about women's successes in finding mentors in GIS can help inform the development of mentoring strategies within the field. Sixty-three percent of participants have not had difficulties finding a mentor. Women's successes in finding mentors (in addition to obtaining jobs through connections) suggest that GIS is a field in which women have good experiences and opportunities for success.

(d) Does GIS fit the "hybrid" solution model?

The primary goal of this survey section was to find out more about what skills women use in their current GIS positions. The first survey question asked participants to rank how often they use different skill categories. Would participants report using both technical and "soft" skills and, if so, would they use one of those skill categories more than the other? There is a body of literature about "hybrid" jobs in IT that require technical and "soft" skills (Guerrier et al. 2009, Roan and Whitehouse 2007). It was hoped that through these types of jobs, female participation in IT would increase (Guerrier et al. 2009, Roan and Whitehouse 2007). However, given the emphasis of use of "soft" skills in these positions, their occupation by women did not serve to increase women's equal participation in technical roles (Guerrier et al. 2009, Roan and Whitehouse 2007). Would GIS be the same?

The results of this survey section revealed that GIS jobs require a diverse skill set. Participants reported the use of both technical and "soft" skills. However, rather than equally drawing from both skill sets, communication skills are more heavily used. The average rank score for the use of all skills is 3.76 (out of 5). The average rank score for technical competencies is 2.88 versus an average rank score of 4.21 for "soft," or communication-related, competencies. Additionally, the participants have an average rank of 3.1 in regards to their use of management competencies. The expectation that women would score relatively lower on the use of technical and management competencies was confirmed.

One of the particularly insightful comments made in reaction to the first question in this section is, *"I am the GIS manager so my job inherently requires more of the 'soft' skills you list. If I were technical staff, those values would be less but still important. I feel that we work in a customer-oriented field—we don't have work unless someone needs what we do so it is important to have good people and communication skills."* This points to the notion mentioned previously that communication skills in GIS are important in general, regardless of how technical a position might be.

The aim of the first question in this survey section was to measure to what degree women use certain skills. The question was not about their skill levels. Collecting this data is an important first step in an effort to find out if women are given opportunities to use all the skills that GIS jobs require, or if gender bias is pushing them toward certain types of work as opposed to others. Are women given equal opportunities to take on technical and managerial work? As also is mentioned in this section, further research that includes men in GIS would be essential to see if there is a difference between the types of work that different people in GIS are performing.

The findings of this survey section (in addition to the questions posed in the paragraph above) are important additions to the discussion under research question (b) that asks whether there is vertical and horizontal segregation of women in GIS. Through this section, it has been found that women utilize their technical and management skills to a lesser degree than they use their communication and workplace skills. This suggests possible vertical and horizontal segregation. However, without knowing to what extent men leverage these same skills, it is hard to determine if vertical and horizontal segregation is truly present. Further research that includes men in GIS would help to clarify the results of this survey to that end.

(e) Pipeline to GIS

The questions in this survey section seek to explore the areas of study that bring women to careers in the professional GIS sphere and how they find out about GIS. Do most women learn about GIS in school or do some hear about it in other ways? Would most women who work in GIS come to their GIS careers via geography educations (or through earth/environmental science/studies type of degrees)? Would this be true for men as well? Is the GIS professional world made up of many geographers or people with geography and/or earth/environmental science/studies backgrounds? The point of this line of reasoning is to further explore how and why the technical GIS realm is different from other technical realms such as IT. Is it partially because the educational background of GIS professionals has shaped the GIS field differently?

It was found that the survey participants are highly educated. Four hundred and fifty participants reported on their educational achievements, indicating whether they attained bachelor, master, or Ph.D. degrees, or certificates, and, if so, in what disciplines. The largest degree category for all levels of education is geography. As mentioned, geography and earth/environmental science/studies are much more common pathways to working in GIS than are degrees such as computer science. A high percentage of participants found out about GIS in school—and if the highest percentage of participants have geography educations, it can be deduced that a significant amount of women learned about GIS through their geography studies.

This section of the survey also explores the incidence of internships among the participants and whether GIS internships tended to lead to full-time GIS positions. Almost half of the participants surveyed have had GIS internships, and for almost half of them this led to full-time work. While it could be argued that internships are important for both men and women, if it is a goal to increase diversity in GIS, then women and other underrepresented groups should be further encouraged to pursue internships.

(f) Does the number of years in the GIS field have any bearing on the survey results?

Specifically, do women with more years in GIS have different perceptions of the status of women in GIS. Will they respond differently to questions such as "Do you think there is underrepresentation of women in GIS?" or "Do women face bias as GIS professionals?" Additionally, will women with more years in GIS have different experiences than do newcomers (thus altering their perceptions)? Do the observations derived from these questions point to a change in the GIS field over time (to a field that is becoming increasingly better for women)?

On average, participants have worked in a professional setting for 14 years and specifically in a GIS setting for ten years. While most of the participants have up to 20 years of GIS experience (91 percent of the survey population), those with more than 20 years of experience drop off markedly (they make up only 9 percent of the survey population, as compared to the group with 10 to 20 years, which is 30 percent of the survey population). Their small numbers and the fact that they were among the first people to join the GIS workforce give them a unique viewpoint.

Survey participants were asked, "Do you think there is an underrepresentation of women in GIS?" Then, "Do women face bias as GIS professionals?" Next, "Is this bias unique to GIS or is it more general?" Sixty-four percent reported that they think that there is an underrepresentation of women in GIS. This confirms the hypothesis that women in GIS would perceive an underrepresentation (this was the hypothesis even if an underrepresentation was not found). Nonetheless, a large percentage of participants perceive an underrepresentation. Unexpectedly, there was no variation in responses to this question according to the amount of experience in GIS variable. It was expected that with more years in GIS, the perception of underrepresentation might increase, because of that group's smaller size (or, conversely, that the perception could decrease, if those women with more experience in GIS observed the field becoming more gender diverse over time). In regard to the other two questions, 48 percent of participants think women face bias as GIS professionals, and only 6 percent of women think this bias is unique to GIS, while 69 percent think that the bias is more general.

Forty-six percent of participants said that getting to where they are in their careers has been difficult. Eighty-two percent view attaining the next step in their careers as having challenges and 40 percent view their gender playing a role in those challenges.

(g) Work-life balance

Previously, we mentioned that framing work-life/family balance as a woman's issue might simply reinforce current gender norms (Bastalich et al. 2007). To address these issues, this survey section was included, both to see if GIS jobs boast good levels of work-life/family balance and to see where women in GIS stand on the issues presented in the literature review.

Ninety-four percent of participants reported that work-life balance is an important characteristic of a job (important and very important combined, 64 percent of those saying it is very important). Most participants (79 percent) say that they have a good level of work-life balance in their current jobs—only 39 percent of whom say "Yes, but could be better." Only 21 percent of participants reported "a little" to "not at all."

Sixty-seven percent of participants believe that work-

family issues are more relevant to women than they are to men. Seventy-eight percent of participants believe that women are more responsible (than men) for caring for children and elderly family members. When asked if they think more policies should be implemented geared specifically toward women that would allow for better work-family balance, nearly half say that, yes, more policies should be implemented geared specifically toward women that would allow for better work-family balance, while the other half say no.

Table 1. Race/ethnicity of survey participants

Value	Count	Percent
Hispanic/Latino	24	5.5%
Black or African-American	8	1.8%
White	374	85.2%
Asian	26	5.9%
American Indian or Alaska Native	4	0.9%
Native Hawaiian or Other Pacific Islander	3	0.7%
Total	479	99%

Even though 67 percent of the participants think that work-family issues are more relevant to women than they are to men, 76 percent of participants view work life and work balance as being an issue for men and women alike. Even though about half of the participants said more policies should be implemented geared toward women, 66 percent of participants feel that gearing work-family policies with women in mind alienates women. The nature of the results of these questions further supports the idea that the issue work-life/family balance is complicated.

Regardless of how complicated this issue may be, 77 percent of participants take advantage of the flexible work arrangements that are available to them at their companies and 85 percent of them feel comfortable doing so. This is different from what was suggested by the literature review, that is, that women would feel uncomfortable taking advantage of family-friendly policies (Cross and Linehan 2006; Guthrie, Soe, and Yakura 2009; also see Prescott and Bogg 2011).

It would be interesting to circulate the survey questions of this section to men in GIS. Would work-life balance be as important to them? Would they share the same views with regard

Table 2. GIS sectors by race/ethnicity

	State Gov.	Federal Gov.	Regional Gov.	Local Gov.	Non-profit	Start-up	Private	Higher Education	Other
Hispanic	3 4.3%	1 2.4%	0 0%	10 10%	1 3%	1 10%	5 3.7%	2 6.5%	1 7.1%
Black/African- American	1 1.4%	0 0%	0 0%	0 0%	0 0%	0 0%	4 3%	1 3.2%	2 14.3%
White	55 78.6%	37 90.2%	5 100%	85 85%	29 87.9%	7 70%	119 88.8%	26 83.9%	10 71.4%
Asian	8 11.4%	2 4.9%	0 0%	3 3%	3 9.1%	2 20%	5 3.7%	2 6.5%	1 7.1%
Am. Indian/Alas. Natives	1 1.4%	1 2.4%	0 0%	1 1%	0 0%	0 0%	1 0.8%	0 0%	0 0%
Nat. Haw./Pac. Is.	2 2.9%	0 0%	0 0%	1 1%	0 0%	0 0%	0 0%	0 0%	0 0%
TOTAL	70	41	5	100	33	10	134	31	14

Table 3. Years in GIS

	Hispanic	Black/ African-American	White	Asian	Am. Indian/ Alaskan Natives	Nat. Hawaii/ Pac. Islanders
0-3 yrs. GIS	5 20.83%	1 12.50%	78 21.02%	10 38.46%	0 0%	1 33.33%
>3 and <=10 yrs. GIS	10 41.67%	3 37.50%	142 38.27%	12 46.15%	0 0%	0
>10 and <=20 yrs. GIS	4 16.67%	4 50%	117 31.54%	4 15.38%	3 75%	1 33.33%
>20 and <=30 yrs. GIS	5 20.83%	0 0%	32 8.63%	0 0%	1 25%	1 33.33%
>30 yrs. GIS	0 0%	0 0%	2 0.54%	0 0%	0 0%	0
Total	24	8	371	26	4	3

Table 4. Race by number of years in GIS

	Average Years in a Professional Setting	Average Years in GIS
Hispanic	14	11
Black/African-American	18	11
White	14	10
Asian	9	7
Am. Indian/Alas. Natives	27	17
Nat. Haw./Pac. Islanders	17	13

Table 5. GIS sectors by age bracket

Age	State Gov.	Federal Gov.	Regional Gov.	Local Gov.	Non-profit	Start-up	Private	Higher Education	Other
21-30	21 27.3%	5 10.2%	0 0%	15 12.7%	11 28.2%	6 60%	45 29.2%	12 29.3%	5 31.3%
31-40	28 36.4%	14 28.6%	3 50%	41 34.8%	16 41.0%	3 30%	62 40.3%	10 24.4%	7 43.8%
41-50	14 18.2%	12 24.5%	1 16.7%	30 25.4%	8 20.5%	1 10%	17 11%	7 17.1%	4 25%
51-60	7 9.1%	9 18.4%	1 16.7%	16 13.6%	2 5.1%	0 0%	15 9.7%	6 14.6%	0 0%
61-70	2 2.8%	0 0%	0 0%	5 4.7%	0 0%	1 9.1%	1 0.7%	1 2.8%	0 0%
TOTAL	72	40	5	107	37	11	140	36	16

to the other questions?

(h) Demographic information about survey participants

The following tables provide background information on the survey participants and are used as a basis for categorizing responses to the other survey questions.

(i) Continuing education

This section aims to measure to what degree women feel the need to take continuing-education classes. However, it might be the case that women also like to take continuing-education classes—as was seen from the survey respondents' responses about their educational achievements, women in GIS are a highly educated group. Based on the number of advanced degrees and other certificates they have attained, it seems that these women are extremely motivated to continue to learn.

However, needing to take continuing-education classes (versus merely liking to) could be a useful measurement of the demands of GIS and if those demands might have any impact on work-life balance. Eighty-two percent of participants report that they feel that taking continuing-education classes is necessary to their current work. Seventy-nine percent of participants feel that taking continuing-education classes would be necessary to obtain a different position. When the participants were asked if they are required to accomplish tasks at work that push them to learn new things, 91 percent said that they enjoy this aspect of their work. So it is possible that the learning that occurs through continuing education is also an aspect that women enjoy and that they might not mind having to take such courses (even if they must be taken during personal time).

On-the-job learning also was measured in this section, as a starting point from which to measure how challenging (and possibly rewarding) GIS positions are and to get a sense of whether there is a relationship between having opportunities to learn at work and feeling the need to take continuing education. Overall, 76 percent of participants reported that they have learning opportunities in their current positions, which possibly reflects the fact that GIS positions are dynamic and can provide people with growth opportunities. However, it seems that there is a possible pattern among those who report fewer learning opportunities at work feeling that they need to take continuing education. For example, 85 percent of participants in federal government feel that taking continuing-education classes would be necessary to obtain a different position (this was the sector with the highest percentage of women reporting this for this question). This sector also has the smallest proportion of participants (62 percent) reporting that they have many on-the-job learning opportunities. Conversely, across race/ethnicity groups, white participants reported least need to take continuing-education classes to obtain a new job and reported the most on-the-job learning opportunities.

(j) The phrase *women in GIS*

Women's take on the word *woman* is very different when it comes to individual identification, as opposed to identification on a group level. Women, for the most part, seem to be okay with the term *women in GIS* but not okay with *woman in GIS.* Only 32 percent of women agree that the term *women in GIS* is

a good way to categorize, or describe, women who work in GIS, and simultaneously 37 percent of women agree that the term *women in GIS* is not a good thing because it separates and alienates women who work in GIS from men. Meanwhile, 94 percent of the survey participants would rather be called *GIS professional* than *woman in GIS*.

Is this difference because, when taken from an individual perspective, being seen as a *GIS professional* is more neutral? Yet on a group level, *women in GIS* affirms a subcommunity of GIS professionals that women can, and like to, participate in? A quote that was submitted in response to the term *women in GIS* speaks pointedly to this idea:

> *I think it is okay to identify ourselves as such since we are a minority. I would only use it as part of a group though. As a person I would like to remove the terms woman from describing professional individuals because then the norm of man first is reinforced.*

CONCLUSIONS

This research started under the premise that there is an underrepresentation of women in GIS and that it is an issue that deserves attention. It turned out that the situation is significantly more nuanced than can be captured by a simple black-or-white question such as whether women are underrepresented. The key takeaway from the research findings is that while there might not be an overall numerical underrepresentation of women in GIS, women might be more underrepresented in certain sectors and in certain types of positions. There are two other general, recent figures with which the results of our work can be compared: According to DOL figures from 2013 cited on the National Center for Women and Information Technology Web site, women hold about 26 percent of computing-related occupations and, according to 2013 National Science Foundation (NSF) statistics, women make up 29 percent of all science and engineering occupations. In comparing the number of women in GIS to these other generalized figures, our research indicates that women in GIS are better represented than they are in these other STEM-related occupations. While an overall underrepresentation of women in GIS was not found, a significant underrepresentation of women was found in certain sectors, particularly private industry.

Women use "soft" skills to a greater extent and scored themselves relatively lower on the use of technical and management competencies. These three sets of findings point to a similar variation among job types occupied by women within GIS as occurs within computer and information technology, science, and engineering. The findings also suggest that, again, while overall female representation in GIS is significant, the details of that representation suggest possibly uneven participation.

Regarding the second main research question, "Do women in GIS experience gender-based obstacles to success?", the answer is both yes and no. We found that the participants generally did not face the same obstacles or at least not to the same degree as women might in IT. However, the survey results suggest that a gender bias might be present that is pushing women toward certain types of work and that women are given more opportunities for certain types of work as opposed to others. A research study that also includes men in GIS would be necessary for a comparative analysis. A similar caveat concerns the sample size of our survey for minority populations (85 percent of our respondents are white), which leaves the question open whether there are possible differences in responses along race and ethnicity lines. The very fact that the field of GIS is predominantly white raises a whole other set of concerns.

It is encouraging to find that GIS seems like a good field for female participation, with its good work-life balance, strong sense of community, opportunities for networking and mentoring, and importance placed on continuing development.

SUMMARY

The data collected as part of this research adds credibility and depth to conversations about diversity in GIS. We hope that our work will serve as a starting point from which to create career and professional development tools specifically geared toward women pursuing GIS careers. There are many reasons why it is important to enhance gender, as well as racial and ethnic, diversity in GIS. Increased diversity in GIS will enhance women's career opportunities and also will strengthen the discipline through the inclusion of diverse perspectives and approaches. As GIS is both a discipline and a tool that is utilized to deal with a variety of real-world issues that affect people, the field of GIS should reflect the diversity of the world at large. Greater diversity in GIS will generate GIS solutions that take diverse viewpoints into account and that will therefore be more equitable and sound.

This article is based on the first author's master thesis supervised by the second author. The complete 280-page thesis with all the data is publically accessible at http://academicworks.cuny.edu/hc_sas_etds/5. We encourage readers to explore the material and share their comments/insights/questions with the authors.

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