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The Glass Obstacle Course: Informal and Formal Barriers For Women Ph.D. Students in STEM Fields

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ABSTRACT
A new metaphor is proposed for understanding the experiences of women pursuing Ph.D.s in science, technology, engineering and mathematics (STEM) fields, based on a study of students in a U.S. Ph.D. program. The notion of the "glass obstacle course" captures the unequal gendered processes at work in women's graduate careers, including exclusion from the "Old Boys' Club", outright sexism, a lack of women role models, and difficult work-life choices. These obstacles are "glass" because they are often implicit and unanticipated: they are "unseen, yet unbreachable" (Federal Glass Ceiling Commission, 1995). In-depth interviews elucidate the gendered and influential aspects of these barriers and the agentic strategies our respondents utilized to navigate them. In this way, career pathways for women scientists and engineers are shaped by ideological and structural constraints, informal and formal biases, and active resistance or accommodation to them. Such accumulated disadvantages can impact women's attrition from and satisfaction with their chosen STEM fields.

KEYWORDS
Women in STEM; gender; graduate education; STEM careers

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INTRODUCTION

Women earn half of U.S. bachelors' degrees in science, technology, engineering and mathematics (STEM) fields (NSF 2011) but their proportions decline notably at the doctoral level. In the U.S. and elsewhere, women's representation varies by field as well as by race, ethnicity, or region (NSF, 2011; InterAcademy Council, 2006). For example, women make up less than a quarter of U.S. doctoral recipients in most physical science and engineering fields, and Black, Hispanic, and Native American women are especially poorly represented. This progressive decline in the proportions of women at higher educational and career levels in the STEM disciplines has been referred to as a "leaky pipeline" (Vetter, 1981). While differing in detail, similarly leaky pipelines are observed worldwide: in a recent UNESCO (2006) analysis, in only 8% of countries surveyed did more women than men graduate from doctoral programs in science and engineering. Globally, women's underrepresentation among Ph.D. earners limits the recruitment of talent into the research workforce of STEM innovators and perpetuates the low diversity of STEM faculties at higher education institutions where the next generation of scientists, engineers, and faculty members is prepared.

Graduate school is a particularly critical juncture for the loss of women from scientific and technical careers. Since 1905, graduate women have reported experiences of hostility in the academy (Nerad and Cerny, 1999) precisely because of assumptions that, as women, they are ill suited for research work. A century later, U.S. women still report more dissatisfaction in their overall experiences during graduate school than men (National Research Council, 2006). In fields dominated by men, the persistence of gender bias contributes to qualitatively different experiences for women and men in graduate school (Fox, 2001). Some of this bias is attributed to women's lack of fit into the masculinized culture that endures in many STEM disciplines (Herzig, 2004; Thiry et al., 2007). Graduate school is an important career juncture for women who enter STEM fields because it is a primary location for socialization into their fields. Individuals learn the values and skills of their disciplinary cultures that are implicitly and explicitly gendered (Sallee, 2011). In fact, in their research on 'non-traditional' career paths taken by women and underrepresented minorities in science, Thiry et al. (2007) suggest that "[w]omen may encounter more barriers in graduate school than during their earlier years in science education" (p. 410).

Wasserman (1998) suggested that women who persist in STEM fields must have a "survival mechanism – the ability to withstand persistent negative cultural and social attitudes regarding scientific careers for women… [They] must be willing to be nonconformists and able to tolerate 'outsider' status to survive in a traditionally male scientific culture" (p. 7). This enduring outsider status contributes to the "chilly climate" for women graduate students (Hirt & Muffo, 1998; Litzler et al.,

2005; Sandler & Hall, 1986), perhaps especially for women of color (e.g., Beoku-Betts, 2004). This in turn fosters women's higher attrition rates (e.g., Lovitts, 2001; Nettles, 1990; Nettles & Millet, 2005; Rosser, 2004 ; Taylor & Antony, 2000). Though many women succeed and fare well in graduate school – perhaps developing that needed survival mechanism – the bias and marginalization experienced by others helps to explain differences in men's and women's experiences and retention in graduate school (Settles et al., 2006).

In this paper we examine closely the experiences of a cohort of American women who were about to earn their Ph.D.s in STEM fields. These women had both positive and negative experiences that influenced their career pathways. We highlight their strategies for navigating negative experiences and the resilience that enabled most to persist in fields that continued to pose challenges for them.

LITERATURE ON GLASS METAPHORS

Social science theories of inequality in the workplace contribute to understanding women's disparate experiences in organizational cultures that are gendered, including those of scientific or technical disciplines. One prominent metaphor for understanding women's experiences in the workplace is the "glass ceiling", used historically to describe the blocked career advancement of women (Morrison et al., 1987; Reskin & Padavic, 1994) and/or minorities (Tang, 1997).[1] The barrier is "glass" because it is not visible as a barrier to the individual, who initially earns promotions and raises but is passed over in favor of male colleagues for subsequent advancements. Formal policies promise her a fair chance to compete for the larger office or lab, greater responsibilities, and higher salary. Yet informal workplace norms and customs undermine these policies, creating the ceiling with which she abruptly collides.

Rosser (2004) applied the glass ceiling metaphor to the sciences in her study of highly recognized women faculty who experienced feelings of isolation and difficulties balancing work and family despite their outwardly successful careers. The metaphor has even been quantified: the "Glass Ceiling Index" is an indicator of gender equity in science (European Commission, 2009). But while useful in describing a linear career path, the metaphor is limited in its ability to capture the recurrent and dynamic nature of the barriers women experience in male-dominated settings.

A more recent metaphor, the "glass cliff" (Ryan & Haslam, 2005) captures the precarious situation of successful women who have penetrated the glass ceiling to reach the executive level. These women in top management teeter on the precipice, bound to fall or fail because they do not have the resources necessary to succeed, were placed in positions of responsibility under crisis, or are not perceived by peers as suitable for leadership (Haslam & Ryan, 2008, Ryan & Haslam, 2005). Because of its focus on the balancing act that women are expected to manage, this metaphor invokes a more dynamic view of the obstacles faced by women in male-dominated arenas.

Our analysis develops a metaphor that emphasizes how the barriers women must navigate in gendered organizations are not static, one-time experiences that can be permanently conquered. Unlike ceilings and cliffs, the obstacles do not sit still for women to come upon them. Nor do they steadily stream toward women like flying enemies in a video game. Rather, the barriers themselves are in action—popping up out of nowhere again and again, like the obstacles in "Super Mario Brothers" rather than the constant bombardment of "Space Invaders."[2] They may appear with little warning or reappear even after being overcome once. A more dynamic metaphor can account for differences in women's experiences, explaining why some may advance further despite working under the same 'ceiling'.

Our interview data highlight the turning points and factors that influence women's experiences and career decision-making during graduate school, based on first-hand accounts by U.S. Ph.D. students in STEM fields. By highlighting both the barriers that women face and the strategies they utilize to navigate them, we illustrate how career pathways for women scientists and engineers are shaped by ideological, cultural, and structural constraints, informal and formal biases, and active resistance or accommodation to them.

METHODS AND SAMPLING

This study took place at a research university ("very high research activity", Carnegie Foundation, 2010) in the Rocky Mountain West of the United States between 2003-2006. This study was conducted under a broader project, funded by a U.S. National Science Foundation ADVANCE grant that sought to improve women's representation in the academy. The portion of the project that focused on STEM graduate students aimed to develop a broader understanding of men's and women's experiences of STEM career pathways.

Our sample of 28 interviewees was derived from an institutional list of 1,148 Ph.D. students. Factors considered in selecting the sample included degree stage, gender, discipline, citizenship, and race/ethnicity. To investigate Ph.D. students' career deliberations, we limited the sample to those who had advanced to doctoral candidacy. In light of international differences in stereotyping, working conditions, and the labor market that affect women's participation in higher education and research (UNESCO, 2006; European Commission, 2009), we focused the study on U.S. citizens who were likely to share elements of their cultural and educational backgrounds, and to pursue careers in the U.S. workforce. Because our project focused on women's experiences, we oversampled women. Finally, the population was sorted by disciplinary group and the interview sample was stratified by discipline, adjusting for the smaller and larger numbers of women students in mathematics and engineering relative to the other groups.

Table 1: Disciplinary representation of the interview sample, by gender

	Total	Life sciences	Geosciences	Chemistry	Physics	Mathematics	Engineering
Women	19	3	3	3	3	2	5
Men	9	1	1	2	2	1	2

We made particular effort to include Ph.D. students from groups underrepresented in U.S. Ph.D. education (see Long & Fox, 1995). Generally less likely than both their White female peers or male same-race peers to earn a Ph.D. or work in STEM fields, women of color face a double bind of racism and sexism—yet their experiences of graduate education are particularly understudied (Ong et al., 2011). However, at this university, 80% of the possible sample was White, and some women of color declined our invitation to interview. The final sample included 19 women (17 White, one Asian, one Hispanic) and nine men (all White), who were generally in their late twenties or early thirties, unmarried, and childless.

Respondents were invited for interviews via email, up to three separate times. The primary author conducted semi-structured interviews with each of the 28 respondents in the spring of 2003. Interviews lasted approximately one hour and were conducted by phone or face-to-face, audio-recorded, and transcribed verbatim. Interview protocols addressed individuals' current stage and progress in their graduate programs, and their personal and educational history. Respondents were asked to discuss their career goals in the short and long term, and ideas for alternate career plans. They were asked about their graduate school experiences with their advisors, faculty, and other students.

As a recently graduated Ph.D. in sociology at the time of the interviews, the interviewer was attuned and empathetic to many of the interviewees' concerns about impending careers, and their troubling experiences in graduate school. The interviewer assured respondents of confidentiality, and each respondent signed an informed consent form. Still, many were apprehensive about their responses being traced back to them, especially when speaking about their primary advisors. Respondents were thus asked to let the interviewer know of any information that would inadvertently identify them, and any such information was removed or masked. Because of these confidentiality concerns, we are intentionally vague about potentially identifying details and adopt pseudonyms when names are used.

Interviews elicit narratives about specific topics of interest; they have the potential to expose lived aspects of status and power in ways that surveys cannot (Bachman, 2000). Using in-depth interviews rather than surveys allowed us to explore differences in experiences across gender via accounts about important events in graduate careers. And, consistent with feminist interviewing methods (Reinharz, 1992), the open-ended questions were designed to capture the nuances of women's (and men's) subjective experiences in a social context where gender was salient.

Analysis began with open, line-by-line coding, followed by focused coding (Esterberg, 2002) that allowed us to develop conceptual categories based on patterns or themes in the data. Following the principles of grounded theory (Glaser, 1978), significant themes emerged from an inductive method of identifying patterns in the data, which was enabled by an increasingly complex coding system that eventually 'saturated' key categories with excerpts from the interviews. In practice, text segments referencing distinct conceptual categories were tagged by code names using *NVivo* qualitative software. Codes were not preconceived, but

empirically grounded: each new code marked a discrete idea not previously raised. Groups of codes that clustered around particular themes were given domain names, and these clustered codes and domains defined the themes of our qualitative analysis. It is with these tools that we have developed the theory of the 'glass obstacle course' described here.

This paper focuses on women's experiences of the organizational structure and culture of graduate school because our analysis uncovered significant themes that men did not discuss to the same extent. While other analyses of these data consider men's and women's perspectives equally (e.g., De Welde & Laursen, 2008), here we draw on men's interviews only where their comments about cultural and organizational aspects of graduate school offer comparative insights.

The interviews were conducted on one U.S. university campus, which is similar to other U.S. research-intensive universities in size, departmental structures, gender ratios, and expectations for graduate education. Because respondents self-selected to participate in the study, it is possible that they had more to say – positive or negative – about their experiences in graduate school than peers who chose not to participate. While these facts place bounds on the generalizability of the findings, our interviewees' accounts of disappointments and successes in their graduate education reveal how gender makes a difference in STEM career pathways and suggest questions for future study.

FINDINGS

Early Experiences: Before the Obstacle Course

With few exceptions, the women we interviewed reported a life-long interest in science or engineering. They described receiving support and encouragement of their interests from family, friends, and throughout their K-12 experiences: "My family's always been really supportive;" "I've *never* felt not supported; "My whole network is super supportive." Though not oblivious to gender stereotypes and sex segregation in their fields, our respondents were not dissuaded from pursuing undergraduate then doctoral degrees in the sciences. One woman in a biological field said, "I never really came across anybody that would say 'Oh, you're such an idiot, you can't do experiments!'" A few told stories about growing up in gender-equitable homes where parents encouraged them to play with scientific or mathematical toys—one woman said her father bribed her with money to do math. Some parents told girls they could be anything they wanted. Others acknowledged that their families may not have understood the work they were doing, but nonetheless felt supported by them. In fact, no women recalled individuals who had been discouraging of their STEM aspirations in their younger years. Early family socialization thus appeared to lay a foundation for these women to feel safe and comfortable in pursuing male-dominated activities.

Many women described supportive teachers from early childhood through college, especially in undergraduate research experiences, and generally did not describe negative, gendered aspects of their K-16 schooling. Not until graduate school did most respondents begin to experience negative effects of being women in male-

dominated environments. Perhaps the greater numbers of women in their undergraduate cohorts mitigated or hid such effects; perhaps women were naïve about the gendered expectations of their fields, or were shielded by their undergraduate advisors.

Emergent Barriers in Graduate School

In contrast with their early family and education experiences, the gendered aspects of STEM disciplines became increasingly evident to many respondents as they progressed through graduate school. We identify four such aspects that were prominent in women's narratives and classify them under two broad types:

1) the *informal culture* of STEM fields that positioned women as outsiders, including both overt sexism and more subtle forms of exclusion from the "old boys' club"; and
2) the *institutional structures* of the academy that women found difficult to navigate: the lack of role models, and conflicts between the traditional timeline of academic careers and women's child-bearing years.

These categories emerged from the analysis as particularly salient barriers for women respondents. Their narratives illustrate how these barriers were influential during their graduate education: feeling excluded from the culture of their field made women question their ability to succeed and thrive in their discipline, while institutional barriers dissuaded them from pursuing academic careers in particular. In the following sections, we elaborate on each of these four types of barriers, then describe how they combined to form an insidious 'glass obstacle course' to women's persistence in STEM and academic careers.

THE INFORMAL CULTURE OF ACADEMIC STEM: WOMEN AS OUTSIDERS

Two of the common barriers reported by interviewees arose from the informal culture of their academic departments, laboratories, or fields, which often relied on traditional gender expectations. First, women had come to recognize that they were excluded from the 'old boys' club' that provided access to knowledge, mentoring, and opportunity. Second, some reported more explicit harassment and objectification in the form of sexist comments or encounters. Both types of plainly gendered experiences evidence the ways in which women remain outsiders in some STEM contexts.

The "Old Boys' Club"[3]

The exclusionary environment of STEM fields is often thought to belong to a previous era in which gender discrimination was accepted practice. Yet, at the Ph.D. level, most STEM fields are still the domain of men. Moreover, academic departments are often modeled after disciplinary norms of inclusion and access that are entrenched and difficult to change (Hirt & Muffo, 1998). In multiple instances, respondents used the term "old boys' club" to describe their departments, research groups, laboratories, or classrooms. Indeed, seven women (and men) used this term specifically, while several others described similar disciplinary or departmental cultures in other language. Membership in the club was valuable: it communicated

the values and norms of their disciplines, provided access to informal networks, and helped to move people along by offering useful information through unofficial channels. But this was not a formal club with "girls keep out" posted on the door. Rather, membership was gained through informal, social processes of "fitting in", as this woman suggested:

> *Well, there is a certain amount of "ol' boy" sort of thing. And, it's not necessarily, "Keep women out" – it's just that "Oh, you're my buddy—good, let's go have coffee," you know? And so that kind of social/work/buddy kind of thing seems to be very effective in getting men what they need, what they want. It's very ingrained, very. It works very well. Everybody knows the rules, the parameters of that situation. (Life sciences student)*

Her understanding of the function and benefits of informal networks highlights the privileged status of men in STEM fields. Men generally did not have to worry about whether they would be invited for coffee, beer, or other social events: they were already and always "in". Women were not automatically granted the "buddy" status that let them in and provided important information. In this case, the speaker recognized that her gender excluded her from these informal activities, and she understood the consequences of being left out.

Though not formalized, the rules to this "club" were widely recognized, as this woman explained:

> *The most frustrating thing is that there's definitely like a boys' club in my field, and you kind of have to do the right things to be incorporated in that boys' club. Like, you have to go out and drink beer… and you can't be too feminine and you can't – like there's just certain rules. None of them are spoken.* (Environmental engineering student)

According to this speaker and other respondents, gaining access to the informal networks required women to be available for socializing, be ready to debate and compete, and have a "tough skin." Other women described the rules for how club members dressed, acted, and presented themselves, which were decidedly not in feminine style. One respondent felt she was not taken seriously at a conference, because, as she described:

> *I looked relatively normal because I don't dress as an engineer, and so they thought that was really strange. You know, I actually looked like a woman. 'She couldn't have possibly done any science on her own,' you know, 'She must have slept with someone to get it done.'*

She recognized that common gender schemas for a "normal" engineer (Valian, 1998) did not include women. Worse, she suspected that others believed she had used her feminine wiles, rather than her intellect, to accomplish the results described in her presentation. The interviewer followed up by asking how her experiences might have been different had she been a man. She jumped in, exclaiming: "I think I would love to be a man at this point; it would definitely be *much easier. People take you more seriously. People automatically respect you.* [emphasizing each word loudly] You don't have to fight your way." For this woman, the journey through graduate school was "a fight" to manage the unexpected situations in which her gender spoke louder than her achievements.

Exclusion from information-rich informal networks can create barriers to success for women (see Sonnert & Holton, 1995). Women students may not benefit from the informal peer mentoring inherent in advice about whose lab to avoid or how to approach certain professors about a recommendation letter. Moreover, the perpetual "old boys' club" atmosphere of some departments added to the isolation and chilly climate that many women reported. This may have been especially common in physics and engineering departments, where women were particularly scarce. As one man noted: "If there's a woman in my office, she's not going to have anybody else who is going to have that connection to her. Whereas, all us guys, we just connect on that level, and so we can commiserate a little closer" (Mechanical Engineering student). Indeed, some women recalled pivotal moments when they took notice of their graduate school environment as excluding them in ways they hadn't observed before:

> *Most of the professors are* (laughing) *little, old, white-haired men – and they're great, but you don't feel very connected to them. I was sitting in my comprehensive exam – you have five professors – and I was sitting looking out at them and they were all these little old, white-haired men… I just don't feel part of that in a lot of ways*. (Mathematics student)

This respondent's poignant realization that she was an outsider came, ironically, at a moment of heightened tension and stress about proving herself, during an exam where any graduate student's confidence would be tested. She went on to explain that the invited lecturers and eminent scholars in her department were all men. This influenced her sense of belonging to her department and her discipline more broadly: "Time after time you just start feeling like, really, I'm not a part of this. Where do I belong in this, you know?" For many women this led to feeling like an impostor, like this woman who confessed: "Oh my gosh, they're going to figure out really quickly that I don't know what the hell I'm doing." (Aerospace engineering student)

For some "outsiders," membership in the club was a better option than no membership at all. A few women chose the strategy of fitting in by compromising or masking certain characteristics. Across disciplines, women described these strategies: dressing in a less feminine manner, inviting themselves out with "the guys" to go out for beers or play sports. Even when they inherently enjoyed these activities, women described deliberate behavioral choices to participate in the informal culture of their departments. Some learned to "act like a man" to be taken seriously, as one physicist explained. Another described de-gendering her appearance so as to feel less like an interloper:

> *I definitely don't feel comfortable acting like a woman. It took me a long time to feel comfortable to dress like a woman. At first I just dressed like a guy, basically, so that [I] could just blend in. But as I started to wear skirts and stuff like that, [I] definitely got the weird look occasionally.* (Physics student)

This exemplifies the kinds of interactions that, manifesting over and over in women's experiences in graduate school, could threaten their performance and

confidence in a domain in which they had already invested highly. Women who were successful at identifying and managing this issue by minimizing aspects of their (feminine) gender found that collaborations became more readily available, they felt more comfortable, and they assimilated better in professional situations. Such coping strategies may be self-protective, reducing the psychic costs of disidentification by selectively dissociating from aspects of one identity group (women) that are seen as counter-diagnostic of successful involvement in another domain (science) (Pronin, Steele and Ross, 2004).

Some men respondents also talked about this "club." While some acknowledged the gendered aspects of the club, like the mechanical engineer quoted above, others suggested that women merely perceived an "old boys' club" that did not actually exist. When asked about the gender disparity in physics, one man suggested that it was not the climate itself that was problematic but rather women's feelings and perceptions about it: "I feel like certainly I can evaluate it on the level of *perception* that women *feel* like it's just a less friendly environment. I feel like the *perception* is something that is a real problem" (original emphasis). Another explained away the "old boys' club" by suggesting that women engineers had the upper hand in gaining employment: "It's no longer a good old boys' network—or it's not *all* a good old boys' network," he stated. "[Women] really own the world when it comes to that sort of thing. If you're a female in engineering and you do well, you can write your own ticket" (original emphasis). These dismissive interpretations of women's experiences reinforced the hegemony of the "club."

In sum, the "old boys' club" was a form of exclusion described as subtle, presumably unintentional, and not always visible to women. While women were frustrated by their exclusion and aware of resources and opportunities that might thus be denied them, none were deterred from pursuing a graduate degree because of these experiences. Several factors may have mediated their persistence. Most reported overall satisfaction with their primary advisors (De Welde & Laursen, 2008), who are pivotal in women's persistence in graduate school. Many also exhibited an unwavering desire for a career in the fields in which they had deep interest, prior training, and had presumably excelled. Others, it appears, were successfully socialized into disciplinary norms such that they developed the tough skin necessary to thrive in environments in which they were routinely reminded that they did not belong.

Sexist Stereotyping and Harassment

A second pattern identified in the data, and also part of the informal culture of academic STEM departments, was the sexism that our women respondents described. In contrast to the often subtle gender segregation of the "old boys' club", some respondents disclosed painful experiences of sexism and harassment that were anything but subtle. Some were angry about these encounters, while others shrugged them off as inherent to the path they had chosen: Incoming Ph.D. students had "better get used to it", said one woman. Like exclusion, sexism and harassment arose from the informal culture of male-dominated STEM fields. Yet while outright sexism undoubtedly helps to explain women's exclusion from the old

boys' club, experiences of sexism and harassment were also barriers in their own right. These experiences could lead to feelings of alienation and exclusion, but they are not the same as the phenomenon of exclusion itself—hence we distinguish sexism and harassment as a separate glass obstacle. The quotations in this section reveal that women's emotions ran high; they felt disrespected, objectified, and infuriated by a double standard that required extraordinary achievement to overcome stereotypes.

In our sample, women in physics and engineering more often reported their own experiences of sexism during graduate school, while women from the other disciplines more often described experiences that had happened to others. Tokenism and stereotyping of women were two ways in which sexism manifested, especially for those who were the only women in their immediate professional circles. This was articulated clearly by a woman who had experiences of tokenism:

> [*Part of it is] just feeling and hearing constantly, "Women don't make it through the program." You just feel like – I'm not talking for me, Kelly, I'm talking for all of womankind. And so if I ask a stupid question, it's not that Kelly has not sufficiently slept, or Kelly did not read the material, but it's that women are stupid*. (Physics student)

Being perceived as a token seriously angered another woman:

> *If you want to make it as a female scientist you have to be* **much** *better than the men… And so they [for example] would want to give a woman a job over a man and then men are… even though* **you've worked your butt off and had to work ten times harder than the men** *– at that point they're like, "Oh, they gave that job to a woman because she's a woman, not because she's qualified." And you have to deal with that* **crap***. And I've definitely had people come up to me and asked me if I actually did the work myself, or was I just a spokesperson.* (Original emphases; Physics student)

Similar to tokenism, women reported stereotyping: being treated unfairly, seen as incompetent, or not taken seriously. Altogether, experiences like these were reported by well over half of our sample. Two interviewees described the implicit gendered hierarchy of informal cultures in the "hard" sciences. One woman said, "I think I had to struggle a little more to get respect and to prove myself…. I don't come in and automatically get respect from other people" (Physics student). A man concurred: "It just seems like some women just come off as airheads no matter how smart they are, or they're perceived as airheads anyway, that's what I meant. So I can see that being a little harder if I was perceived as an airhead. And, you know, I'd have to prove that I'm not" (Chemistry student). Their comparable understandings of the prevailing culture suggest that women and men alike acknowledge that women are subject to stereotyping.

Another example of how hard work could be undermined by stereotyping came from a chemical engineer. Though her undergraduate advisor had been supportive and encouraging throughout her education, his recommendation letter for her graduate school application described her as "sunny". She commented,

> *I don't think that my undergrad advisor would've described me as "sunny" had I been a man. It always bugged me…. I'm like, "What a sexist thing to say! 'Cause I don't think you would write that about a guy! That's not gonna get me a job." Why did he include that?*

Looking back, she recognized his comment as a potential obstacle for her career aspirations, especially because advisors play a key role in graduate students' career paths (De Welde & Laursen, 2008).

Stereotyping and tokenism were precursors to the sexual objectification that over a third of our respondents reported experiencing. Women reported being harassed and groped by professors, asked out by male peers because they were the only women perceived as available, or having strangers at conferences assume that they were sexually involved with their professors. For example, one woman had previously planned a career in aerospace engineering until she experienced *quid pro quo* sexual harassment as an undergraduate:

> *I also had a situation where an instructor in a class – it was a key class for aerospace engineering – made an overture to me about how to pass his class. And I did pass his class, though I did not accept the overture. I kinda played it awhile, because I needed the grade, but I didn't accept the overture. That was the last aerospace engineering class I took. It turned me off, even though I could play the game when I had to….* (Life sciences student)

Several women commented on being "hit on" by men professors or peers. They reported a variety of strategies to cope with these unwanted advances: one woman told of peers who wore simulated wedding bands to signal their unavailability to men colleagues; others downplayed their femininity by dressing or acting "like a man." An engineer gave the following example of "horrible" harassment she experienced:

> *I was at a conference one time and, you know, conferences are very social; people go out after the conference and hang out. So, this one particular scientist who—he's not much older than me, not one of the old guys, you know what I mean? —I'd say he's in his 30s. He made a comment that, basically, the only reason that I was a first author on a paper in science was that —and this is a direct quote—'I was surrounded by brilliant people.' So, basically implying that I wouldn't have done it on my own if I hadn't had these other people. That was the first comment.*
>
> *(continuing) The second comment came later in the night. [Someone asked if I knew] this professor [at my university], and I said, "Yeah." [Then, he] implied that I would know other physical things about this guy. [I thought,] 'No, this just didn't happen.' So this is the attitude: that I'm only good enough to know certain things about professors and that I wouldn't have got science on my own. You hear it enough times and you start to believe it.*

Such brazen sexism was often startling to the women who encountered it. They did not anticipate discrimination, harassment, and hassles simply because they were

women. Stories like this revealed how such experiences critically affected their confidence and shifted their perceptions at vulnerable moments in their early careers.

In this data set, instances of sexism and harassment were not isolated, but systemic and systematic. Sexism and harassment were more evident in contexts where women had not reached critical mass, so were not sufficiently numerous to affect the local culture. The data offer examples of informal norms that reinforced and reflected disciplinary cultures where women were routinely harassed, targeted as sexually available, and disregarded. Moreover, women's responses showed how such norms could contribute to women's sense of not belonging and perhaps choosing to leave a STEM field. While the norms in some fields may have shifted such that women are routinely represented and face minimal harassment, the overrepresentation in our sample of negative accounts from physics and engineering, among the most male-dominated disciplines, supports the argument that women's critical mass is important.

In sum, overt sexism and exclusion from the old boys' club were two prominent challenges for women Ph.D. students that arose from the informal cultures of STEM disciplines. These glass obstacles were "glass" because unanticipated, and "obstacles" because they denied women access to networks that offered insider knowledge, mentoring, and career opportunities, and caused them to experience discouragement and loss of confidence.

THE STRUCTURAL REALITIES OF ACADEMIC STEM: FEW WOMEN PRESENT

Throughout our interviews, women described the structural realities of academic careers in STEM fields as potential barriers to pursuing such careers. These manifested as two major themes. First, in many STEM fields women are still few in number, resulting in few role models for women students. Second, the structure and timing of academic careers are such that the extended "proving years" conflict with biologically favorable years for childbearing. These two realities emerged as significant factors in our respondents' career decision-making, especially as they considered careers in academic STEM.

Flawless Role Models

Lack of women role models is a key factor in women's attrition all along the STEM pipeline, as there is strong evidence for the importance of adequate and sustained mentoring of women students by other women (Fox, 2003; Rosser, 2004). Women entering STEM graduate programs expect to encounter low numbers of women professors. But only late in their studies did our respondents recognize their need for women role models who could represent the possibilities of success and offer examples to emulate. In our study, male advisors mentored their women students effectively (see De Welde & Laursen, 2008), yet our respondents still needed to see that women could succeed. The absence of women role models in the academy meant that women students had too little evidence to visualize possible futures of their own in this setting.

Interestingly, when asked about influential role models, our women respondents did not describe superstar scientists or award-winning scholars, although such women had been inspirational to them in early childhood. Instead, women students articulated a strikingly similar image: a woman who had secured a tenure-track job, juggled intense work responsibilities with visible child-rearing obligations, yet remained friendly and energized. In 16 discrete mentions of women role models, only one speaker did not describe family obligations as part of her imagined role model. One woman equated femininity with motherhood as she explained: "There are no good role models within departments [here] for being able to be a woman… you know, have a family and hold down a tenure-track position." (Biology student) Such characterizations point to the significant weight for women students of family/work/life balance in considering possible careers and setting measures of future success. In contrast, men respondents were less specific when describing role models; they described multiple publications, successful labs, or promising careers. Only one man in our study mentioned family obligations in describing a role model.

Positive role models—or their absence—had significance for women's persistence, especially in academic STEM careers. One woman explained how even a distant role model could have an encouraging impact:

> *One of the female professors in my department—even though I don't talk to her that much, I did TA for her a semester—and she seems to have it all, from an outside perspective. She's got two young kids, she's tenured, and is one of the leaders in her field, and seems to not have a lot of grey hair and huge bags underneath her eyes. So, to look –and even if I don't talk to her that much –to be able to say, "Well, there's somebody who did it. You know, I might be able to do it too," is great.* (Aerospace engineering student)

It was important for women students to know other women who were juggling multiple responsibilities. Seeing it proved that it could be done; being able to talk to and seek advice from another woman further along in her career was even better. For example, a woman who had no accessible role model commented:

> *There aren't very many women I can point to and be like, "That's where I want to be. Let me go talk to her so I can find out how I can do it." I definitely think it makes it hard not having, necessarily, somebody you can go [to who can say], "Well, one thing that you really need to know is that you should do this".* (Engineering student)

Her need contrasted with the experience of a mathematician who described how her undergraduate advisor inspired her to pursue graduate work and provided a vision of how it could be done:

> *If I had been at a different school and didn't have that particular person pushing me, I don't think I would have come here. I don't know what I would've ended up doing, maybe some programming job or something like that.* (laughs) *But I wouldn't have thought that I could have gotten through this. And I think knowing her history*

> *helped me a lot – knowing that she just hadn't been the superstar that shot through grad school, but that she had problems, she had time off, and difficulties, and still made it—and was still extremely successful. That helped me to realize that the whole process doesn't have to be linear for it to be good.* (Mathematics student)

This student had defended her dissertation, she was expecting a child, and preparing to move to another state where her husband had accepted a job. She planned to return to an earnest search for a tenure-track job within the year. Her role model had given her hope that she could manage her new family responsibilities and achieve her career goals. Nor was she alone in having a positive role model. As another woman stated, "I've actually seen some pretty decent role models of women that I've known who have finished grad school and are capably juggling being a professor who's on a tenure-track position *and* having a more traditional family role along with that" (original emphasis, Life sciences student). These examples show how positive women role models made a significant difference in respondents' perceptions of the possibilities for their futures.

Women described also an additional feature of their ideal role model: she should not show signs of stress. To many of our respondents, visible embodiment of the difficulties of balancing academic work with family and personal life seemed to undermine what were otherwise images of success. Words used to describe them included: "stressed out," "unhappy," "bitches," "workaholic," and with "huge bags under their eyes." One woman explained her theory on the lack of women in tenure-track positions compared to women doing non-academic research in her field: "I think a lot of it is the family issue, I really do. You know, you see these women that are crazy, psycho workaholics and you don't want to be like them. And so then you just choose another path." (Geology student) As discussed in the next section, our respondents recognized how formal structure of academic careers added to their professors' hurdles, and did not necessarily blame them for their circumstances. Nevertheless, these descriptors underscored that negative role models were as powerful as positive ones in influencing career decisions. Not all of our respondents wanted children, but they wanted to know – even if it was not for them – that it could be done.

Competing Clocks

Women identified a second set of structural issues as salient at this stage of their careers, especially in their consideration of academic careers in STEM: the inherent conflicts between the timing of academic careers and having children. While their descriptions of role models suggest that women students expected nothing less than heroism from their women professors, our respondents recognized that tenure expectations and institutional requirements in academia contributed to the impossibility of "having it all". Women graduate students often cited tenure clocks and biological clocks as competing; the dedication they saw as required to achieve tenure caused many to hesitate to pursue an academic career. On this issue, women and men were in agreement. Several joked that the only way a woman could have a child and achieve tenure simultaneously was to have a "stay-at-home

husband" or a "wife". And both women and men noted that most women professors they knew either waited until after tenure to have children, or did not have children at all. While men scientists also have difficulty balancing work-family responsibilities (Ecklund & Lincoln, 2011), our male respondents were not very concerned about it at this stage, while for women this was a significant variable in their career decisions.

Though fewer respondents spoke about competing clocks in research, industry, or government careers, some did note the difficulties of juggling families and careers in those settings. One of three women in our sample who planned to leave her field after obtaining her degree felt that the demands of any STEM career were excessive. She described how none of the women faculty at her undergraduate institution had children while working towards tenure, and how a friend at a national laboratory referred to working conditions that made family life "out of the question". She added: "And I think that's an awful lot to ask of people. I mean, how much dedication can you expect people to have? Even if you don't want to have a family, just to have a life outside of your work is very important to me."

Such concerns echo a pervasive conversation in the U.S. and elsewhere about work-life balance and better family policies in all careers. These concerns may be even stronger in STEM fields because of the research postdoctoral position, a standard career stage in STEM. Lasting one to four years, the timing of the postdoc during the "proving years" places young women with plans for children in a time conundrum. Many of our respondents had deliberated carefully over their work and family planning, calculating time to degree, time to academic job, and time to tenure. One woman, who was contemplating leaving her field because of the stress of pursuing an academic career, laid out this problematic timeline:

> *I think it's more stressful for a woman, because if you want to have family, you do a postdoc and that takes two years. And I'm almost 29, so by the time I'd finish a postdoc, I'd be 31 or 32. And then you have to apply for these universities and then you get to the university at 32 or so. And you start a lab, and then you spend four or five years trying to get tenure. And by the time that's over, you're 36 or 37, and it's kind of hard to start a family at that point. And then if you haven't actually met anyone and you're not married by the time you start a professorship, how are you ever going meet anyone?* (Physics student)

Some respondents were inspired by rare examples of professors "doing it all," especially if these examples were women. One woman described an assistant professor in her department who had a young child. She and her husband, also a junior faculty member, managed to alternate their schedules and family leave in ways that benefitted their family but did not appear to impact their careers. The speaker was quick to suggest that such examples were rare, and noted the availability of family leave as important in this case. But not all students recognized the structural aspects in play. For example, one man described a former professor: "My undergraduate research advisor, she had a two-year-old, and she would bring the two-year-old into class in a pouch on her back and teach an entire class with that two-year-old back there. And for the most part, I was amazed by this!" He

was struck by how his professor managed to integrate normally segregated aspects of an academic's life. However, as analysts, we were struck by his inattention to the organizational aspect of his story: that this woman may not have had on-site day care or adequate family leave, and thus had to teach a class while simultaneously caring for a toddler!

Our data suggest how positive images of women and men as both parents and academics could make a difference for graduate students' ability to envision their future careers and lives. But supportive institutional policies are needed to enable such choices to be meaningful. As the excerpts above demonstrate, these choices were framed as a firm dichotomy: either family or academe, but not both. In navigating the foreseeable obstacles derived from structural work norms that seemed to demand complete dedication, women sometimes opted out of tenure-track careers, especially at research-intensive universities, to pursue career paths in industry, government, or teaching-intensive colleges (see De Welde & Laursen, 2008, De Welde, 2009). While these choices may make sense for individuals, they also ensure that subsequent generations of women Ph.D.-seekers too have few women role models.

These narratives show that graduate women needed to see that they could have productive careers—including academic careers—in their chosen fields without sacrificing other aspects of their lives. If women did not see their hypothetical lives represented among the career choices they were considering, they were less likely to pursue those paths. The influences of career structures and work norms shaped what these students saw as possible. Changes to the academy that offer positive role models and policies that are more supportive of family life may not only assist women faculty, but may help persuade women students like our respondents that academic careers are possible and even desirable. In this case, the structural obstacles to academic STEM careers are not entirely invisible to women, but are unexpectedly difficult to penetrate.

DISCUSSION

The women in our study described a series of barriers encountered along their path to a STEM Ph.D. These obstacles unexpectedly appeared, withdrew, and reappeared over time. Based on the data, we offer a new metaphor for understanding these women's experiences: a glass obstacle course. This metaphor captures three key aspects of women students' experiences in their STEM graduate programs:

1. Women encounter career path obstacles that can stop their forward progress and prevent them from arriving at their initial career goals or choosing freely among career options.
2. The obstacles are gendered, because they are specific to and significant for women, but not for men.
3. The obstacles are glass, because women can see through them and thus do not see them as barriers until after experiencing and (in some cases) reflecting upon them.

The evidence from this study suggests that women knew the process of obtaining a graduate degree and pursuing a career in a STEM field would be difficult. However, many difficulties were not anticipated or even visible until they collided with respondents' realities. These obstacles were unexpected and persistent; they combined to form a long "course" that depleted many and exhausted a few. Emerging from both informal, cultural norms and formal structures within STEM education and career paths, the obstacles influenced the choices women made.

Our analysis identified a set of informal cultural practices that together form the obstacle course. Experiences of the "old boys' club" included isolation, marginalization, exclusion, and outsider status. Within the "old boys' club" gender (and race) privilege operated as a glass obstacle; it was invisible, unmarked, and generally unexamined (Kimmel, 2010; McIntosh, 1998). Looking around and seeing people like oneself widely represented, expecting to be taken seriously and to be included in the informal culture of one's department or research group were all things that men in our study experienced as normal, but that, in their absence, added to the glass obstacle course for women. As one woman in a life science field explained: "The boys' club tends to keep women as outsiders. And because there are fewer women, other women don't persist, and women rarely reach critical mass in departments."

This lack of critical mass of women faculty and students is consequential for women graduate students (Meinholdt & Murray, 1999). In fields with low numbers of women (like engineering and physics, in our study), women more often discuss exclusionary practices, feelings of isolation, and lack of camaraderie (Rosser, 2004). Other research likewise indicates the persistence of the "old boys' club" in STEM settings with segregated environments where "non-merit prevails" and where "whether or not the person 'fits in' to the culture, image or environment" becomes a selection criterion (Still, 2006, p. 185). For example, Rosser (2004) identified a "boys' club" in laboratory cultures where women were seen as anomalies. Varma (2007) and Margolis and Fisher (2002) discussed the androcentric "geek culture" in computer science and computer engineering. Hewlitt et al. (2008) suggested that a primary reason for women's attrition in these fields is a "macho culture" that is hostile to women. Such cultures are not likely to change without a critical mass of women, and their members are thus less likely to promote or adopt structural or organizational policies to recruit and retain women (see Frehill, 2006, for an alternate perspective on critical mass).

Women who experienced sexist comments or sexual harassment by peers or faculty were taken aback by such behavior. These interactions presented obstacles for our women respondents by suggesting that women's gender was more salient than their productivity, intellect, or skill. And though some women knew that these barriers existed, bumping up against them in person often took them by surprise.

Formal structures that shape STEM training and career paths too can contribute to the obstacle course. The lack of women role models was not necessarily an obstacle to graduate school for our women respondents, who had been supported by good academic advising and mentoring and were soon to receive their Ph.D.s

(see De Welde & Laursen, 2008). But obstacles did arise out of the absence of role models as they made career choices. That is, the influence of not having positive role models in academic positions is the glass obstacle, as women did not see other women who could manage successfully science careers and full personal lives.

Another structural reality perceived as a career barrier was the intersection between many women's desire to start families and the timing of academic careers. Our respondents' perceptions were not ungrounded, as research has demonstrated that women who delay children are more successful early in their careers, and that more women than men delay children for their careers or have fewer children than they want (Mason & Goulden, 2002; Spalter-Roth & Erskine, 2004; Ecklund & Lincoln, 2011), and that women more than men may choose against academic careers because of family concerns (van Anders, 2004). Although the glass ceiling metaphor may incorporate the lack of family-friendly policies that hinder women's advancement in the workplace, the "maternal wall" (Williams, 2005) is a more specific metaphor for how this operates in academia. Our "glass obstacle" metaphor highlights not just the lack of family-friendly policies, but also the "competing clocks" that many women face in their decision-making (see also Armenti, 2004; Ward & Wolf-Wendel, 2004).

While other metaphors describe fixed obstacles, women's coping strategies show that these are dynamic barriers to navigate. Some women chose to delay or forego children, while others chose alternative paths within or outside the academy that seemed more family-friendly. And some planned to forge ahead, perhaps eventually becoming the type of role model that they as students craved. Many women planned to use their postdoctoral years to make these important decisions, ultimately hoping that as they progressed in their careers, they would find personal solutions to these structurally based dilemmas. Our respondents' apprehensions reflect widespread concerns about the elusiveness of work-life balance across careers, for both women and men (Gerson & Jacobs, 2004; Hochschild, 1989, 1997; Stone, 2007).

The glass obstacle course is dynamic and subject to reinterpretation, resistance and change as individuals reproduce, interact with, resist, succumb to, and challenge these realities. Indeed, our respondents used a variety of strategies to navigate the obstacles. Weary of harassment or perpetual marginalization, some women left science entirely. In fact, two women, both in physics, who had experienced extreme sexist hostility from their advisors and others in their fields, had decided to abandon careers in physics after obtaining Ph.D.s. (De Welde & Laursen, 2008). Their selection of self-preservation over self-destruction may offer insight into the very low numbers of women in physics and other STEM fields. Most of our respondents, however, were not deterred by hostile and marginalizing environments. Most intended to pursue postdoctoral positions and many had long-term career goals in their STEM fields. Thus, the majority of women we interviewed were resilient, adopting strategies to cope with the overall climate, carefully muddling through, or submitting to negative experiences as part of their chosen careers.

CONCLUSION

Our findings support Sonnert and Holton's (1995) deficit theory, which suggests that informal and formal aspects of science disciplines create differential and often negative experiences for women. Accumulating over time, these environmental deficits disadvantage women, leading to higher attrition, lower satisfaction and success, and a pattern of negative and demoralizing experiences even for women who persist in STEM-related careers. The barriers that we have conceptually identified as informal/cultural and formal/structural work in tandem to produce the glass obstacle course. For example, androcentric cultural norms and values in many STEM fields, especially where women are scarce, are reinforced by inadequate policies for flexible tenure paths. Transformation to improve diversity in STEM fields must occur at the levels of culture *and* structure.

The "leaky pipeline" metaphor works as a statistical description of STEM attrition and persistence, but does not describe the experiences of individuals. The "glass obstacle course" metaphor instead emphasizes the drivers of attrition – the set of individual women's experiences that collectively account for the statistical declines. During graduate school, when emerging scholars are vulnerable, instances of exclusion or bad behavior are more devastating than they might be later when interpreted as mere irritations. Thus, the obstacles or barriers outlined here affect women differentially, causing them to lose confidence and further doubt themselves at a time when this matters a great deal. To attract and retain women in STEM fields, substantial changes must be made to make academic informal cultures and formal institutional policies more inclusive, less sexist, and more accommodating of 21st-century women's lives.

FOOTNOTES

[1] The terms "sticky floor" (Berheide, 1994) and "concrete ceiling" (Moore and Jones, 2001) have also been used to describe minorities' and women's blocked advancement in the workplace.

[2] Stéphanie Mercier has brilliantly visualized a career woman's obstacle course as a video game in her short animation, Les filles sont nulles aux jeux video, http://vimeo.com/12625441 (accessed 11/7/11).

[3] We interpret this concept as different from Margolis and Fisher's (2002) "boys' club," which denoted (primarily) high school spaces where boys tended to congregate and monopolize time on computers unless forced to share with girls.

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