AC 2007-2403: ENCOURAGERS AND DISCOURAGERS FOR DOMESTIC AND INTERNATIONAL WOMEN IN DOCTORAL PROGRAMS IN ENGINEERING AND COMPUTER SCIENCE

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Encouragers and Discouragers for Domestic and International Women in Doctoral Programs in Engineering and Computer Science

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Abstract
We are engaged in a large NSF-funded study (#0634519) that seeks to understand and to address the problems of retention for women in doctoral programs in engineering and the physical sciences from the student viewpoint. We examine the women's experiences through the everyday encouragers and discouragers that they encounter in these programs. We are especially interested in the small discouragers that occur daily and accumulate to the point that a woman decides that pursuing the doctoral degree is no longer worth it.

A unique component of the current research program is our attention to the special circumstances that apply to women in engineering and the physical sciences where their numbers are already low and the enrollment of international students is substantial. In addition to reviewing national findings, we have used focus groups at Arizona State University to enrich our understanding of the everyday experience of domestic women and international women in the target programs.

This paper highlights issues that have emerged from the focus group discussions of domestic and international doctoral women in engineering and computer science. Our aim is to better understand the role of national and cultural influences on what women experience and how they respond. We describe some of the commonalities and differences between domestic and international women with respect to their perceptions of everyday encouragers and discouragers and how they cope with them. In a broader context, we consider how these experiences may contribute to their intentions to complete their doctoral programs. We also discuss possible interventions and support that can be given to help retain discouraged female doctoral students who consider leaving their programs. Finally, we suggest areas for additional research to help us better understand both the domestic and the international woman doctoral student in engineering and computer science.

I. Introduction

The problem of attrition from doctoral programs is receiving new attention. It is estimated that only 5 out of 10 doctoral students across all fields complete their degrees, and that the completion rate for women is lower than that of men. Preliminary estimates suggest that the attrition of women from some doctoral programs in engineering and the hard sciences may be twice that of men. Low numbers of women entering doctoral programs in these fields combined with high attrition results in an even lower number of doctorates actually earned each year by women in science, technology, engineering and mathematics (STEM).

To put the lack of progress of women in engineering into perspective, we have only to compare the percentage of women in engineering with the percentage of women in law. The total proportion of engineers who are women is estimated at 10%. In 1971 only 9.5% of lawyers were women. In 1974 the percentage was 20.1. A plan to have at least 20% women lawyers by 1980 was easily met with 35.8% women lawyers in 1981. There were over 44% women lawyers by 1996 and experts say that soon there will be as many women lawyers as men lawyers.[2]

In contrast, the percentage of women engineers in the U.S. workforce went from 5.8% in 1983 to just 10.9% in 2000. Because the percentage of women receiving bachelor's and master's degrees in engineering has been about 20% for several years with the percentage of women receiving engineering doctoral degrees even lower, the rate of growth in the percentage of women engineers in the workforce has been extremely slow. In spite of many efforts to increase the numbers and percentages of women in engineering, not much is happening. Some would argue that the reason that engineering enrollment for both women and men has not kept up with the increased numbers of students choosing to go on to college, is that engineering now has more attractive competitors such as medicine and law for talented young women to choose.[1] Engineering has not done a good job of marketing itself as creative, interesting, and exciting. The lower division engineering curriculum is composed mostly of mathematics, chemistry, physics, and now biology, without connecting the dots and helping the young engineering student to understand why she needs to study these topics to achieve her goals. Actually this argument is also a strong reason why engineering needs more women trained in engineering to increase diversity in the values and perspectives of engineering personnel and to change methods and processes of delivering material to future generations of engineers.

In 2001, Lazarus, Ritter, and Ambrose underscored the seriousness of the lack of women in engineering and science doctoral programs in "The Woman's Guide to Navigating the Ph.D. in Engineering & Science."[2] They reported that of the 5,919 engineering doctorates awarded in 1998, only 769 (13%) were earned by women. These figures do not reflect the continued under representation of domestic women in engineering programs. Table 1 presents the national summary of PhD degrees in engineering earned in 1999 and 2005. We see that the slight increase in the number of engineering degrees earned by women was accompanied by a drop in the proportion of domestic women earning such degrees (from 9.2% to 7.6%). On the other hand, the number of international or foreign women has more than doubled in the past six years, and their percentage of total engineers now exceeds that of domestic women. What this will mean for change in the number of practicing women engineers in the U.S. is unclear. Although there is an increase in the total number of women earning engineering doctorates, many of the international women expect to return to their native country after a few years of experience in the U.S. after completing their degree. These figures underscore the urgent need to address retention issues in doctoral programs in engineering, particularly for domestic women.

National Summary Ph.D. Degrees in Engineering						
1999			2005			% Increase
All	5,833	% Total	All	7,276	% Total	+24.7%
All Women	858	14.7%	All Women	1,322	18.2%	+54.1%
Domestic Women	537	9.2%	Domestic Women	578	7.6%	+ 7.6%
Foreign Women	321	5.5%	Foreign Women	744	10.2%	+131.8%

Table 1. National Summary of Ph.D. Degrees Awarded to Women in Engineering for 1999 and 2005. [3, 4]

Figures from the Ira A. Fulton School of Engineering at Arizona State University (ASU) also illustrate the importance of examining the situation in detail. The total percentage of women receiving doctoral degrees in engineering at ASU has increased during the past six years, but the increase has been due to an increase in international women. Table 2 shows that at ASU there has been a 47% increase in the number of engineering Ph.D. degrees in the last six years with a 67% increase in the total number of Ph.D. degrees by women in engineering. Although there has been a 50% decrease in the number of domestic women earning Ph.D. degrees in engineering, there has been a 1000% increase in the number of foreign women receiving Ph.D. degrees in engineering. Although the numbers involved here are small, the ASU trend follows the national trend.

ASU Summary Ph.D. Degrees in Engineering						
1999			2005			% Increase
All	68	% Total	All	100	% Total	+47.1%
All Women	9	13.2%	All Women	15	15.0%	+66.7%
Domestic Women	8	11.7%	Domestic Women	4	4.0%	-50.0%
Foreign Women	1	1.5%	Foreign Women	11	11.0%	+1000.0%

Table 2. Arizona State University Summary of Ph.D. Degrees Awarded to Women in Engineering for 1999 and 2005.[5, 6]

For the past twenty years, the U.S. has had a critical shortage of engineers and scientists in several fields and in particular a shortage at the Ph.D. level. Why aren't more women earning a Ph.D. in engineering? It is well known that engineering is a difficult and challenging area of study and that doctoral programs in engineering fields are very demanding. But medicine is a demanding field as well. What is it about engineering or computer science fields that make the doctoral degree so difficult to obtain? And, at the same time, why are the numbers of international women earning an engineering doctorate increasing so much more rapidly than those for domestic women?

We are interested in understanding doctoral women's experiences through the everyday encouragers and discouragers that they encounter in their programs. We want to learn how these discouraging experiences accumulate to the point that a woman decides that pursuing the doctoral degree is no longer worth it. This study has been funded by the National Science Foundation (#0634519).[7] This paper examines the encouragers and discouragers identified by female engineering and computer science doctoral students with the goal of identifying differences in the experience of domestic and foreign women. First we will examine selected research findings on the experience of women in

engineering doctorate programs. Next we will discuss our research approach and highlight the experiences identified in focus groups of female engineering doctoral students. We will then consider the differences and similarities among encouragers and discouragers for domestic and international women. Finally, we will offer some recommendations for increasing retention of women in engineering doctoral programs.

II. Prior Research on Women in Engineering Doctorate Programs

Researchers have identified several factors that affect the experience of students in graduate programs. These include academic and social integration in the department, quality of mentoring and advising, research productivity, difficulty in balancing program demands with the family, predictability of financial support, and program climate issues.[2,8,9] Programs like NSF's ADVANCE have made significant strides in addressing institutional structural and policy changes that may improve conditions for faculty women in STEM.

When examining doctoral programs, we must understand that there are few standard rules in graduate school. The same general process is usually followed, but each school and each department may have its own requirements and rules. Some universities have a formal graduate school, while others do not. For any student contemplating a doctoral degree, it is imperative for them to learn and to understand the formal rules as well as to discern the hidden rules. A PhD program is designed to equip the student to create new knowledge—this is both exciting and challenging. It is common for doctoral students to doubt themselves and their ability to survive and to attain the degree. "Recognizing that stress and self-doubt are a natural part of any significant experience, including graduate school, tends to help." [2]

In the past, white men went on for doctoral degrees while women stopped at bachelor's degrees, often in teaching. Differences between how men and women fare in doctoral programs has only recently begun to attract attention. For example, Lazarus, Ritter, and Ambrose[2] claim that many women meet "invisible barriers" that make the doctoral work even more demanding. The barriers and the system are unknown to most women because of their marginal status in the system, with less access than men to information and contacts. Even when engineering departments welcome women, they may later find themselves isolated by a system established long before their arrival. Three of these barriers are: finances, stereotypes that characterize women as inferior intellectually, stressed-out, or just waiting to get married and have children, and greater demands on their personal time at home, especially if they are a wife, mother, or care taker of an elderly parent. In addition, women who are wives, mothers, or caretakers also have more of their time taken by what is asked of them at home.[2] These strains can diminish the personal strength and self-confidence of a female graduate student.

"The belief in yourself and your ability to succeed, as well as your passion for learning and study, will help you make it through graduate school. When you enjoy what you do, working hard to succeed is worth it. Probably no other situation in your life to date will be as overwhelming---or rewarding."[2] Lazarus, Ritter, and Ambrose identify four

primary areas of "potential storms" for the woman doctoral student in engineering and science: self-esteem, feeling alone, learning by critique, and balancing competing needs.

A University of Georgia study recently showed that the necessary conditions for optimal doctoral completion include four conditions: the right people apply for doctoral study, the right applicants are admitted as doctoral students, student and faculty form productive working relationships, and student experience social support from fellow students.[10] In their study on advisor-advisee relationships, 30 faculty members and 30 doctoral students from 15 programs in seven areas, including Civil Engineering, were respondents. Their study identified productive and non-productive working relationships and six recommendations for program improvement in order for faculty to be good advisors.[10]

The overall goal of the larger NSF-funded project is to understand and to address the problems of retention for women in doctoral programs in engineering and the physical sciences. In the larger project, and after we gain a thorough understanding of the discouragers and barriers that women experience, we aim to develop a series of Internet-based interactions designed to assist women in resisting or coping with situations that might interfere with their completing their doctoral studies. Given differences in the direction of the proportions of domestic and international women attaining engineering degrees over time, understanding how the experiences of these two groups of women might differ became of particular interest to us.

III. Focus Groups as an Initial Research Approach

We sought to understand the many critical incidents or interactions with faculty, peers, family members, and others that in aggregate may lead to experiencing encouragement or discouragement. The best way to learn these details was to speak to the students themselves and to ask them what techniques had either worked or failed in combating discouragement.

A common response to learning about findings from previous studies is "but that sort of thing doesn't happen these days". Hence, we wanted to verify that what the literature said about the challenges and difficulties that women face in engineering and computer science doctoral programs were actually happening in 2006-07 at Arizona State University. In order to better understand what the doctoral women were experiencing and how they felt about their experiences, we held focus groups. Focus groups do not take the place of surveys (planned for the future), which will yield quantitative data, but are recognized as a useful method "to find out *why* people feel as they do about something or the steps that people go through in making decisions." [11]

With the appropriate approvals by the Institutional Review Board, we received permission to contact by email and phone doctoral women in engineering and computer science who were in at least their second year of a Ph.D. program or their first year of a Ph.D. program with a Master's degree already earned. There were 118 engineering and computer science women students who met our criteria: 49 were domestic, U.S. citizens or permanent residents, and 69 were international students. Twenty-five of these women participated in four focus groups – 10 domestic women and 15 international women.

We invited the students to focus groups separated by majors according to gender balance and domestic/international status although there was a little crossover between the groups due to the participation times that were convenient for the student. After sending an initial email of invitation, we learned that personal contact either in person or by phone was the most effective method for interesting the student to participate in a focus group. Our goal was to include 6 to 10 students in each focus group.

Two trained moderators facilitated the sessions and referred to the students by number to protect their identities. The researchers explained confidentiality and that the results would be reported only in aggregate form. Graduate students on the research team were trained as note takers for the sessions, two were used for each session, and the session was taped.

After the introductory script, each focus group was asked the same basic questions and approximately 15 minutes were allowed for each in the 90-minute session. The first three questions asked were:

1. How does being a woman play a role in your progress through the doctoral program?
2. What types of things happen in your days that encourage you to keep going in your program?
3. What types of things happen in your days that discourage you from continuing in your program?

The participants were asked the questions with no prodding for the answer. After all of the participants had responded to a particular question, the moderator used probes as necessary. The probes were included in the script for topics not mentioned by the group. The participants were asked to clarify subjects and asked if any of the items on the probe list pertained to them.

The issues highlighted below are based on the researchers' preliminary review of the notes taken on participants' responses during the focus groups. Comparisons and contrasts are made with examples given as a way to portray the types of encouragers and discouragers that were described by the domestic and international women in the engineering and computer science focus groups.

IV. Does Being a Woman Play a Role in the Progress Through a Doctoral Program?

The majority of the engineering and computer science graduate students within the Fulton School of Engineering are international students. In fall 2006, there were a total of 1,797 graduate students in engineering and computer science, with 52.8% international students and 47.2% domestic students. Only 22.2% of these graduate students were female. See Table 3 for the 21st day enrollment in fall 2006. If we look at only the doctorate students enrolled in engineering and computer science for fall 2006, we see that there were 659 students, 547 men (83%) and 112 women (17%). Of the 112 women, 68 (60.7%) were international. Six of the women that we identified for our study were not on the 21st day

enrollment for fall 2006. The majority of the international students are from China and India. The next largest, but smaller, groups of international students in engineering and computer science are from South Korea and Mexico.

ASU Engineering and Computer Science Graduate Students Enrolled Fall 2006				
	All Graduate Students		All Doctoral Students	
	Total	%	Total	%
All	1,797	100	659	100
Men	1,398	77.8	547	83.0
International Men	734	52.5	352	64.4
Domestic Men	664	47.5	195	35.6
Women	399	22.2	112	17.0
International Women	215	53.9	68	60.7
Domestic Women	184	46.1	44	39.3

Table 3. ASU Engineering and Computer Science Graduate and Students by Total, Doctoral Students, Gender, and Citizenship.[11, 12]

Because there are so many international graduate students in engineering and computer science, we assumed the international doctorate women would feel more comfortable in their programs than domestic women. . When walking on the ASU campus, it is common to see groups of international students from the same country talking with each other. These groups usually include women and men. We believed that even though the international woman might be one of a few women in a class or lab setting, she would usually be surrounded by other international women and international men who would give her support To our surprise, even though the international women often mentioned doing activities with other students from their home country, the international women, in general, had the same things to say about their doctoral program experience as the domestic women.

We first asked the women groups, how being a woman played a role in their progress to their doctoral degree. Although a few women in the engineering and computer science groups said that there were no differences in their doctoral program because they were a woman, most of the women cited several common problems. Women in each focus group said their additional responsibilities as care givers set them apart from men. Women with children feel a constant stressor in their doctoral program due to the time demands by both their academic work and their family. Single, women parents caring for young children have an especially difficult time with time allocation and enough time to do well in both the academic and family arenas. An international mother spoke of the difficulty of leaving her young child with her husband in their native country in order for her to pursue a doctoral degree in the states. The question, “Is it worth it?” popped up frequently.

A second area mentioned by both domestic and international women doctoral students included physical problems inherent in a laboratory situation. The lab may require heavy manual work such as carrying 10 gallons of water. The women do not want to ask for help since they do not want to be perceived as not up to the demands of a lab, but may go

home at night with a backache. The presence of certain chemicals and toxins in some labs present a very tough situation for women. If they were to learn that they were pregnant, they would have to leave the laboratory and their work. In fact, some women reported that they had been warned that they should not become pregnant until they had been away from such a laboratory for at least nine months. The marriage and pregnancy situation also builds stress because some of the doctoral women students will be in their late thirties by the time they complete their degree, leaving very little time to bear children as their biological clock is ticking. A related physical problem reported by the women was the menstrual cycle. Although they may be experiencing severe cramps making lab work very difficult that day, they do not feel comfortable explaining the situation to their advisor (usually a man).

In a few cases the women students thought that their advisor was more supportive because they were a female in the minority in their lab or field or both and therefore their opinion was respected and listened to. However, most of the women perceived that their advisors (mostly male) were friendlier with the men in the program. They felt that as a woman they could not easily discuss their research with this academic advisor. Other women reported especially awkward situations when the research group was on a trip or excursion and they were the only woman. While the other students shared a room, the woman was alone. Some women students thought that they were left out because they did not go out and drink beer with the men students and the male advisor. Women who had joined such a group on occasion said that they really did not want to drink beer and were not interested in "talking sports all night."

Another common complaint of both domestic and international women was that men from cultures in which women are considered inferior to men treat women (both domestic and international) as their servants in the lab. The men leave the lab in a mess and tell the women (domestic or international) to clean up their lab space for them. While a domestic woman was insulted that she had been asked to do this, an international woman in the same lab agreed that it was not right, but said that to argue would not help and that she might as well do the clean up since that is the way it has always been in her country. One focus group woman reported that a male from such a culture asked her to make copies of some of his work. The women declined and tried to explain to the man that they were colleagues. Another woman complained that the men in her lab freely shared equipment among themselves, but even when she politely asked ahead of time for a short period in which she could use the equipment, she was refused. The women reported that men, in general, are not very good about working in a team or helping anyone else.

Several women reported that they felt stressed to constantly prove that they were as good as the male graduate students with whom they worked.

V. Encouragers

The second question asked in the focus group was, "What types of things happen in your day that encourage you to keep going in your program?" The women shared their positive experiences and later as a group ranked the items according to importance. The

rankings were not the same with each group, but there were common themes. A strong positive encouragement in the academic arena for all of the women is that their research was going well, especially if they have set up goals and have now reached a goal. Even if infrequent, research successes kept the women encouraged, especially if they were very interested in their research. A plus is if their advisor also recognizes their accomplishments and praises them for their work. High among the encouragers appreciated by the women was a positive, encouraging advisor, who responded to emails, gave regular constructive feedback and guidance, gave help when needed, and maintained a friendly, cooperative research group, and had confidence in them and their work.

A second primary source of encouragement comes from peers (usually other women) or role models. "If I can do it, you can do it," coming from a peer is very encouraging. Students reported that they cherished encouragement from their spouse, significant other, or family members. For international students, associating with a group of students from their homeland in leisure time is very encouraging to them. Tied in with this encouragement is a positive sense of belonging.

A third source of encouragement was being able to move toward a clear goal of the degree and the career they wanted and expected to have because of the degree. One student who had already completed a Master's degree and with considerable effort was now pursuing her doctorate reported that in her context, she was moving toward her goal and every day was good.

VI. Discouragers

As might be expected, the students had much more to say about discouragers than encouragers. The students were asked, "What types of things happen in your day discourage you from continuing in your program?" The responses again were from two major categories: academic interactions and their personal interactions and responsibilities. The major discourager among all students is a "discouraging advisor." The "bad" advisor is described as critical, demeaning, too busy to pay attention to the student, gives no feedback, cares only about getting another publication, has harsh expectations, and is a poor match with the student work style. Related to the academic setting, research failures and no progress are understandably discouraging.

Although the students in the focus groups did not have present financial worries, they were often worried about finances because they were not told if they had teaching or research assistant support until the last minute before a semester started. A worry for students with children was being able to find adequate child care and having adequate resources to pay for that care.

In the academic setting, the women reported feeling invisible, marginalized, and alone. They felt gender stereotyping, a hostile environment with their peers, inadequate research group oversight, their ideas were not given consideration, ignorant of problematic practices in how to pass an oral defense, isolated, and a lack of fit with the culture. This

culture included competitiveness, male interests in beer and sports, and a hierarchy in the lab.

On the personal side, the women felt that they were alone with little or no emotional support. They worried about someday having a husband and children and would they be able to have children by the time they finished their degree. Those with a husband and children felt a role conflict and conflicts of commitment to family and to their eventual career. The physical strain of coming home each night to cook and clean besides taking care of children leaves little time for sleep. Added to this situation may be heavy lifting in the lab, severe periodic cramps, and the woman needs to cry. During periods like this, the women report that they start reconsidering, "Is this really worth it?"

The women recognize that there are personal characteristics that contribute to being discouraged. These characteristics include low self-esteem, the imposter syndrome, oversensitivity, poor time management, perfectionism, guilt over conflicting roles, loss of commitment to the goal, and lack of "having a life."

VII. Domestic vs. International Doctoral Women

Domestic and international doctoral women appeared to have similar experiences in their programs. The international women had issues with international males expecting them "to clean up the lab" as well as domestic women. The international women however, had different major discouragers for them, not experienced by domestic women. The first of these discouragers was language. On top of everything else going on in their lives, many international students have to put extra effort into making sure that they are understanding and comprehending correctly what they hear and read, as well as express themselves correctly. Some students had to spend many hours writing and rewriting English before their report or thesis was correct.

The second major discourager for international women is being "homesick." Being in a new land, in a harsh academic climate, with language struggles, made the women feeling particularly alone and lonely for their home life. One international woman reported that she spoke to her mother every day for encouragement. The "homesick" discourager was stated by several international women, even though, at the same time, they reported being encouraged by meeting with other students from their home country.

The strong cultural expectation that they be married and begin to have children by 29 or some particular age was the third major discourager for some of the international doctoral women. This conflict with their culture added to their fear that they may be too old to bear children by the time they completed their degree. Also because of this cultural expectation, some of the women did not receive strong encouragement from their families back home to complete their degree.

VIII. Analysis

We were surprised to find very few differences between the encouragers and the discouragers of the domestic and international students. The international women identified their status as a doctoral student primarily in terms of how they were treated differently as a woman, not as a majority international student. Being a woman seemed to affect the treatment of the female international students more than the fact that she might be in a majority situation with the other international students.

As we discussed the encouragers and discouragers with the women, we also asked them how they responded to the discouragements and what solutions they had tried. Since a major discourager centered on the academic advisor, the women were very strong with their recommendation to choose an advisor carefully, very carefully. They noted that it was important to choose an advisor that fits their work style. Being in a lab 8 or more hours each day at regular times may not be the most efficient way to do research for some students. It was clear that even if the advisor was troublesome, those women who had a supportive spouse or significant other could handle the situation easier knowing that at the end of the day she would go home to a big hug. Other women stressed the importance of meeting regularly with other women both as a checkpoint ("Is it me?") and as a support ("We can do this."). Certainly our findings beg for faculty workshops to be developed to make faculty aware of the intense impressions and discouragement they can give to a doctoral student, especially a woman. We intend to develop training on approaches that a student can take to improve the relationship between herself and her advisor. These approaches will include help with decision making (when should I choose another advisor), problem-solving and conflict resolution.

In labs where the availability of equipment is crucial to the doctoral research, the women in engineering and computer science are usually a small minority. The students reported that the advisor or post doc running the lab usually establishes the tone of the lab. In some cases, a report to the post doc or advisor about discrimination in the lab will be enough to right the situation, but in many cases the complaint is waived off lightly with the advice of "just talk to the student". For situations where just talking to the peer student did not work, our intervention will include role-playing and examples of successful resolution.

Because the women often reported being lonely and feeling isolated, we encourage the woman doctoral student to become involved with a graduate student organization or a club centered on some common interest. Taking short breaks from the intense academic situation is necessary for good mental health. The intervention tool will include links to sources of mentors and other supportive organizations, as well as "herstories" from women who have gone through similar situations and survived.

IX. Conclusions and Future Research

Admittedly we are reporting the results from a small group of students through focus groups, but we are reporting themes. However, the discouragers reported by the women mesh very well with the literature. A real value of the focus groups was putting flesh on the major discouragers. These insights will help us to describe the common discouragers

and methods to cope with them in a way that can help a student recognize the source of her discouragement and give her some practical pointers on relieving the situation. In order to make sure that we are not missing any major areas of discouragement, we will soon be speaking with women who have chosen to discontinue their doctoral program.

The research project still has many facets to develop. Eventually we want to make sure that the woman doctoral student we are describing is fairly standard for students across the nation. We plan to survey women doctoral students across several universities to confirm our initial findings and to include facets of the woman doctoral life that we have not yet discovered. With case studies and "herstories" from career women who have survived the same discouragers reported by the women students, we hope to be able to increase the retention of women in engineering and computer science doctoral programs.

Acknowledgement

This material is based upon work supported by the National Science Foundation under Grant No. REC-0634519 to Bianca L. Bernstein. The authors gratefully acknowledge the contributions of Sarah Dixon-Lyding to the framing of focus group questions and the training of note-takers; Jennifer Bekki, Kathryn A. Clark, Quinn Spadola, Julia Steinberg, Shelley Erickson, Lisa Rodrigue, and Silva Hassert for serving as note-takers; and Cara Weddington for logistical support.

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